Analysis of Luria Memory Tests for Development on Mobile Devices

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Abstract. Specialist in mental health and neuropsychology apply tests to patients to evaluate impairment level of people cortical functions. Luria tests are designed to treat defects caused by local lesions that may affect the higher functions of the man. In particular, Luria test study the memory and intellectual processes. An application of Luria test is determinate the level of memory impairment. An example of suffers of memory impairment are older adults. The application efficiency of Luria memory tests in older adults decreases owing to biological factor such as inability moving to place of performance testing. In addition, there are a great demand for health services compared with the number specialist capable of addressing mental deterioration. This increases the complexity of control and monitoring patients. A solution for the problem of application efficiency of Luria tests is a digital implementation of the Luria tests on mobile devices, taking advantages of the characteristic of mobile computing. This solution requires an analysis of the Luria memory tests considerate the HCI factors, the different mobile interfaces, the elements of interaction of mobile devices and in the case study of older adults, the special considerations for this kind of people.

Keywords: Luria memory test, mobile devices, older adults, mobile interfaces, HCI factors, collaborative systems.

1 Introduction

Specialists in mental health apply many test to patients to evaluate impairment level of people cortical functions [1]. Luria tests aim to find the fundamental defects that are caused by local lesions in the brain. According to the general approach of A. R. Luria in [2], Luria tests are directed to the study of motor functions, visual functions, hearing functions, functions of language, writing, reading, calculus operations and memory and intellectual processes. There are variants of the Luria tests, such as WAIS test, used to measure the IQ, and Neuropsi test, which proposes a scale to interpret results of evaluations of cognitive functions [3].

An application of Luria tests is determinate the level of memory impairment in patients who have decreased their memory functions [4]. For example, suffers of memory impairment are older adults. Ageing causes physical limitations that

V.G. Duffy (Ed.): DHM 2014, LNCS 8529, pp. 546–557, 2014.

affect quality of life of people, such as decreased visual and hearing abilities, reduced mobility of hands and fingers, decreased attention and reasoning abilities and memory impairment. [5] [6] [7]. For example in Mexico, approximately, 8.6% of older adults have memory impairment [8]. Therefore, it's possible apply the Luria tests to older adults to determinate their level of memory impairment.

The application efficiency of Luria memory tests decreases in older adults owing to biological factors that are pertaining to the human body such as genre, age, and race [1] [9]. For example, inability or difficulty moving to the place of performance of testing, or difficulty in solving the test due to visual deterioration or motor skills. Another problem that has been detected is the coverage to meet the demand for health services. Few health centres and specialists capable of addressing mental deterioration. Each specialist can have a significant number of patients who must apply the tests, which increases the complexity of monitoring patients. In particular, specialists apply the tests and take control and monitoring traditional and face shape (pencil, paper and paper files). One solution is to provide a software tool to assist in this process and have the flexibility to take advantage of mobile technologies.

A solution to the problem of the application efficiency of Luria tests is a digital implementation of the Luria tests on mobile devices. Taking the mobility advantages of this devices, with a mobile system the users can use this tool every time and every place, only if they have an internet connection [10]. This solves the problem of patients mobility. In addition, mobile devices have interaction elements such as touchscreen, microphone, speaker and camera, etc, which providing usability to user [10].

In this paper, we focus in an analysis of Luria tests applied in the research of memory processes and the feasibility of implementation on mobile devices. In addition, it's considerate the analysis for case study of older adults including the terms of interface design and usability for these kind of people [11] [12].

2 Related Work

Currently, there are software tools oriented to treating memory impairment. For example, in the *Sistema Interactivo de Ejercitación de Memoria para Personas Mayores de 50 años*, an implementation of an interactive system was perform, which present Beta-IIR and WAIS test for treating the memory impairment. The system is composed for a web application and a local application in a PC [13]. Another example is *ACTIVAMENTE*, it's a stimulation of cognitive activity software developed to prevent or intervene the memory impairment. *ACTIVAMENTE* has 4800 different exercises and use multimedia elements such as text, sounds and images. It was developed by *Neuroinnovation* enterprise, dedicated to cognitive functions research. Today, it's a system only for PC [14].

3 Luria Tests in the Research of Memory Processes

In neurology and psychology research related with disturbances of the higher cortical functions caused by local lesions of the brain, cognitive, motor or symbolic impairments stand frequently [2].

According with A. R. Luria, the fundamental task of the study of cortical functions is to highlight the fundamental flaw of local brain lesions. From this defect, resulting secondary systematic alterations, thus closer to the explanation of the syndrome that is the result of the primary defect. By this way, the clinical-psychology research can help to brain lesions diagnosis and form and essential part in the general system of clinical research patient. Exist many methods focused to the accomplishment of this task, which constitute the appearance of research neuropsychology methods of patient. In this methods, there are the Luria tests sets directed to the study of motor functions, visual functions, hearing functions, functions of language, writing, reading, calculus operations and *memory and intellectual processes* [2].

In particular, the study of memory processes is one of the most developed parts of the clinical-psychology research and has a particularly great significance for the analysis of the pathological alterations of the psychic processes [4] [2] [9]. The research method of memory processes, that has a particularly importance for the clinical study, are presented in this analysis [2].

4 Interfaces in Mobile Devices

Today, use of mobile devices has increased significantly with the appear of many kind of smartphones and tablets which operate with different platforms oriented to mobile computing [15].

Use of mobile devices has also led to research in the Human Computer Interaction (HCI) area to improve the interaction and users experience on mobile devices, through the different elements of interaction and the types of interfaces that can be leveraged.

Some HCI researchers, are looking for ways to provide computer systems with natural forms of communication, in order to provide the human computer interaction. There are a wide range of development of techniques for mobile devices interaction, which seek to make better use of user capabilities. When the users interact with mobile applications have a limited number of interaction styles available that can take advantage [16]. This interactions is shown below [17]:

- *Hearing interfaces*: From the point of view of mobile interaction design, the audio input and output between the user and device is very attractive and provides a more natural user experience.
- *Haptic interfaces*: The mobile phones have haptic interfaces that are very simple, such a "vibration mode" or touchscreen technologies that allow users to interact directly on the device screen with different finger movements that are interpreted as signals to perform some action.

– *Gestural interfaces*: Research on gesture goes from simple to complicated movements of the device head movement (Augmented Reality), which provide a practical way to enter information.

An important characteristic of mobile devices that are involves in the creation of interfaces is the display [19] According with [20], mobile devices are used under a wide range of environmental conditions with different lighting, which is usually brighter than the brightness of the mobile device display, and this causes that the user cannot visualize correctly what is on the device screen. The tablets and smartphones tend to be held by users at different angles that collect more light from the natural environment unlike desktop computers and laptops that have a vertical orientation. The contrast, the visibility and legibility of the screen depend on the combination of display brightness and reflection on the screen. As greater is the brightness and lower is the screen reflection the better visualizes the contents of the screen [20].

Exist different sizes and resolution for mobile displays [15] [19]. The table 1 shows the classification resolution of Android mobile devices since smartphone to tablet [20]. In this paper, the display considerations are based on the classification shown in the table 1 because the Android platform is open.

Table 1. Resolution of Android mobile devices. From [20].

Screen size	Resolution
Small	426 x 320
Normal	470 x 320
Large	640 x 480
Extra-Large	960 x 720

5 Analysis of Luria Memory Tests for Mobile Devices

According with Steve Love, Human Computer Interaction (HCI) refers to the study of interaction between users and computer systems and applications of everyday life. From this HCI study, exist the concept of Human Centered Design (HCD), which seek the greater usability in an application. Usability refers if an applications is easy to learn, easy to use and friendly to use for final users. Usability is a essential factor in the design of different products, including applications for mobile devices [16] [18].

The analysis of Luria memory tests is performed for the purpose of granting an alternative general implementation of these tests on mobile devices, from point of view of HCI and HCD, considering elements of interaction and the interfaces of mobile devices such as smartphones, tablets, laptops, etc. In addition, the analysis considers each test within an application scenario with general functions, such as send to and data receive from server and storage and query database if the test needed.

The test involved in the memory processes research shown below. For each test under analysis, First briefly describe the test procedure and after presented the implementation analysis for mobile devices. In general, the instructions of every test should be able to show in a pop-up with legible text before the applications solicited an action. A button in the interface must have the functionality to open the current instructions pop-up.

5.1 Words Learning

Description: Are presented to the person many words or numbers, not linked to each and whose number exceeds the amount that can remember. Usually the series consist of 10 to 12 words o 8 to 10 numbers. The patient is asked to recall and repeat the series in any order. After recording the number of items retained, presents to the patient again the series and re-record the results. This process is repeated 8 to 10 times and the data obtained are shown in graphical form called "memory curve". After complete all repetitions and spent 50 to 60 minutes, the specialist must ask to the patient the series of words without mentioning it to the patient again.

The application must download the series of words in a database containing common series for this test. Must have a variety of these series, so that no repetition between tests. The test shows that words can be read to the patient or in the form of text. In this analysis we consider two cases.

- For the case in which the words are presented in the form of text, must take the general considerations of a text in this analysis. The words are displayed on screen with an appearance time for the user to have a chance to read the word and hold it. In this analysis it is proposed that the time of occurrence for word is 5 to 10 seconds.
- For the case in which the words are presented in the form of audio, playback of sound files is required in the mobile devices. This represents a higher data download and use more features. This form is recommended for this test, because it's similar to testing experience between the patient and the specialist.

Once the series of words presented to the patient, the application indicates that the patient must enter the words that were presented above. These instructions can be displayed as text on screen. The test suggests that the reproduction of the words to be spoken instead of being written. This requires a hearing user interface. The implementation of a speech recognition algorithm for mobile devices solves this problem. When the user pronounce the words that recalls, the application transform the received audio into text, allowing to store as a string the words the patient recalls. Once record a word, the application must request more words until the user indicates that they no longer remember more words or reached the total words. The application should display a button to indicate that the user does not remember more words and will terminate the test process. Currently, there are dedicated speech recognition research on mobile devices can

be applied in this solution [21]. A simpler way to implement this phase of the test is to apply the words through a text input, that is, the user will write the words remember and these strings register for the test. Incorrect orthography is a problem when validating a user input word belongs to the series of words.

After all the repetitions, an automatic task in the application, must indicate to patient spend for 50 to 60 minutes to repeat the words of the series presented in the same way that in each repetition. The results of this test, it should be stored in a database that subsequently can generate the curve on the memory.

5.2 Mediate Memory

Description: It is proposed the subject to remember a series composed of 12 to 15 words, using appropriate images that will serve as support for memorization. The images doesn't must directly represent the meaning of the words, the patient selects the images by setting a certain relationship between the meaning of the word and image. The number of images must be of 15 to 20. Once the patient has chosen an image to associate with a word, specialist must ask the patient why chose that image, this relationship should be considered and the patient must remember this association. After 40 minutes, the specialist should show to the patient the selected pictures and asked to mention the word that associate with that image.

In this test we must considerate the size of the images because their represent objects or everyday items, therefore this images must be distinguishable. The test indicates that the patient should be able to see all the images at once. If we consider that the largest number of images in the test are 20, it is clear that they can not be displayed properly on devices with small and medium screen size. Therefore, the suitable screen size is large or extra-large and it is recommended, if possible, use the smallest number of images allowed (15 images). For ease, the patient should be able to select an image to view larger.

Once the images shown, the application must show the patient the series of words to associate with images. The words can be presented in audio or text form. For this test we take the considerations mentioned early in *words learning* test. After the applications present a word, the user must select the image that he related with the word, this association is saved and the application will request the patient to indicate why he choose that image for the current word. In this phase of the test, there are two solutions again: audio or text input. In the audio input case, a file audio will be generated by the mobile device and send to a database so that the specialist can play it later and get results. However, the audio input represents complexity because can be generate a file too big and this implies a problem with the storage of results. A solution for this problem in this case is stablish a time limit to the patient for record his explanation about the association, thus the size of the audio file always be the same. A time limit of 1 to 2 minutes is enough for the patient and won't generate a file too big. In the text input case, the application will display a text entry box for the patient to enter a long string giving the explanation of the association that will subsequently be consulted by the specialist.

After 40 minutes, the application will display in the screen the selected images one by one asks the patient to enter the word that he associate with the current image. The words can be introduced, again, via audio or text input. At this stage, the application should display a button that allows the patient to indicate that he do not remember the word that is asked. The data obtained in the reproduction must be storage in the database.

5.3 Pictogram

Description: This test is a variant of the *mediate memory* test. The test consists of presenting to the patient a series of 12 to 15 words. For each word the patient should draw any sign or figure that can be used to remember the word.

To present the words in this test, we can use the analysis in the *words learning* test. For each word, the application request to the patient draw a figure that associate with the current word. For this is needed a haptic interface. The touch-screen technology allow the user to do actions with the fingers, in this case the action is draw. The draws maked by the patient must be saved in a lightweight format such as JPEG. This images will be shown to the patient after 40 minutes just like the words reproduction in the *mediate memory* test.

5.4 Reproduction of Stories

Description: The reproduction of the contents of stories is a test considered a proposal for the recognition of hearing footprints. The specialist should read the patient any single story and is proposed to the patient who narrates. Then the same is done with a second story (which includes elements of the former). After the patient is asked to narrate the second story, the examiner asks the patient to remember the first story.

The application must provide both the patient stories in audio form. Audio files of the stories should be obtained from a repository. Remember that these stories have elements in common. The application displays a button to start playing the story. After the patient hear the story, the application should ask the patient to narrate the story. This is a audio input similar problem to the *mediate memory* test. We can use the same solution given in this test but with some modifications. The time limit on this test must be at least the time of the original story. Based on the examples described by A. R Luria, the playtime of the stories beyond the original story playtime. Therefore, the time limit of the audio input will be the duration of the original story by adding an additional time. In this analysis, the additional time will consist of half the time the original story. Another solution to this problem is to use text input. The application should display a text box where the user can type the reproduction of the story.

At the end of the test, we will have three sets of data, either text or audio,that the specialist would be responsible for analysing: the first reproduction of the first story, the reproduction of the second story, and the second reproduction of the first story. This information must be stored in the database.

5.5 Direct-Fixation Footprints Test

Its purpose is to establish to what extent the patient is able to maintain direct footprints (visual, hearing ans tactile) produced by different stimulus and clarify whether or not volume alterations and strength preserving footprints.

The research beginning with the analysis of the after-images, that are defined as the footprints that remain a certain time after a visual, hearing or tactile stimulus, and there are test for every type of after-images [2].

In this analysis, we don't including tactile test because it cannot be implemented on mobile devices yet.

Visual Afterimages Test. *Description:* Consists in presenting the patient with 3 or 4 bright red geometric figures over a heterogeneous background (white or gray) for 15 or 20 seconds each one. After this, the patient must be draw the figures that can remember.

For testing visual footprints, it is possible to present 3 or 4 random geometric figures (square, circle, pentagon, etc) bright red on the mobile device display, indicating that remain for 15 to 20 seconds and must be indicated in the instructions that the patient should remain viewing this pictures during this time. The application solicit to the patient to draw the figures that was showed before. As *mediate memory* test, in this test its needed a haptic interface that can be implemented with the touchscreen technology. The draws maked by the patient must be saved in a lightweight format such as JPEG and send to the database.

Hearing Afterimages Test. *Description:* To study the retention of hearing footprints, some methods for short-term memory are used, for example a three-step test is used: first series of three, four and finally five words is read to the patient, after listen the patient must repeat immediately. In the next step, a pause of 5-10 seconds between reading and reproduction is done. In final step, the reproduction of the series of words separated from its presentation by a break of 10 to 15 seconds, during which the patient is distracted talking. In all these cases, the patient must reproduce the words in the same order they were presented.

For this test, the interface can only be hearing. The series of words must be obtained from a repository as audio files that will be played on the mobile device. For the first phase, the words were presented in order and as the series has finished playing, the application should ask the patient to repeat soon. In subsequent phases, the indication is the same, just the break time to retry the number of words should be indicated. At the final step, the distraction in the break mentioned in the test can be an element of multimedia, like a video or a lyric selected by the specialist. The user interface should also indicate the stage at which it is and the necessary buttons to start the test at that stage. This test can use the same audio input method that was mentioned on *words learning* test. The words that the patient mentioned will be compared with the original series and storage that result.

5.6 Summary

In table 2, we can see the summary of the analysis of memory tests shown above and the suitable mobile device for the implementation of each test, generally. Also consider the input and output of each procedure involves testing, according to the proposed solution is also considered in the analysis.

Table 2. Summary: General analysis of memory Luria test

Test	Input	Output	Suitable device
Words learning	Audio or text	Audio or text	Smartphone/Tablet
Mediate memory	Text and images	Audio or text	Tablet
Pictogram	Text	Images	Tablet
Reproduction of stories	Audio or text	Audio or text	Smartphone/Tablet
Visual after-images test	Images	Images	Smartphone/Tablet
Hearing after-images test	Audio	Audio	Smartphone/Tablet

6 Case Study: Older Adults

As seen, Luria test are applied to patients to determinate the level of memory impairment. The older adults are a potential kind of people for application of Luria memory tests, because memory impairment are a common factor that affects quality of life of older adults [7] [9] [8]. However, the use of Luria memory tests by specialist to older adults decreases its efficiency due to limitations of individuals because of ageing, for example, inability to move to where the tests are performed.

A digital implementation of Luria tests on mobile devices is a solution to the problem of the application efficiency of the test and to the problem of patient mobility. In addition, in this case study, take into account the limitations of older adults caused by ageing.

The analysis of Luria tests made in this work provides an alternative implementation on mobile devices with HCI considerations in general. For this case study, the analysis must take a new approach: design interfaces with HCI considerations for older adults applied to mobile devices [5] [6].

Based in the general analysis showed before and design recommendations in [5] and [6], the next general design considerations are proposed for the case study of older adults:

- *Display*, with large or extra-large screen size to reduce visual limitations and with touchscreen technology.
- *Information*, the text showed, including instructions, must have Sans Serif font and contrast color with backgrounds for a grater understanding.

- *Buttons*, big dimensions and must use text instead icons to the user to determine the function of the button more easily.
- *Audio*, must exist a volume control for the user, preferably use female voices with a level of acuity below average. This is according with [5].

Table 3 shows a summary of the analysis of memory tests with HCI considerations for older adults. With the limitations of older adults as new factor in this case study and the new design considerations presented above, the input and output data and the suitable device for each test may change according with needs of this kind of users. Note that for this population the suitable device is a tablet, because the tablet dimensions and display characteristics help reducing visual and haptic limitations.

Table 3. Summary: Analysis of Luria memory tests for case study of older adults

Test	Input	Output	Suitable device
Words learning	Audio or text	Audio or text	Tablet
Mediate memory	Text and images	Audio or text	Tablet
Pictogram	Text or Audio	Images	Tablet
Reproduction of stories	Audio or text	Audio or Text	Tablet
Visual after-images test	Images	Images	Tablet
Hearing after-images test	Audio	Audio	Tablet

7 Conclusion

Based in the analysis made, this paper has identified a considerable Luria memory tests set that can be implemented on mobile devices. There are some tests that can't be implemented because the current technology in mobile computing doesn't offer the usability required for these tests, for example direct-fixation in tactile footprints test. Create a mobile application that containing greater part of Luria memory tests analysed in this paper, will assist significantly to neuropsychology specialist and patients when applying the tests to determinate the level of memory impairment, reducing the number of consultation meetings.

Luria tests, in particular those focused on memory processes, have a wide range of potential users for its application. The analysis made of case study of older adults in this paper, determined that also is possible to make an user-centred implementation taking account the different capacities and limitations of older adults and the usability factors of HCI which can be applied in mobile computing.

In the analysis of the tests, different implementation solutions that can be used for the same test were explored, considering the capabilities that users might have. This might result the beginning to create adaptable solutions which depends of the user capacities and abilities and the different characteristics of mobile devices that can be exploited. This refers to plasticity, a capacity of

interactive systems to adapt to context of use while preserving the usability of the application [22]. This concept can be applied in the case study of older adults. For example, the speech recognition algorithms for mobile devices may replace the traditional input text in displays when people with health problems that limit the haptics capabilities, for example arthritis. Therefore, in this case the user needs a natural interface.

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