ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

DEVELOPMENT OF MOBILE COGNITIVE TEST SOFTWARE APPLICATION ON SITUATIONAL AWARENESS

M.Sc. THESIS

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Department of Computer Engineering

Computer Engineering Programme

JANUARY 2014

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DURUMSAL FARKINDALIĞI BELİRLEYEN MOBİL BİLİŞSEL TEST YAZILIM UYGULAMASININ GELİŞTİRİLESİ

YÜKSEK LİSANS TEZİ

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OCAK 2014

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To my sweetheart and spouse,

FOREWORD

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ABBREVIATIONS

ADAS-cog	**:** Alzheimer's Disease Assessment Scale-Cognitive Subscale
ADT	**:** Android Developer Tool
ANAM4^{TM}	**:** Automated Neurophysiological Assesment Metrics
CANS-MCI	**:** Computer-Administered Neuropsychological Screen for Mild Cognitive Impairment
CANTAB	**:** Cambridge Neuropsychological Test Automated Battery
CGS	**:** CogState
CNTB	**:** Computerized Neuropsychological Test Battery
CSI	**:** Cognitive Stability Index
MBT	**:** Mobile Cognitive Screening
MCIS	**:** Mild Cognitive Impairment Screen
MMSE	**:** Mini Mental State Examination
MoCA	**:** Montreal Cognitive Assessment
OS	**:** Operating System
PC	**:** Personal Computer
RT	**:** Reaction Time
SPSS	**:** Statistical Package for the Social Sciences
XML	**:** Extensible Markup Language

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DEVELOPMENT OF MOBILE COGNITIVE TEST SOFTWARE APPLICATIONON SITUATIONAL AWARENESS

SUMMARY

Neuropsychological assesment tests have an important role in determining the cognitive changes that occur in early stages of dementia. Dementia is characterized by memory impairment, progressive decline in daily activities, a variety of psychiatric symptoms and behavioral problems. The most crucial risk for dementia is the age. By aging, people may have significant changes in intelligence, concentration, spatial and visual perception, attention and language skills.

The cognitive tests used in the world are generally applied by paper-and-pencil and rarely used on personal computers (PC). The tests on PCs typically have an unfriendly interface which does not take people's capabilities and their ages into consideration.

Our aim is to develop a Turkish neuropsychological test software application called Mobile Cognitive Screening (MBT) Test which can help the diagnosis of dementia. MBT is important for being the first Android based mobile neuropsychological test software applicationrunning on tablet computers. It is composed of 33 tests in 14 different types chosen from the paper-and-pencil tests by the specialists. Tests that are compatible for the tablet computers having Android operating system has been developed with Android Developer Tool for Java (Java-ADT).

The tests in thedevelopedmobile applicationare namedtrail making test, clock drawing test, attention test, visuospatial test, shape similarity test, shape matching test, arithmetics test, proverb test, naming test, numbers test, colorful shapes test, market test, date test and story recall test. During the design of the tests, we are inspired by Montreal Cognitive Assessment (MoCA) and Automated Neurophysiological Assessment Metrics (ANAM4^{TM}) tests.

The tests have been applied to dementia patients and healthy control group.Also, MoCA scale was applied to both groups for the correlation studies and the comparison of the first diagnostic accuracy.

In order to analyse the data, Statistical Package for the Social Sciences (SPSS) has been used. It has been proved that the applicationis able todistinguish betweendementia patients andhealthy control groupand it has a significant correlation with MoCA.

DURUMSAL FARKINDALIĞI BELİRLEYEN MOBİL BİLİŞSEL TEST YAZILIM UYGULAMASININ GELİŞTİRİLESİ

ÖZET

Nöropsikolojik testler demansın ilk evrelerinde meydana gelecek bilişsel değişimleri belirlemede önemli işleve sahiptir. Demans; hafızada bozukluk, günlük yaşam aktivitelerinde ilerleyici gerileme, çeşitli psikiyatrik belirtiler ve davranış bozukluklarıyla karakterize edilir. Yaşlılık demansın en önemli risk faktörlerinden biridir. Yaşlılık dönemine giren bireylerde zeka, konsantrasyon, dikkat, konuşma becerisi, görsel ve uzaysal algılama fonksiyonlarındaönemli değişiklikler gözlenmektedir.

Dünyada kullanılan nöropsikolojik testler genellikle kağıt-kalem kullanılarak, nadirende kişişel bilgisayarlar (PC) ile uygulanmaktadır. PC'ler ile uygulanan testler kişilerin yeteneklerini ve yaşlarını göz önünde bulundurmayan arayüzlere sahiptir.

Amacımız, demans tanısında kullanılmak üzere tablet bilgisayarlar üzerinde çalışacak Mobil Bilişsel Tarama (MBT) isimli Türkçe nöropsikolojik test yazılım uygulamasının geliştirilmesi ve hedef hasta gruplarında uygulanabilir olup olmadığının değerlendirilmesidir. MBT tablet bilgisayarlarda kullanıma uygun ilk Türkçe mobil nöropsikolojik test yazılım uygulaması olması açısından çok önemlidir. Uygulama;bilişsel nöroloji ve nöropsikoloji alanlarında uzman kişiler ile birlikte, kağıt-kalem testlerinden hangilerinin tablet formuna uyarlanabileceği tartışılarak, 14 farklı 33 testten oluşmaktadır. Testler Android işletim sistemli tablet bilgisayarlar için Java Android Developer Tool (Java-ADT) kullanılarak geliştirilmiştir.

Hazırlanan mobil uygulama; iz sürme testi, saat çizme testi, dikkat testi, görsel test, şekil benzerliği testi, şekil eşleştirme testi, 4 işlem testi, atasözü testi, adlandırma testi, sayılar testi, renkli şekiller testi, market düzenleme testi, tarih testi ve öykü testinden oluşmaktadır. Katılımcının her bir testte farklı bilişsel yeteneklerideğerlendirilmeye çalışılmıştır.

İz sürme testinde; katılımcının dikkati sürdürme ve set değiştirerek bir işi tamamlama becerisi ölçülmektedir.

Saat çizme testinde; katılımcının planlama, soyutlama ve görsel süreçler gibi birçok bilişsel fonksiyonu değerlendirilmektedir.

Dikkat testinde; katılımcının sürdürülebilir dikkat performansı değerlendirilmektedir.

Görsel testte; katılımcının görsel konfigürasyonu ve frontal fonksiyonları değerlendirilmektedir.

Şekil benzerliği testinde; katılımcının görsel ve uzaysal işleme yeteneği değerlendirilmektedir.

Şekil eşleştirme testinde; katılımcının görsel ve uzaysal işleme yeteneğinin yanı sıra öğrenme ve bellekgibi bilişsel yetenekleri değerlendirilmektedir.

Aritmetik testinde; katılımcının basit hesaplama, hafıza ve konsantrasyon yetenekleri değerlendirilmektedir.

Atasözü testinde; katılımcının anlamsal ilişkilendirme ve soyutlama gibi bilişsel yetenekleri değerlendirilmektedir.

Adlandırma testinde; katılımcının adlandırma becerisi değerlendirilmektedir.

Sayılar testinde; katılımcının dikkat ve hesaplama gibi bilişsel yetenekleri değerlendirilmektedir.

Renkli şekillller testinde; katılımcının dil, algı ve verilen bir yönergeyi anlama becerileri değerlendirilmektedir.

Market testinde; katılımcının kategorize etme ve mantıksal illişkilendirme yetenekleri değerlendirilmiktedir.

Tarih testinde; katılımcının zaman yönelim fonksiyonları değerlendirilmektedir.

Öykü testinde ise; katılımcının işitsel ve görsel algılarının yanı sıra bellek fonksiyonu da değerlendirilmektedir.

Uygulama içerisindeki bu 14 test değerlendirdiği bilişsel yeteneklere göre de 8 gruba ayrılmış ve alt analizlere geçilmiştir. Bu alt gruplar; yönetici işlevler, görsel, dil, hafıza, dikkat, soyutlama, yönelim ve aritmetiktir.

Testlerin hazırlanması aşamasında Montreal Bilişsel Değerlendirme Ölçeği (MoCA) ve Otomatik Nöropsikolojik Değerlendirme Ölçeği (ANAM4^{TM}) testlerinden faydalanılmıştır.

Geliştirilen testler demans hastaları ve sağlıklı kontrol grubu olmak üzere 23 kişiye uygulanmıştır. İlk tanısal doğruluğu kıyaslama ve korelasyon çalışmaları için MoCA ölçeği de uygulanmıştır. MoCA, kağıt kalem ile uygulanan, geçerlik güvenirlik çalışmaları yapılmış bilişsel bozukluğun ilk evrelerini değerlendirmek üzere geliştirilmiş bir tarama ölçeğidir.

Alınan ölçümlerin Statistical Package for the Social Sciences (SPSS) ile analizi neticesinde MBT testininin yönetici işlevler, görsel, hafıza, dikkat, yönelim alt test gruplarında hasta ve kontrol grupları için ayırt edici olabilirken; dil, soyutlama ve aritmetik alt gruplarında anlamlı bir korelasyon sağlayamamıştır. MoCA testi ise; görsel alt grup dışında diğer bütün gruplarda ayırt edici olabilmiştir. Yine de, sonuç olarak MBT testinin demans ve kontrol grubunu ayırt edebildiği, MoCA testi ile anlamlı bir ilinti oluşturduğu belirlenmiştir.

Bataryanın hazırlanması sırasında yaşanan problemler ve birçok güncelleme sonunda uygulamamızın MBTv1.3 versiyonu kullanılmaktadır. Testin sonunda bütün bilgiler elektronik olarak saklanmakta ve uzman kişiye bir fikir vermek amacı ile katılımcının puanları ile ortalama kontrol grubu değerleri radar grafik olarak MBT alt gruplara göre gösterilmektedir.

Gelecek çalışmalarımızda da, amacımız bataryamızın ingilizce versiyonunu oluşturulmak ve ayırt edici olamayan dil, soyutlama ve aritmetik MBT alt test gruplarının geliştirilerek mobil uygulamamızın daha anlamlı bir korelasyon oluşturmasını sağlamaktır. Ayrıcı olgu grubumuzu artırarak testimizin geçerlik ve güvenirlik çalışmaları da yapılmaya çalışılacaktır.

Böylece MBT'nin, uzmanlar tarafından bilimsel ve akademik araştırmalar için de kullanılabilmesi sağlanmış olacaktır.

1. INTRODUCTION

The diagnosis and the treatment of the diseases are becoming more efficientdue to the improvements of technology in medical field. As a result of these improvements, the life expectancy is getting longer and the incidence of the diseases correlated by older age is getting higher. One of the most important health problems in older age is dementia [1]. Dementia is characterized by memory impairment, progressive decline in daily activities, a variety of psychiatric symptoms and behavioral problems [2]. In 2010 there were 35,6 million people with dementia in the world and each year 7,7 million people is added to this number[3]. Since the old age is the most crucial risk for dementia, people may have significant changes in intelligence, concentration, spatial and visual perception, attention and language skills by aging. The neuropsychological tests have an important role in determining these cognitive changes occurring in early stages of dementia [3, 4]. The most commonly used international tests for dementia assessment are Mini-Mental State Examination (MMSE), word learning test for verbal learning, story recall test, ADAS-cog with the subgroups, semantic fluency test, Boston naming test, digit span test for attention and trail making tests [5]. These cognitive tests used in the world are generally applied by paper-and-pencil and rarely on personal computers (PC).

1.1 Purpose of Thesis

Our aim in this study is; i. improving the cognitive tests for helping the diagnosis of people with suspected dementia, ii. establishing the software to enable these cognitive tests applicable on tablet computers by using the technological facilities, iii. applying the software to the groups having a normal cognitive level and groups diagnosed with dementia, iv. evaluating the correlation between the software and a commonly used test called Montreal Cognitive Assesment (MoCA) which is applied by paper-and-pencil, v. determining the utilization of the software for the future by statistically analyzing the the results.

1.2 Background

1.2.1 Computer-Based Neuropsychological Tests

There are many neuropsychological tests used by clinicians for the diagnosis of dementia worldwide, and computer-based tests started to be evolved in recent years. These tests are listed in table 1.1.

Table 1.1 : Computer-basedcognitive state assessment tests [6].

Test	Evaluated Domains
ANAM	Memory, attention, psychomotor speed, language reaction time(RT)
Computer-Administered Neuropsychological Screen for Mild Cognitive Impairment (CANS-MCI)	Memory, language, executive function
Cambridge Neuropsychological Test Automated Battery-CANTAB	Working memory, attention, visuospatial memory
CNS Vital Signs-CNVS	Memory, psychomotor speed, processing speed, cognitive flexibility, sustained attention
Computerized Neuropsychological Test Battery-CNTB	Language, information-processing, motor speed, attention, spatial, memory
CogState-CGS	Working memory, executive function, attention, RT
Cognitive Stability Index-CSI	Memory, attention, response speed, processing speed
Mild Cognitive Impairment Screen-MCIS	Memory, executive function, language
MicroCog	Memory, attention, RT, spatial ability, reasoning/calculation,
Mindstreams	Memory, executive fx, visuospatial, verbal fluency, attention, motor skills, information processing

During the preparation of this unique neuropsychological test software application MBT which is compatible for 10.1-inch Android-based tablet computers, we are inspired by the existing tests that are being used in the international area. In order to

validate MBT, the results of MoCAand MBT are compared for the same group of people.

1.2.2 Montreal Cognitive Assesment

Montreal Cognitive Assesment (MoCA) is a screening test which is developed for the evaluation of cognitive impairment's first stage. The abilities that are evaluated with this test are memory, visual-spatial processes, attention, concentration, abstraction, orientation and language functions. Duration of the test is about 10 minutes and the total score is 30 points. If the participant takes minimum 21 points, s/he is considered to be in the normal group [7].

MoCA test has been chosen for the correlation studies in this thesis because its validity and reliability studies has been done and this test is used very often for the diagnosis of the dementia.

2. METHODOLOGY

2.1 Tests and Interfaces

MBT is important for being the first Android based mobile neuropsychological test software application running on tablet computers. It is composed of 33 tests in 14 different types. Some of these tests are taken from paper-and-pencil test and adapted for tablet computer interface. Some tests are originally designed by neurologist specifically for tablet computer.

Tests are developed by using Java Android Developer (ADT) for tablet computers running on Android operating system. In this pilot work, each test counts as 1 point and the total score is 33 points [8], but the exact scoring may be redefined after the correlation studies with paper-and-pencil tests the sub-analysis on the weight factor of each tests have been done.

Tests in the application are described in detail below:

Start-up screen: There are many demographic factors that may affect the cognitive processes of patients. As in all clinical studies, the identification information of the patients are saved. Particularly, factors such as age and education level affect the cognitive performance in each test and this may be challenging for elder patients who areless familiar with tablet devices. On the other hand, these tests can be very simple for patients who have a high level of education which give rise to ceiling effect [9]. In our application, there are questions about detailed demographic information at the start-up screen of the application in order to keep the factors that may impair the test results. Demographic data entry screen is shown in figure 2.1. Also, the questions asked in the Start-up Screen are listed in the table 2.1.

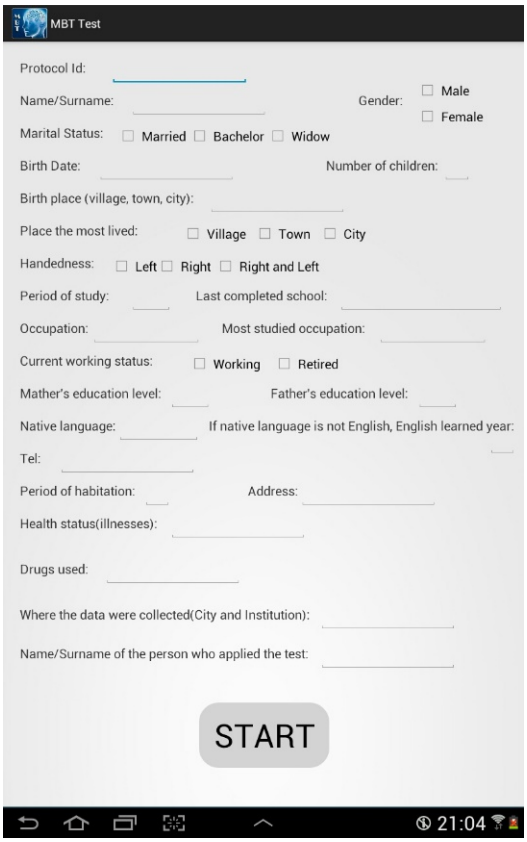

Figure 2.1 : Start-up screen.

Table2.1 : Questions asked in the Start-up Screen

Name/Surname	Gender	Marital status
Birth date	Number of children	Birth place
Place the most lived	Handedness	Period of study
Last completed school	Occupation	Most studied occupation
Current working status	Mother's education level	Father's education level
Native language	If native language is not English, English learned year	Telephone number
Period of habitation	Address	Health status
Drugs used	Where the data were collected	Name/Surname of the person who applied the test

Trail making test: There are numbers from 1 to 5 and letters from A to E. It is expected from the participant tocombine the numbers and letters clicking initially the number then the letter. The instruction for the participant to apply the test is as follows: "Try to combine the numbers and the letters sequentially from the beginning to the end clicking primarily the number button then the letter button(Ex: 1→A→2)." With this test, sustaining attention and especially the ability of completing a task by changing the set is evaluated. Such tests are very sensitive to early impairment

inforebrain functionality. If the test is completed correctly, the participant gets 1 point. Trail making test interface on the tablet computer screen is shown in figure 2.2.

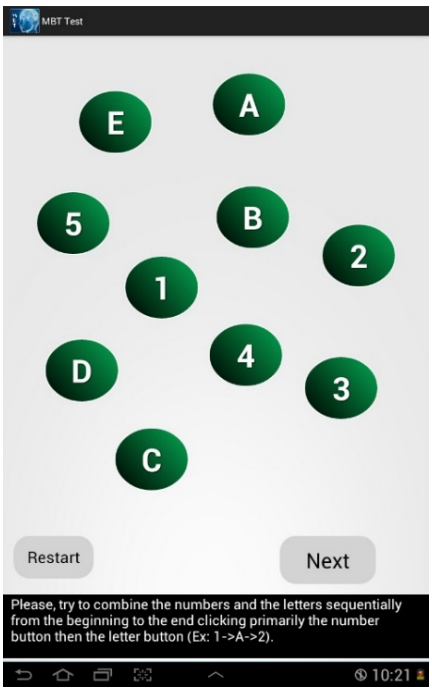

Figure 2.2 : Trail making test.

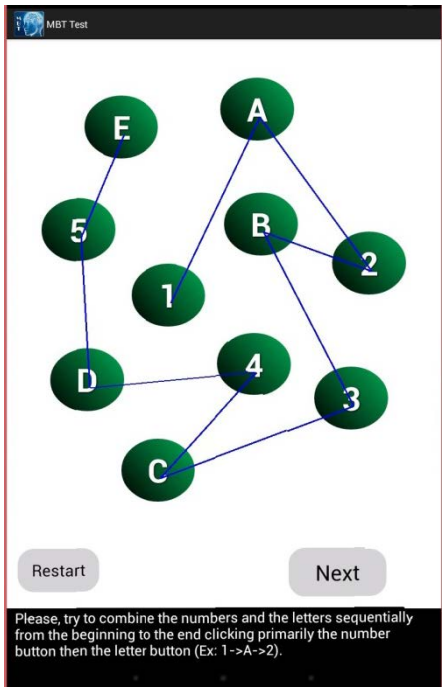

Figure 2.3 : Trail making test2.

Clock drawing test: On the screen, a circle for the clock and hour and minute hands are seen. There are also sorted numbers from 1 to 12. It is expected from the participant to drag the numbers into the circle according to the layout of the real clock's numbers and rotate the hour and minute hands in order to set the time as 11:10. The instruction for the participant to apply the test is as follows: "Try to drag all numbers into the circle according to the clock layout and rotate the hour and minute hands setting the time as 11:10." Clock drawing is an easy and special test that provides to evaluate many cognitive functions together. Briefly, this test is reviewed as a basic frontal process test which includes planning, abstraction and visual processes. If the test is completed correctly, the participant gets 1 point. In figure 2.4 clock drawing test interface on the tablet computer screen is shown.

Attention test: On the tablet computer screen, 30 letters which include 9 "A"s are displayed continuously every 2 seconds in 1 minute. It is expected from the participant to click the button named "CLICK" when s/he sees the letter "A". The instruction for the participant is: "Shortly after, different letters will be displayed on the screen. When you see the letter 'A', click the button named 'CLICK'." After this

instruction, there is also one more message box which is texted as “Click the button only when you see the letter ‘A’ ” to draw the participant’s attention more. With this test, continuous attention performance of the participant is evaluated. If the test is completed without any fault or only with a single miss, the participant gets 1 point. In figure 2.6 attention test interface on the tablet computer screen is shown.

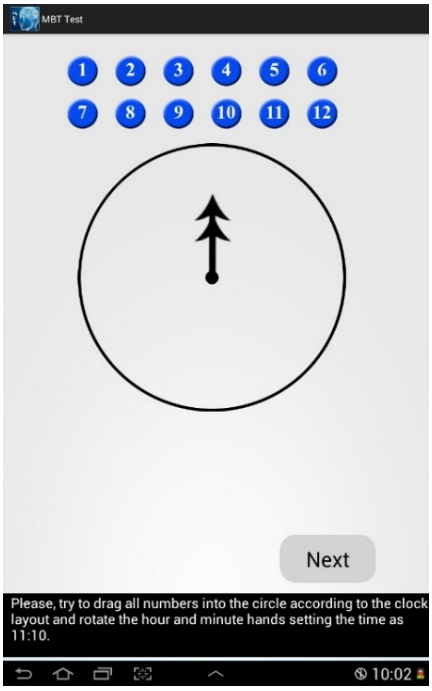

Figure 2.4 : Clock drawing test.

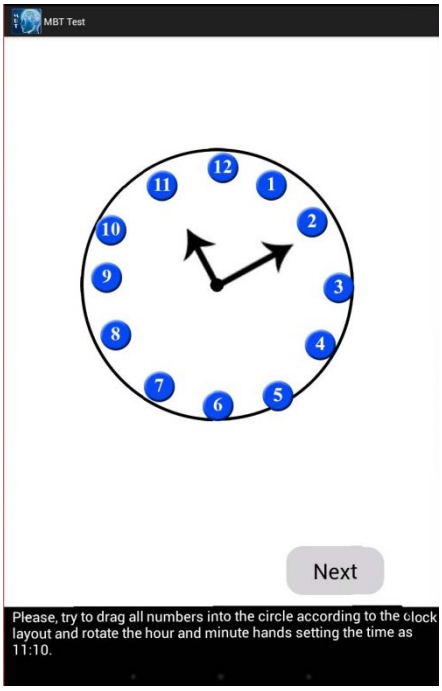

Figure 2.5 : Clock drawing test2.

Figure 2.6 : Attention test.

Visual test: There is a manikin on the screen and a ball under one of the hands of the manikin. It is expected from the participant to find the position of the ball. If the ball is under the right hand of the manikin, the participant is expected to click the "RIGHT" button, if under the left hand "LEFT" button should be clicked. There are 4 different positions of the manikin in each 4 test and the instruction for the participant to apply each test is as follows: "Clickone of the buttons assigned 'LEFT' or 'RIGHT'considering the position of the object under the hand of manikin." This test evaluates the visual configuration and frontal functions. Each test is 1 point and if the participant give correct answers to all 4 tests, s/he takes 4 points. Visual test interfaces on the tablet computer screen are shown in figures2.7 - 2.10.

Shape similarity test: There are 2 shapes of 4x4 grids on the screen. It is expected from the participant to specify these 2 objects according to their similarity. The instruction for the participant is: "If these 2 objects seen on the screen are similar click the button named 'SAME', if not similar click the button named 'DIFFERENT'." Participant should complete these 2 different shape similarity tests. With this test, visual-spatial processing ability is evaluated. Each test is 1 point and if the participant answers both correctly, s/he takes 2 points. In figure 2.11 and figure 2.12 shape similarity test interfaces on the tablet computer screen are shown.

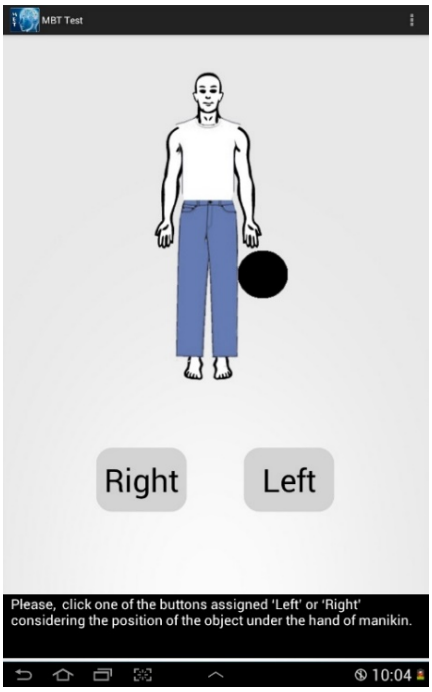

Figure 2.7 : Visual test 1.

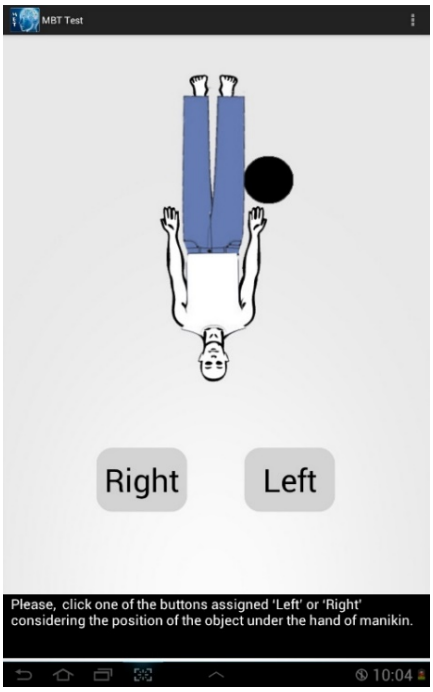

Figure 2.8 : Visual test 2.

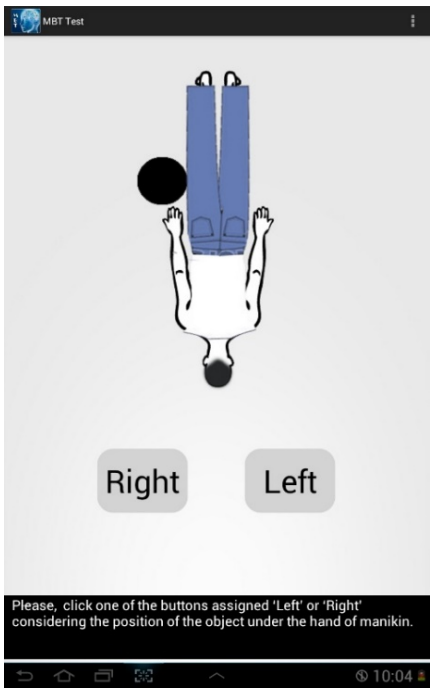

Figure 2.9 : Visual test 3.

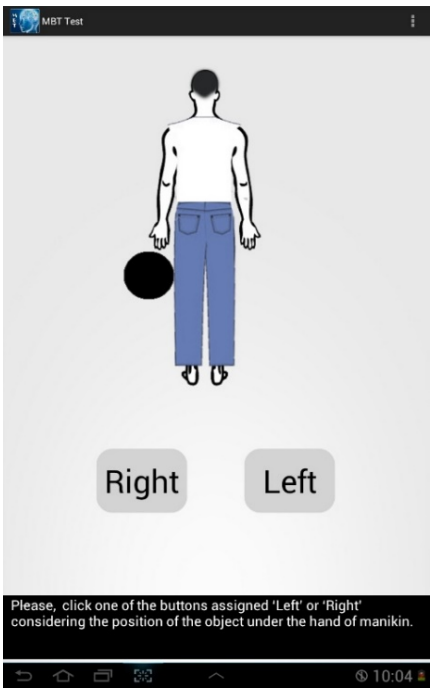

Figure 2.10 : Visual test 4.

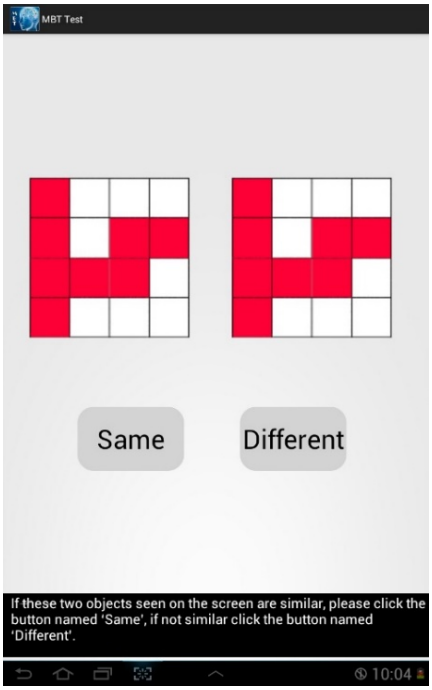

Figure 2.11 : Shape similarity test 1.

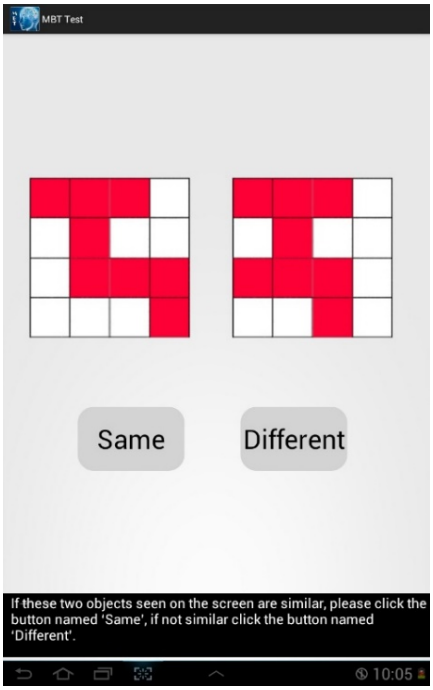

Figure 2.12 : Shape similarity test 2.

Shape matching test: There is a shape of 4x4 grid on the screen. It is expected from the participant to be able to choose which of the 2 shapes seen on the screen is exactly the same with the shape s/he sees on the previous screen. The instruction for the test is: "Please look at the shape on the screen carefully. After you

totallyunderstand the shape, click the ‘OK’ button for skipping to the other screen having 2 different images, then touch the image which is exactly the same with the previous one.”Participant should complete both of the shape matching tests.

This test evaluates the visual-spatial processing, learning and memory abilities. Each test is 1 point and if the participant gives correct answers to these 2tests, s/he takes 2 points. In figures2.13, figure 2.14, figure 2.15 and figure 2.16 shape matching test interfaces on the tablet computer screen are shown.

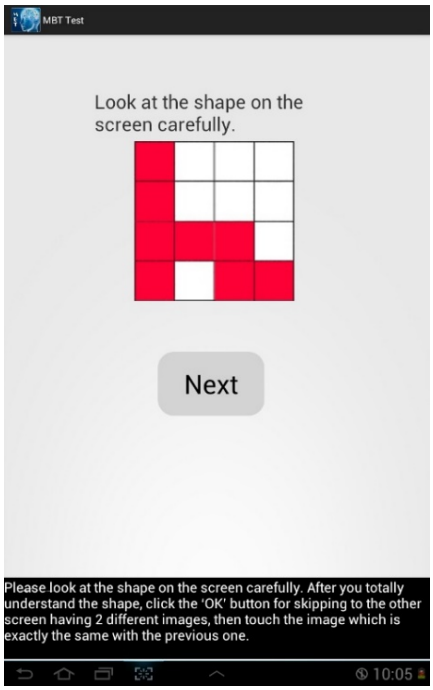

Figure 2.13 : Shape matching test 1a.

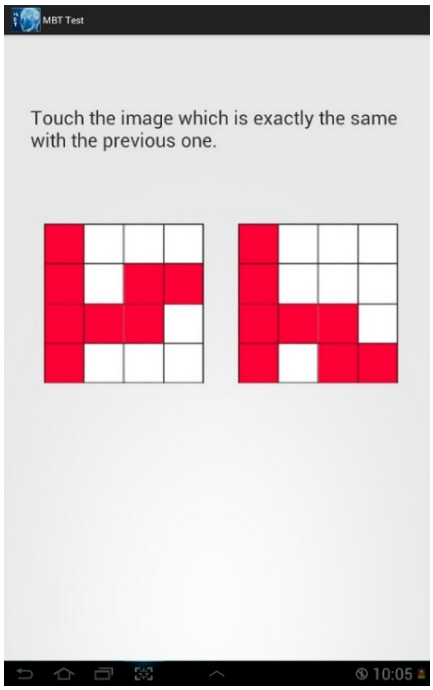

Figure 2.14 : Shape matching test 1b.

Arithmetic test: There are 4 different tests including summation, subtraction, multiplication and division arithmetic operations. In each test, it is expected from the participant to calculate the result and click the button assigned with the result number. The instruction for the participant to apply each test is as follows: “Answer the mathematical operation clicking the button assigned with the number showing the result.” With these tests; basic calculation, concentration and memory processing abilities are evaluated. Each test is 1 point and if the participant gives correct answers to these 4 tests, s/he takes 4 points. In figure 2.17, figure 2.18, figure 2.19 and figure 2.20 arithmetic test interfaces on the tablet computer screen are shown.

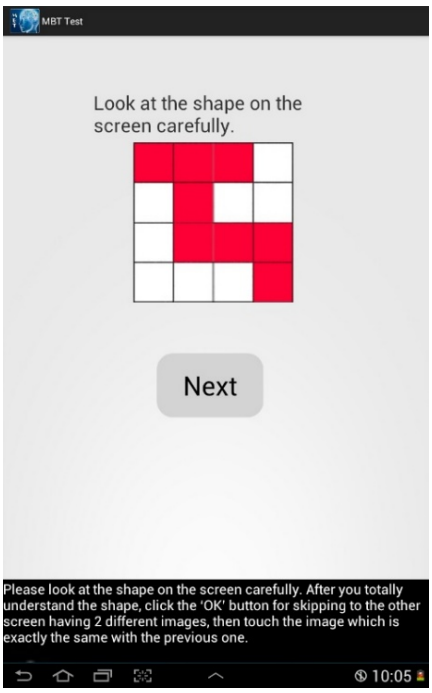

Figure 2.15 : Shape matching test 2a.

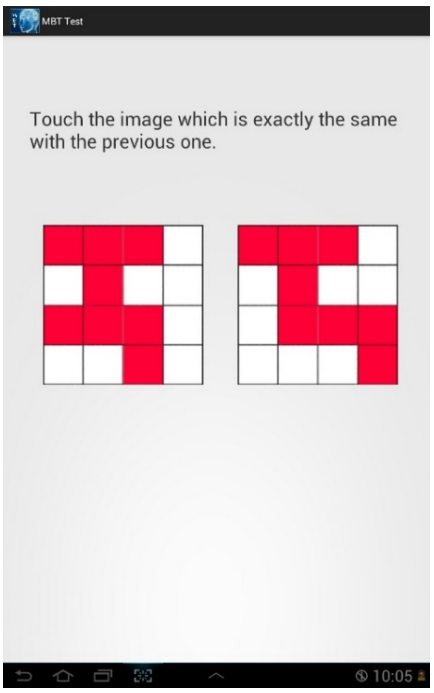

Figure 2.16 : Shape matching test 2b.

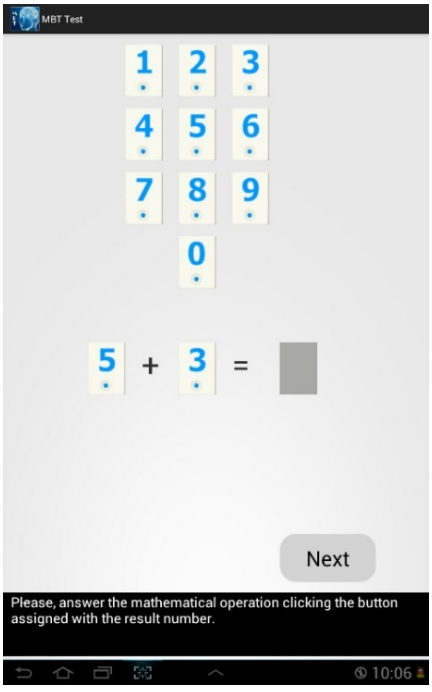

Figure 2.17 : Arithmetic test 1.

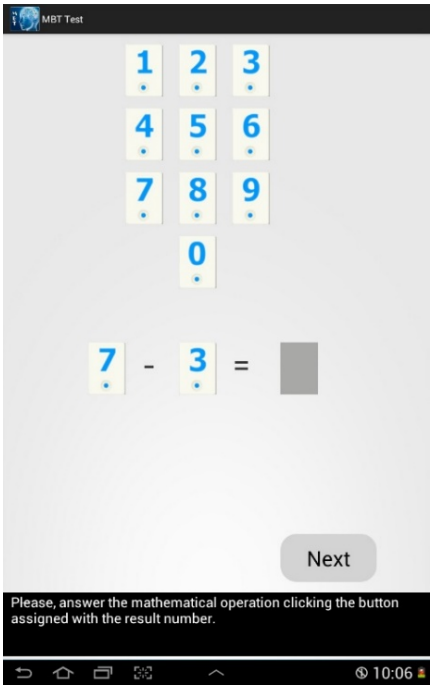

Figure 2.18 : Arithmetic test 2.

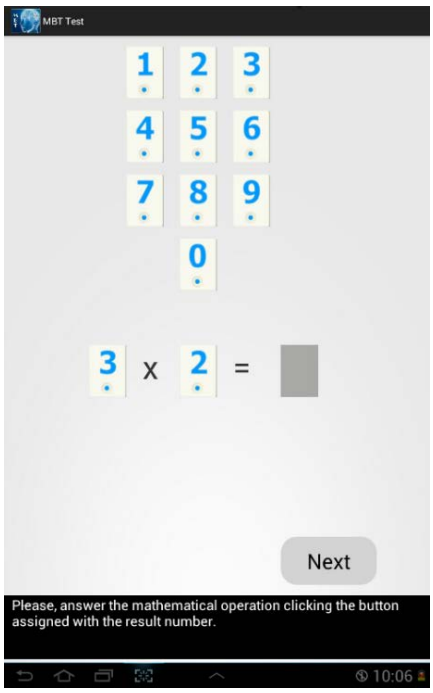

Figure 2.19 : Arithmetic test 3.

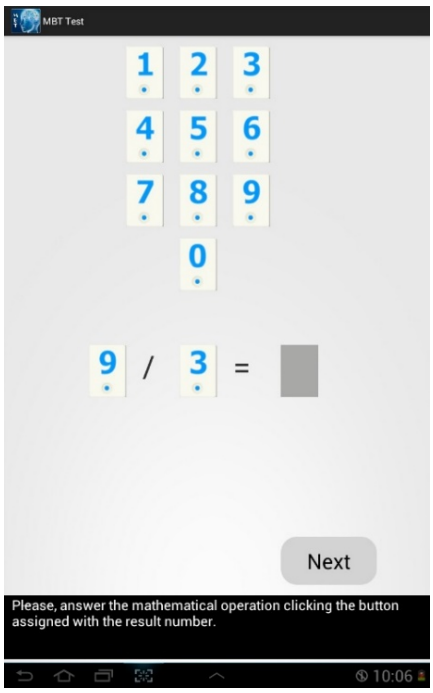

Figure 2.20 : Arithmetic test 4.

Figure 2.21 : Proverb test 1.

Figure 2.22 : Proverb test 2.

Figure 2.23 : Proverb test 3.

Proverb test: There are 3 different Turkish provebs on 3 different screens in the pilot application. In each test, there are 3 pictures showing the abstract, concrete and irrelevant meanings of the given proverb. It is expected from the participant to choose the picture with the abstract meaning. The instruction for the participant to apply each test is as follows: “Choose the picture showing the exact meaning of the proverb and click on the picture.” With these tests, semantic association in abstract notions is evaluated. Each test is 1 point and if the participant gives correct answers to these 3 tests, s/he takes 3 points. In figure 2.21, figure 2.22 and figure 2.23 proverb test interfaces on the tablet computer screen are shown.

Naming test: There are 6 tests in which 6 different pictures of some objects or animals are shown on the tablet computer screen. It is expected from the participant to write the name of the object or the animal correctly by using the letters shown on the screen. The instruction for the participant to apply each test is as follows: “Write the name of the object or the animal by clicking the appropriate letter buttons.” These tests evaluate the naming ability of the participant. Each test is 1 point and if the participant gives correct answers to these 6 tests, s/he takes 6 points. In figures2.24 – 2.29naming test interfaces on the tablet computer screen are shown.

Figure 2.24 : Naming test 1.

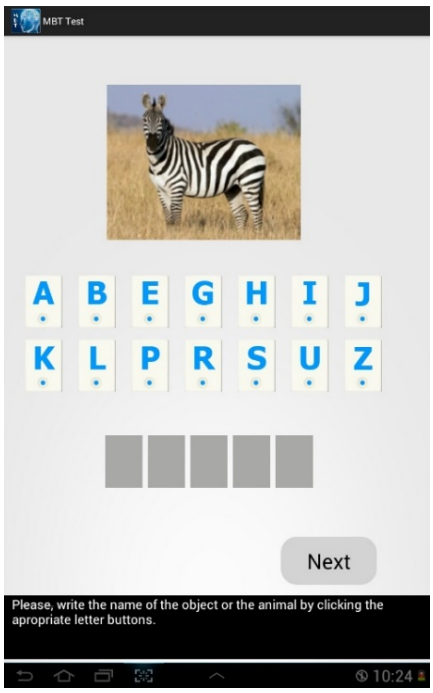

Figure 2.25 : Naming test 2.

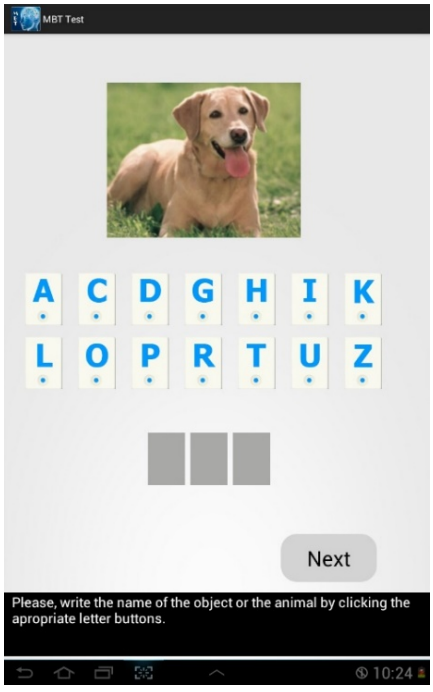

Figure 2.26 : Naming test 3.

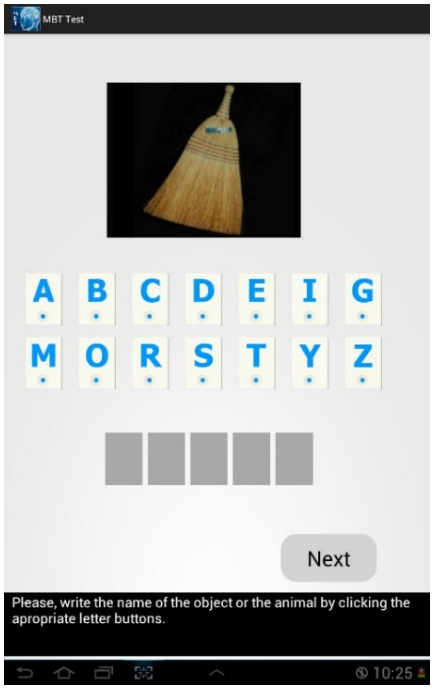

Figure 2.27 : Naming test 4.

Figure 2.28 : Naming test 5.

Figure 2.29 : Naming test 6.

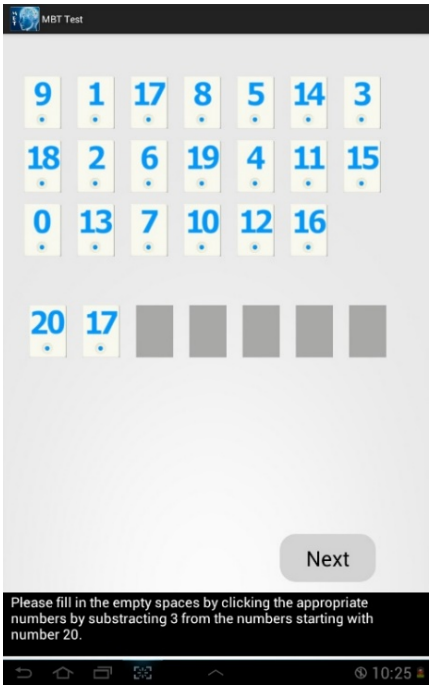

Figure 2.30 : Numbers test.

Numbers test: There is a sequence on the tablet computer screen consisting of numbers starting from 20. It is expected from the participant to continuously subtract 3 from each number starting with 20 and fill in the empty spaces by clicking the appropriate numbers shown on the screen. The instruction for the participant to apply the test is as follows: “Please fill in the empty spaces by clicking the appropriate

numbers by subtracting 3 from the numbers starting with number 20.” This test evaluates the participant’s attention and calculation functions. If the test is completed correctly, the participant gets 1 point. Numbers test interface on the tablet computer screen is shown in figure 2.30.

Colorful shapes test: On the tablet computer screen there are objects with different sizes, different colors and different shapes in 3 different colorful shapes tests. It is expected from the participant to choose the right object which is defined audially and nominally. The instruction for the participant to apply the test is as follows: “Please drag the defined object to the basket.” This test evaluates the participant’s language ability, the ability for understanding the instruction and the perception ability. Each test is 1 point and if the participant gives correct answers to these 3 tests, s/he takes 3 points. In figure 2.31, figure 2.33 and figure 2.35 the interface of the colorful shapes test on the tablet computer screen are shown.

Market test: On the tablet computer screen, there are greengrocer and charcuterie products. It is expected from the participant to place the products to the appropriate section. The instruction for the participant to apply the test is as follows: “Please place the products on the screen correctly either to the greengrocer section or the charcuterie section. Click the product button first, and then click the empty space on the appropriate section which you would like to place the product. If you would like to remove one of the products, you need to click the space in which the product is placed.” This test evaluates the participant’s categorization and semantic association abilities. If the test is completed correctly, the participant gets 1 point. The interface of the market test on the tablet computer screen is shown in figure 2.37.

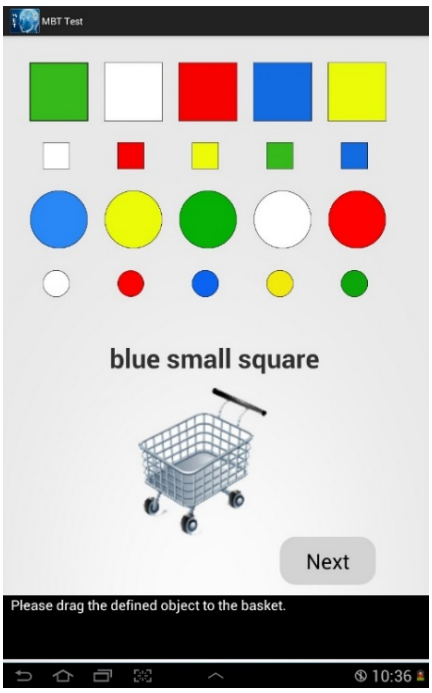

Figure 2.31 : Colorful shapes test 1.

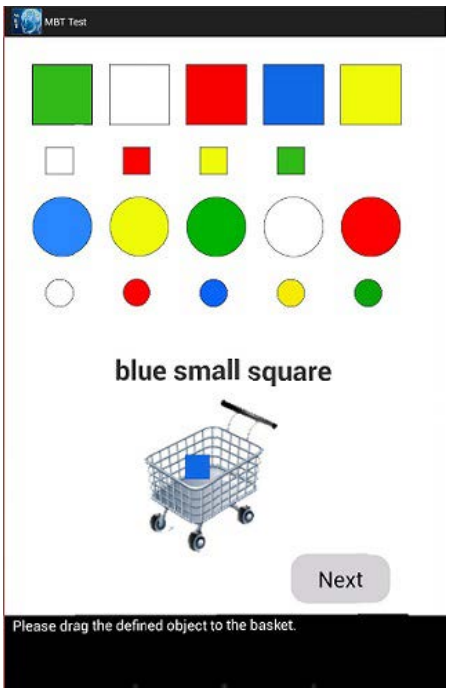

Figure 2.32 : Colorful shapes test 1a.

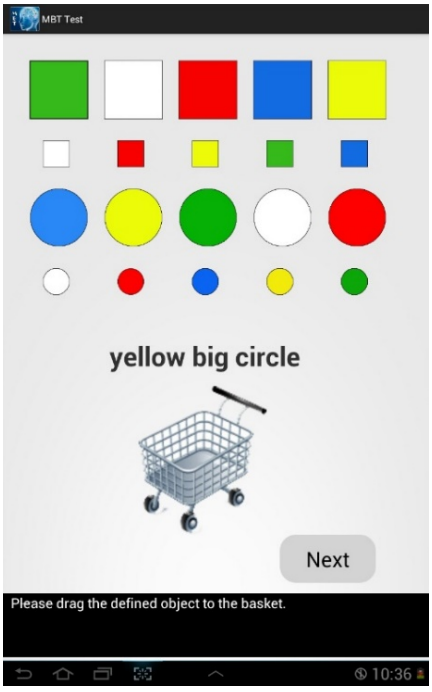

Figure 2.33 : Colorful shapes test 2.

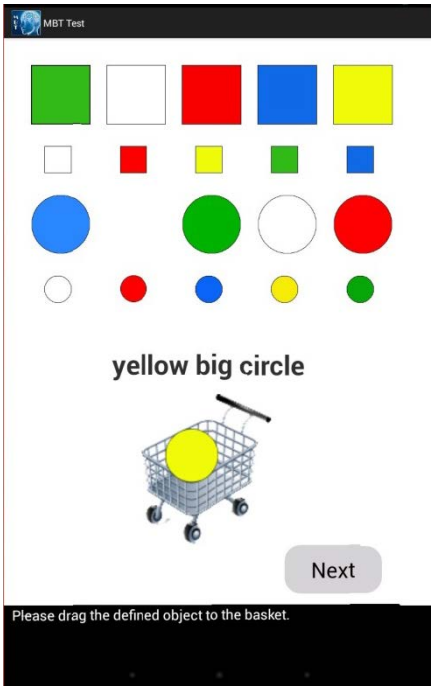

Figure 2.34 : Colorful shapes test 2a.

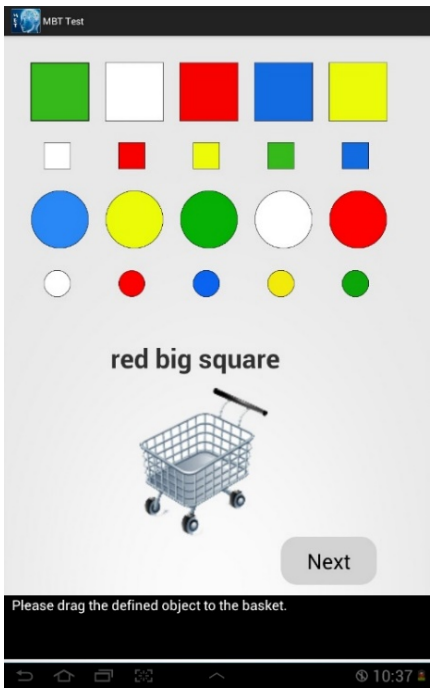

Figure 2.35 : Colorful shapes test 3.

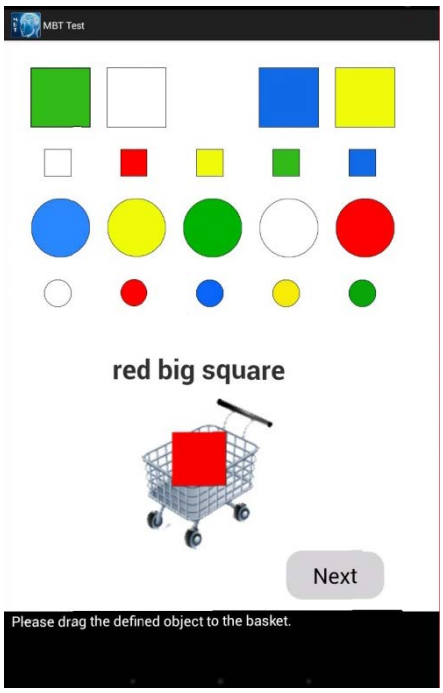

Figure 2.36 : Colorful shapes test 3a.

Figure 2.37: Market test.

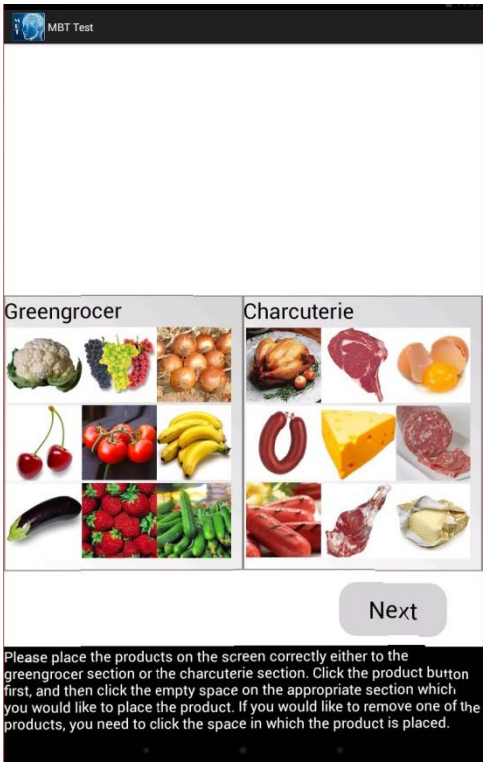

Figure 2.38 : Market test2.

Date test: In this test, it is expected from the participant to assign the date of the day on which the test is applied as day, month and year. The instruction for the participant to apply the test is as follows: “Assign today’s date by choosing the correct day, month and year.” This test evaluates the participant’s time orientation function. If the test is completed correctly, the participant gets 1 point. The interface of the market test on the tablet computer screen is shown in figure 2.39.

Story recall test: In this test, a story is seen on the tablet computer screen. The story shown on the screen is also read audially at the same time. After the participant listens to the story, 3 different multiple choice questions come out on next 3 screens. It is expected from the participant to choose the correct answers. The instruction for the participant to apply the test is as follows: “Please listen to the story shown on the screen carefully and answer the questions correctly which will be shown on the next screens.” Story recall test evaluates the participant’s perception of audial and visual language and memory functions. Each question is 1 point and if the participant gives correct answers to these 3 questions, s/he takes 3 points. In figure 2.40 the interface of the story is shown and the interface of the questions are shown in figure 2.41, figure 2.42 and figure 2.43.

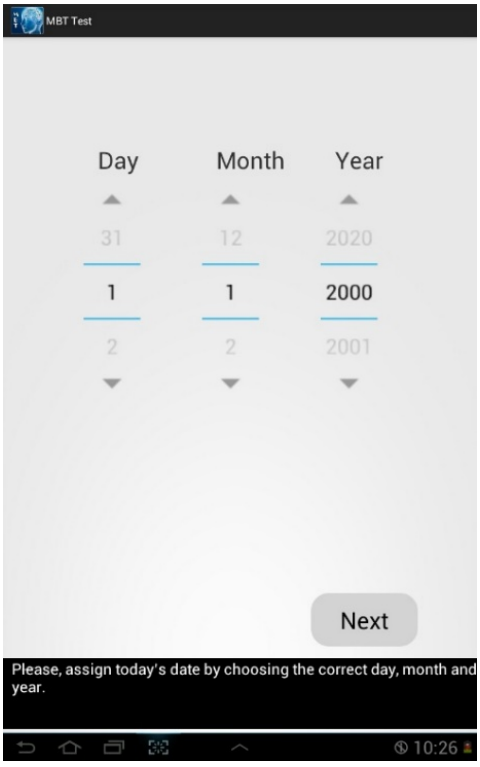

Figure 2.39 : Date test.

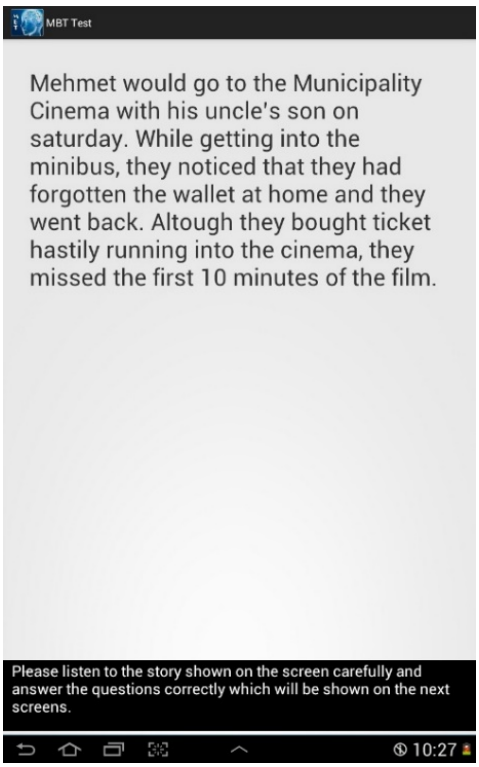

Figure 2.40 : Story recall test.

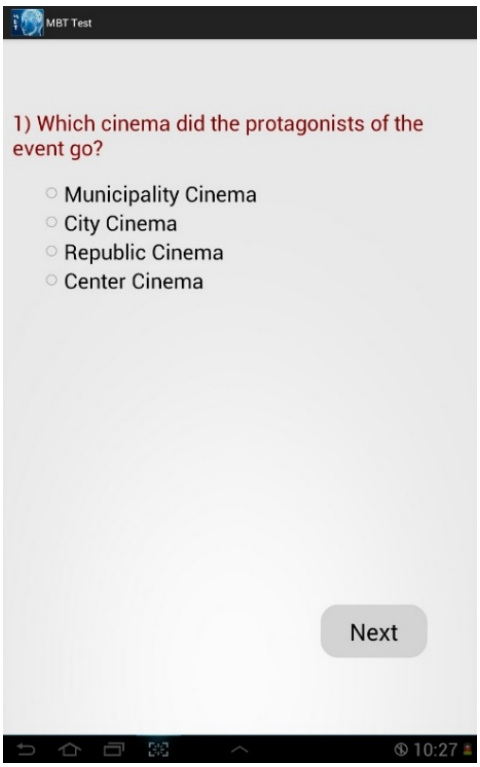

Figure 2.41 : Story recall test 1.

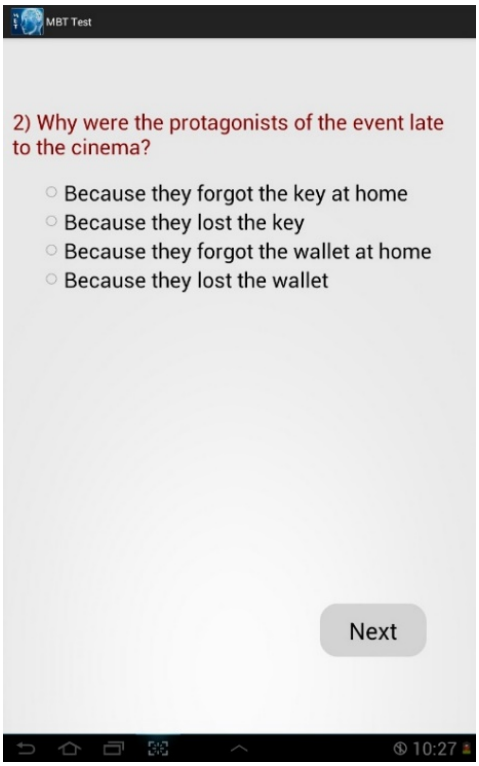

Figure 2.42 : Story recall test 2.

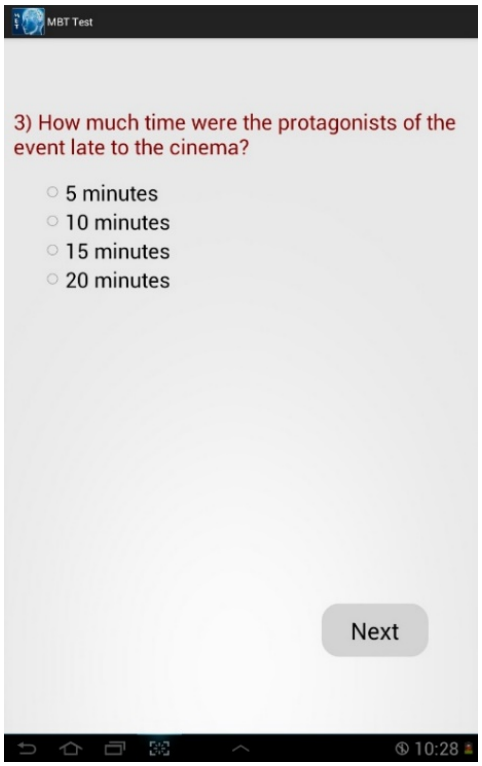

Figure 2.43 : Story recall test 3.

2.2 Design and Implementation of MBTv1.3

Software is developed by using the Eclipse editor in Java language on a device that has Windows 8 OS with Intel(R) Core(TM) i5-3210M CPU @ 2.50GHz processor and 8.00 GB RAM. Application consists of 38 activities.The first activity is the screen that the demographic information is received and the last activity is the screen which displays the graphical result of the participant. Other 36 activities are the screens that the tests are applied.

All Android software consist of Activities. Activities control which data will appear on the screen on what time and how to answer user input or interactions [10].

Transition between activities is provided by intents.Intents combine the independent components of an application forming one system and provide the connection of these components with the Android platform [10].For example, the activity_main.xml file being the first activity belonging to the screen where the persons' demographic information is obtained is set in onCreate method of the MainActivity.java file using the setContentView function. The activity1.xml file belonging to the first test which is the next screen is also set in onCreate method of the Test1.java file. At this point, the transition from activitiy_main to activity1 is established in the java code as follows:

First of all, an intent variable should be defined in MainActivity.java file.

Ex:`Intent intent = new Intent(getApplicationContext(),Test1.class);` Then,
`startActivity(intent);` command should be called where it is needed.

Moreover, the components of the application are described by manifest. The manifest presents essential information about the application to the Android system. Every application must have an AndroidManifest.xml file in its root directory [11]. AndroidManifest.xml in our application is shown in Appendix C. The class diagram of the application is available in this link (http://web.itu.edu.tr/gzorluoglu/files/MBT_cd.jpg)

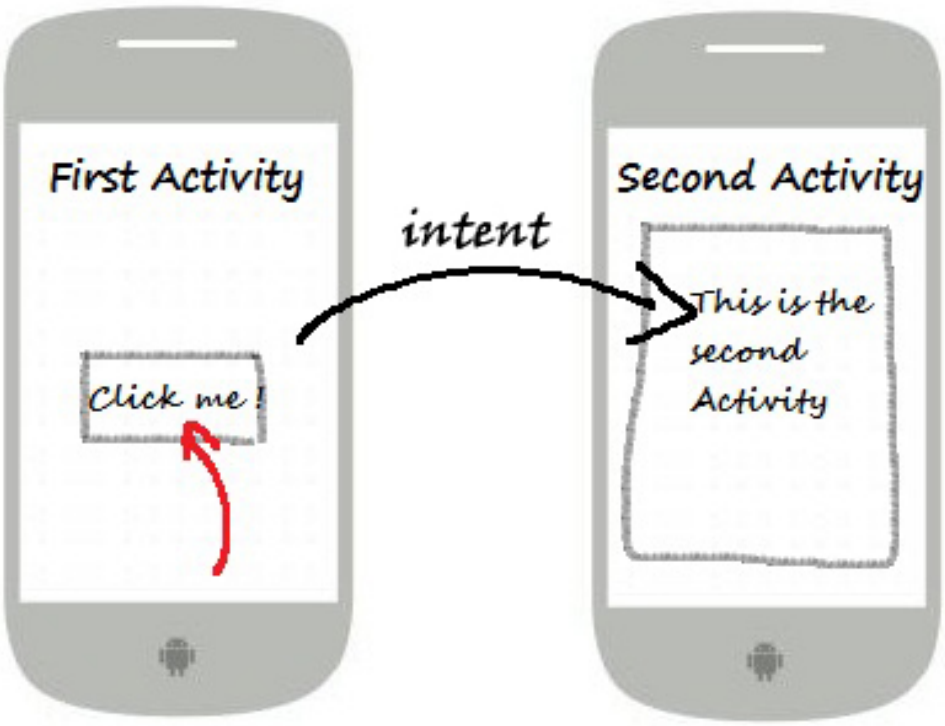

Figure 2.44 : Android example sketch.

2.3 Output of MBTv1.3

At the end of the test,all demographic information about the participant, the total score and detailed information about the wrong answersinthe tests are written to a text file. Besides, participant's full name and scores of each test are saved in an XMLfile. All participants' information is in one XML file and it is easy to check all participants' scores promptly with their corresponding protocol ID number. In addition to this, it is possible to share all the results onlineeasilyby using the XML file if needed. The results are also shown by radar chart to detect the difference between the patient's scores and the average value in each test. The labels in the radar chart are the subgroups of the tests which are expressed in the result section of the thesis. These subgroups are visual, language, memory, attention, abstraction, orientation, arithmetic and executive functions abilities. One of the participants' output files and the radar chart of results are shown below:

Table2.2 : Ouput text file of one of the participants.

Protocol Id: 0001
Name/Surname: John Stendhal
Gender: Male Marital Status: Married
Birth Date: 13.07.1946 Number of children: 3
Birth Place: city
Place the most lived: City
Handedness: Right
Period of study: 11 Last completed school: high school
Occupation: artisan Most studied occupation: artisan
Current working status: retired
Mother's education level: 5 Father's education level: 8
Native language: English If native language is not English, English learned year: -
Tel: 05327240011
Address: Uskudar
Period of habitation: 23
Health status(illnesses): good
Drugs used: none
Where the data were collected(City and Institution): Istanbul
Name/Surname of the person who applied the test: Gokhan Zorluoglu
---
** Clock Drawing Test is unsuccessful. The placement of the numbers and the position of the hour and minute hand is wrong*
** Attention Test is unsuccessful. While 'A' was clicked 6 times, different letters were clicked 3 times.*
** Visual Test 3 is unsuccessful. Left-Right confusion*
** Proverb Test 1 is unsuccessful. The picture which has a concrete meaning was clicked.*
** Story Recall Test 2 is unsuccessful. The answer called "Because they forgot the key at home" is given*
Score: 28

**The information above is representative*

Table 2.3 : Ouput XML file of one of the participants.

```
<?xml version="1.0" encoding="UTF-8"?>
<records>
    <participant id="0001">
        <name>Mehmet Nadir</name>
        <trailmaking>1/1</trailmaking>
        <clockdrawing>0/2</clockdrawing>
        <attention>0/1</attention>
        <visual>3/4</visual>
        <shapesimilarity>2/2</shapesimilarity>
        <shapematching>2/2</shapematching>
        <arithmetic>4/4</arithmetic>
        <proverb>2/3</proverb>
        <naming>6/6</naming>
        <numbers>1/1</numbers>
        <colorfulshapes>3/3</colorfulshapes>
        <market>1/1</market>
        <date>1/1</date>
        <storyrecall>2/3</storyrecall>
        <totalscore>28/34</totalscore>
    </participant>
</records>
```

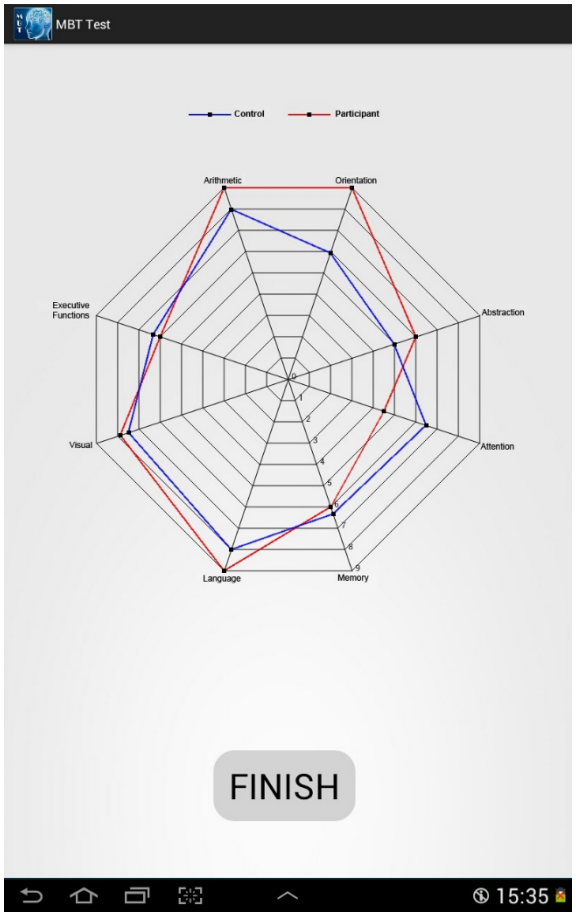

Figure 2.45 : Radar chart representation of one of the participants'scores accordiong to the subgroups of MBT.

2.4 Design Challenges

The tests in the application are designed for an old participant's friendly usage and with our continuous upgrading pilot works, our basic aim is to develop the software application in which it can be applied in the best comfortable way. In order for the participants to understand the test easily, we have paid attention to give the instructions with a basic language written in big fonts. The instructions given in the beginning of the tests are also integrated into the test screen in case the participant has a need to read the instruction again.

It is thought that it would be hard for the participant to use the touch keyboard; therefore, instead of using textboxes, letter and number images which have ClickEvent functions are added into the tests for answering the questions. Additionally, the text of buttons used in the tests are chosen from the words which are not confusing and long.

Also, in case the participant clicksthe “NEXT” button more than one time by mistake, we have made the button visible in the next screen after 1 second has passed. The problems and the changes in each test are given below:

In the trail making test, at first we used DragEvent listener to connect the letter and the number buttons but it was hard for the participant to perform the drag action. Thus, instead of using DragEvent, we switched the listener into the ClickEvent. In the test there is a reset button to restart the current test. The text of the button was “CLEAR”, but the participant could not understand the function of the button. That’s why, we rewrite the text of the button as “RESTART”. Moreover, the thickness of the line between nodes is increased and the color of the line is switched from green to blue for the participant having no problem in connecting the letter and the number buttons.

In the attention test, participants had a hard time to understand that they should click the button when they only see the letter “A”. Thus, we added one more instruction explaining that the button should be clicked only when the letter “A” appears. In addition to this, the number of the letter “A”s was increased to keep the participant’s attention longer. The button was also made invisible as soon as it is clicked, in case the participant makes more than 1 click by mistake. The partipant used to get 1 point when s/he detects all “A”s at first, but in this way there was no difference between the participants who have 1 mismatch and the ones who were able to detect all “A”s. That’s why, we also decided to give 1 point to the ones having only 1 mismatch or 1 skip.

In the clock drawing test, the properareas of each number on the clock circle were expanded for the participant in order to place the numbers in a wide area easily. The hour and minute hands were rotated by the seekbar at first, but this action was decided to be made with TouchEvent listener of the hour and minute hand images in order to make it easier.

In the arithmetic test, instead of using “*” sign, it was decided to use “x” sign for the multiplication operation to make it morecomprehensible.

In the numbers test, the numbers are dragged into the empty spaces to complete the test but the DragEvent was not useful for the participant. That’s why, the listener of the number images were switched from the DragEvent into the ClickEvent.

In the market test, there was a greengrocer section and a charcuterie section and these sections did not include any divided parts in them; thus, it was hard for the participants to understand where s/he should place the products. Therefore, each section was separated into 9 equal spaces in order for the participant to be sure of where s/he should make the replacement. The image of the products' listeners are also changed as ClickEvent instead of using the DragEvent due to the fact that the participant has difficulty in the dragging action.

In the date test; day, month and year sections were designed as a ListView at first, but the participant could not easily use the ListView to assign the date. That's why, NumberPicker was used forassigning the date since the usage of NumberPicker is more comfortable. In addition to this, the font size of the numbers are increased so that it was easier for the participant to see.

In the story recall test, the duration between the story screen and the questions' screen was increased because the time was not long enough formemorizing the story.

After we had taken the problems we had during the duration of the trial measurements of the mobile cognitive test software application and clinicians' demands into consideration, our application was upgraded and MBTv1.3version is being used now.

3. RESULTS AND DISCUSSION

In this section, the results of the statistical analysis obtained by the application of MBT and MoCA are reported. Statistical Package for the Social Sciences (SPSS) is used for this statistical analysis. The limitations of the study are also expressed in this section.

3.1 Experimental Results

One control group consisting of 9 healthy people and 14 patients being diagnosed as dementia are included in this study. Instituitonal Ethical approval was taken for this study (see appendix), and a consent form was signed by each participant. The average age of the patients whose ages are between 73 and 89 is 81.78±4.77, the average age of the control group having the age range between 63 and 95 is 72.55±9.95. While 78.57% of dementia patients are female, 22.43% of the patients are male and 78.78% of control group are female, 22.22% of this group are male. The average year of educationof patients who are graduated from secondary school, high school or university is 13.71±4.14; the average year of education of control group who are graduated from primary school, secondary school or university is 13.66±5.07. The demographic information of groups is given in table 3.1.

Table 3.1 : Demographic characteristics of dementia and control groups.

Group	**Age**	**Years of Education**	**Gender (%)**	
			Female	**Male**
Control	81.78±4.77	13.66±5.07	78.57	22.43
Dementia	72.55±9.95	13.71±4.14	78.78	22.22

Initially, the correlation between the education level and MBT score in the group of dementia patients has been considered, but it has been seen that this correlation is not statistically meaningful.

As a result of the analysis, the average score of MBT in dementia group is 19.92±4.41, in the control group it is 26.88±3.48.

Besides, the average score of MoCA in the dementia group is calculated as 13.57±5.61, in the control group it is 24.55±3.08. The difference between the scores of dementia and the control group in both MBT and MoCA tests is statistically meaningful ($p<0.01$). The distribution of MBT and MoCA scores in the dementia and control group is shown in table 3.2.

Table 3.2 : Distribution of MBT and MoCA scores in the dementia and control groups.

Test	Group	N	Score	p*
MBT	Dementia	14	19.92±4.41	p<0.01
	Control	9	26.88±3.48	
MoCA	Dementia	14	13.57±5.61	p<0.01
	Control	9	24.55±3.08	

** P value is associated with a test statistic. In practice, statistical significance levels which are frequently used are 5% (0.05), 1% (0.01) and 0.1% (0.001). The smaller the p-value, larger the significance.*

Therefore, the average scores of MBT in all cases is 22.65±5.28, the average of the MoCA scores is 17.86±7.21. The correlation between the scores of MBT and MoCA is meaningful ($p<0.01$). Distribution of MBT and MoCA scores in all cases is shown in table 3.3.

Table 3.3 : Distribution of MBT and MoCA scores in all cases.

Test	N	Score
MoCA	23	22.65±5.28
MBT	23	17.86±7.21

The tests in MBT and MoCA are divided into 8 groups which are executive functions, visual, language, memory, attention, abstraction, orientation and arithmetic; afterwards sub-analysis is performed. Subgroups of MBT and MoCA are shown in figure 4.4. Although there is a meaningful difference ($p<0.05$) between the scores of patients and healthy cases in the executive functions, visual, memory, attention and orientation subgroups of MBT, the difference in the language, abstraction and arithmetic subgroups is not meaningful.

Eventhough in the subgroups of MoCA which are executive functions, language, memory, attention, abstraction and orientation the difference between the scores of patient and healthy cases is meaningful ($p<0.05$), in visual subgroup a meaningful difference is not determined between the scores of patients and healthy cases. Distribution of MBT and MoCA subgroups' scores in the dementia and control groups is given below:

Table 3.4 : Subgroups of MBT and MoCA.

Group	MBT Tests	MoCA Tests
Executive Functions	Trail Making Clock Drawing Market	Trail Making Draw Clock Fluency
Visual	Visual 1 Visual 2 Visual 3 Visual 4 Shape Similarity 1 Shape Similarity 2 Shape Matching 1 Shape Matching2	Copy Cube
Language	Naming 1 Naming 2 Naming 3 Naming 4 Naming 5 Naming 6 Colorful Shapes 1 Colorful Shapes 2 Colorful Shapes 3	Naming Repeat
Memory	Story Recall 1 Story Recall 2 Story Recall 3	Memory
Attention	Attention Numbers	List of Digits List of Letters Serial 7 Substraction Starting at 100
Abstraction	Proverb 1 Proverb 2 Proverb 3	Abstraction
Orientation	Date	Orientation
Arithmetic	Summation Substraction Multiplication Division	

Table 3.5 : Distribution of MBT and MoCA subgroups' scores in the dementia and control groups.

Test	Group	N	Score	p
MBT-Executive	Dementia	14	1.07±0.91	p<0.05
	Control	9	2.11±0.60	
MBT-Visual	Dementia	14	5.35±1.27	p<0.05
	Control	9	6.66±1.11	
MBT- Language	Dementia	14	7.21±1.62	p>0.05
	Control	9	8.00±1.32	
MBT- Memory	Dementia	14	1.14±1.09	p<0.05
	Control	9	2.11±0.92	
MBT- Attention	Dementia	14	0.64±0.74	p<0.05
	Control	9	1.44±0.72	
MBT- Abstraction	Dementia	14	0.85±0.77	p>0.05
	Control	9	1.66±1.22	
MBT- Orientation	Dementia	14	0.21±0.42	p<0.05
	Control	9	0.66±0.50	
MBT- Arithmetic	Dementia	14	3.21±0.89	p>0.05
	Control	9	3.55±1.01	
MoCA- Executive	Dementia	14	2.92±1.63	p<0.05
	Control	9	4.44±0.72	
MoCA- Visual	Dementia	14	0.42±0.51	p>0.05
	Control	9	0.77±0.44	
MoCA- Language	Dementia	14	2.50±1.09	p<0.05
	Control	9	3.88±1.26	
MoCA- Memory	Dementia	14	0.28±0.82	p<0.05
	Control	9	2.11±0.92	
MoCA- Attention	Dementia	14	3.64±1.73	p<0.05
	Control	9	5.44±1.01	
MoCA- Abstraction	Dementia	14	0.85±0.86	p<0.05
	Control	9	1.55±0.52	
MoCA- Orientation	Dementia	14	3.07 ±1.97	p<0.05
	Control	9	5.77±0.66	

According to the subgroups of MBT results, the radar chart representation of the average scores belonging to the dementia and control groups are shown below:

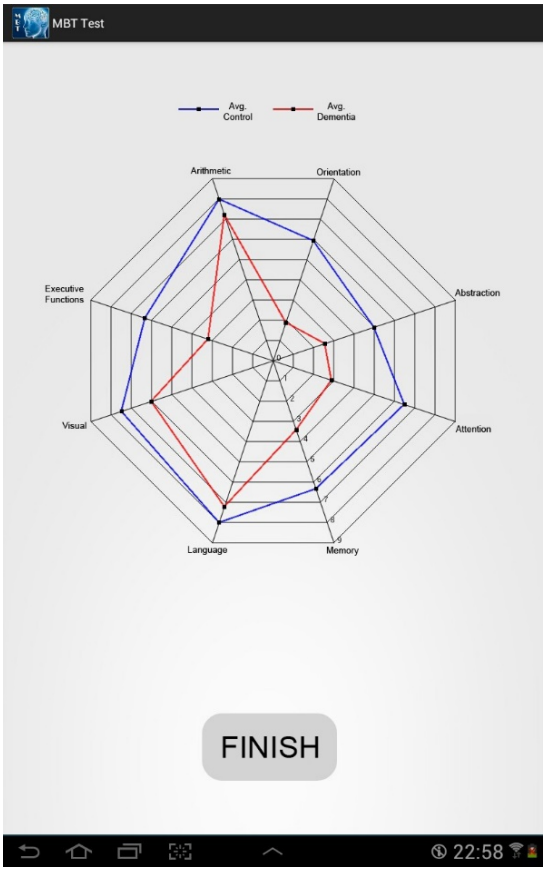

Figure 3.1 : Radar chart representation of the average scores of dementia and control groups.

3.2 Evaluation of the Results

During the experiments, participants applied not only MBT Test, but also MoCA Test which is applied by paper-and-pencil and it is aimed to determine the relevance between the designed tests with MoCA. First of all, it is examined whether there is a relationship between the age and the scores or not. The results of MBT show that, the younger participants get higher points than the elders. Additionly, there is no correlation between the education and the MBT score. It is thought that the reason why a meaningful correlation does not exist is becausealmost all participants are bachelor and they have adequate literacy to apply the tests.

There is a meaningful difference between the scores of the control and the patient groups in both MBT and MoCA Tests. Therefore, MBT Test can distinguish control and dementia groups from each other like MoCA test. According to the scores in all the cases, it is seen that there is a positive correlation between these scores. As a result of the analysis, if the participant gets high points in MoCA test, s/he alsogets high points in MBT test and if the participant gets low points in MoCA Test, s/healso gets low points in MBT test.

According to the subgroups of MBT and MoCA shown in table 4.5, executive functions, visual, memory, attention and orientation subgroups can distinguish control and dementia groups from each other; however, language, abstraction and arithmetic subgroups are not distinctive in MBT Test. Among 6 naming tests which are in the language subgroup, participants generally have difficulty in naming zebra, the other 5 tests are almost done correctly. In the proverb tests which are in abstraction subgroup, even healthy participants give incorrect answers clicking the pictures which have the concrete meaning instead of the ones having the abstract meaning. In the arithmetic subgroup, the mathematical operations are very easy. The reason why these 3 subgroups are not distunguishing is because the number of the participants is not enough and the tests are very easy. That’s why, the tests in these subgroups need to be updated.

In MoCA test, the visual subgroup does not distinguish the control and dementia groups from each other,and the reason is supposed to be that there is a limited number of participants.

One of the limitations of our study is the number of cases’ being not enough. The study is not challenged with a greater number of cases for now, since the application is going to be updated after the results of the first analysis. The other limitations of the study are the challenges experienced during the application of the tests.

4. CONCLUSION AND FUTURE WORKS

In this study, it is aimed to develop a Turkish neuropsychological mobile cognitive test which can be applied on tablet computers to assist the diagnosis of dementia. This Android application consists of 14 different tests and it has an output including the detailed information of the test results and radar chart representation of the participant's scores. According to the experimental results, there is no correlation between the education level and MBT test score. However, MBT assists to distinguish between the healthy and dementia participants and has a meaningful correlation with MoCA test. In spite of the fact that executive functions, visual, memory, attention and orientation subgroups of MBT can distinguish between control and dementia groups, language, abstraction and arithmetic subgroups are not distinctive. In this pilot work, the number of the participants is not enough in order to get significant results. For further analysis, these subgroups will be developed in order to make the tests more distinctive. English version of the application will also be developed for the future works.

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APPENDICES

APPENDIX A: Ethical Committee Report
APPENDIX B: MoCA test
APPENDIX C: AndroidManifest.xml file

APPENDIX A

İTÜ

İSTANBUL TEKNİK ÜNİVERSİTESİ-İNSAN ARAŞTIRMALARI ETİK KURULU

(İTÜ-İNAREK)

5 Mart 2013

Reference No: 9/2013

İstanbul Teknik Üniversitesi Elektrik- Elektronik Fakültesi Bilgisayar Mühendisliği Bölümü öğretim üyelerinden Sayın Doç. Dr. Mustafa Kamaşak ve Denizcilik Fakültesi Deniz Ulaştırma ve İşletme Mühendisliği Bölümü öğretim üyelerinden Doç Dr. Leyla Tavacıoğlu yürütücülüğünde ve de Gökhan Zorluoğlu'nun araştırmacı olarak yer aldığı "Alzheimer Hastalığının Ayırt Edici Tanısında Kullanılmak Üzere Tablet Bilgisayar İçin Geliştirilmiş Bilişsel Yeterlilik Değerlendirme Yazılımı" adlı projesi değerlendirilmiş ve proje etik açısından uygun bulunmuştur.

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Boğaziçi Üniversitesi
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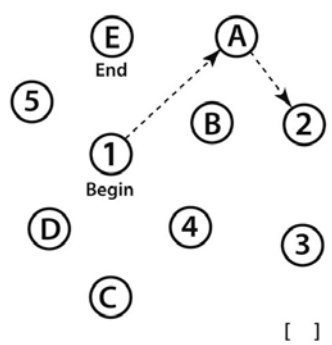
APPENDIX B

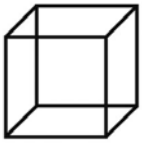
MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE — POINTS



Copy cube



[ ] [ ]

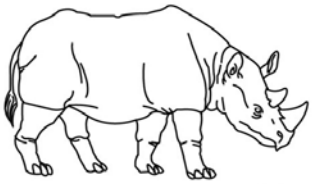
Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands

__/5

NAMING

[ ]



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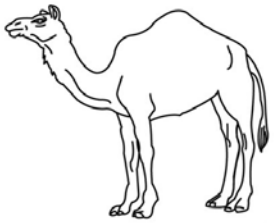

[ ]

__/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.).

Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2

__/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

__/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

__/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ]

__/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)

__/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler

__/2

DELAYED RECALL

	FACE	VELVET	CHURCH	DAISY	RED	
Has to recall words **WITH NO CUE**	[ ]	[ ]	[ ]	[ ]	[ ]	Points for UNCUED recall only
Optional Category cue						
Optional Multiple choice cue						

__/5

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

__/6

© Z.Nasreddine MD www.mocatest.org Normal ≥ 26 / 30

TOTAL __/30
Add 1 point if ≤ 12 yr edu

Administered by: _____

APPENDIX C

```
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```

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Editorship:

- Editor of 5thNationalMaritimeCongressProceedings

Patents:

- MobileCognitiveScreening Test, domestic.

Projects:

- Tubitak 1002 - Short Term R&D Funding Program, "Demans Tarama Amaçlı Mobil Bilissel Test Yazılımı Gelistirilmesi ve Dogrulanması", scholarship

Other:

- Member ofthe organizing committee of 5thNationalMaritime Congress, Istanbul, 11.11.2013