User Experience in Older Adults Using Tablets for Neuropsicological Tests in Mexico City

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Abstract. In Mexico, the health gap has increased, so that the population with health problems exceeds the capacity of the available medical specialists. The population sector of the elderly has difficulty moving to medical care sites to undergo treatments. The use of eHealthy tools can help reduce the problem of the health gap by expanding the coverage of medical care to sectors of the population that have difficulties accessing health services. Neuropsychological tests can be digitized on mobile devices and help in the area of neuropsychology. It has been detected that tablets are an ideal mobile device for older adults due to the size of their screen and the different types of interaction they offer. Several neuropsychological tests have been developed: 10-word learning, Poppelreuter and Raven, among others, in tablets. In this paper we present the results of user experiences when testing these applications in seniors in various centers for older adults in Mexico City.

Keywords: eHealth · Mobile devices · Neuropsicological tests · Older adults · User experience

1 Introduction

Mexico has become an urban country. The concentration of elderly population in urban areas of Mexico has increased [16,19]. Currently, the municipal authorities are those that attend the programs of the third age. The increase in demographic aging is due to three main factors: the fall of the fertility rate, decrease in mortality and migratory phenomena [4,23]. The developing countries have greater growth in their population of older adults [11].

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Many government policies on old age assistance provide for older adults with disabilities to remain at home as much as possible. This allows problems of exclusion by keeping them in their current environment. Therefore, a home care network is proposed. In the United Kingdom, this solution has proven to be the most economical for the care of the elderly [24].

In Mexico, some programs aimed at providing care to the elderly through the community have been developed, such as the cases of the "Comparte" program (which arises as a result of the 1985 earthquakes) implemented in the Tepito area in Mexico City, in this program only the female gender will be used to care for the elderly [7]. Another approach are the "clubs of the third age" under the direction of the Municipal System for the Integral Development of the Family (DIF) and National Institute of Senescence INAMAP. In the meetings of these clubs, the elderly practice dancing, they are given talks of self-esteem, health and hygiene, legal advice, among others activities [7,8].

In Mexico, the family continues to be the main institution responsible for the care of the elderly. However, social changes (such as the increase of women in working life) increase the number of older adults who do not have any type of company, loneliness affects 9.8% of older adults [23].

In Mexico in 2005 the 7.1% of the population are older adults. The 27% of the elderly (2.2 million people) are older than 75 years old and present more risks of dependency. According to the National Institute of Statistics and Geography (INEGI) of Mexico, 30% of older adults can not read and write, and the 70% of this group are women.

Projections for Mexico indicate that by 2030 the proportion of people over 60 years old will be 18% and in 2050 the proportion will be 28%. 73% of the concentration of older adults live in cities that have more than half a million inhabitants, 23% live in rural populations and 4% live in cities with less than 500 thousand population. The cities with more than 500 thousand population (Mexico City, Puebla, Monterrey, and Guadalajara to mention a few) concentrate hospitals and specialty clinics for the elderly. The states with the highest increase in older adults are: Chiapas, Veracruz, Oaxaca, Mexico City and Sinaloa [23]. The states with the largest concentration of older adults are the State of Mexico, Veracruz, Mexico City and Jalisco [23].

Although in the cities in Mexico where there is more concentration of older adults are those who have more medical services for this group of people, coverage is not enough to provide care to everyone. 44% of the population is not guaranteed access to medical services. This situation increases in rural communities and in small cities.

One option is to develop e-health tools to increase health coverage for older adults in Mexico. In particular, the area of neuropsychology can benefit from the use of e-Health. Neuropsychology, studies the relationship between the mental and behavioral processes of the brain [5]. Many older adults may have neuropsychological problems, due to cognitive impairments that occur with age. Neuropsychological tests that are used in older adults can be implemented in tablet-type mobile devices. Thus, specialists can attend to more patients in person or remotely, follow up on the system's reports. Mobile applications of neuropsychological tests have been created, such as the word-learning test, Poppelreuters, Raven, and Yerkes, and Luria's test for memory [3,9,10,15].

To prove that it is feasible to use Luria's tests as eHealthy technologies in older adults, it is necessary to know what is the acceptance and the user experience that this group have with the neuropsychological tests that have been implemented as applications for tablets. In this paper we present the results of usability and user experience (UX) evaluations of applications in tablets of some neuropsychological tests of Luria in older adults in Mexico City. These tests have been designed by an interdisciplinary group of professionals from IPN, Cinvestav and UNAM in Mexico. Our experiments allow us to see that there is no resistance to the use of eHealth technologies.

2 Healthy Gap Problem in Mexico

The resources allocated for health services in Mexico are not enough to cover the demand. For example, the Mexican Social Security Institute (IMSS) in 2017 provided medical care for more than 53% of the Mexican population. Only 18.3% of the medical staff is specialized to treat chronic generative diseases. The IMSS has foreseen that the population of beneficiaries will continue to increase, so measures must be taken to provide medical attention to all those who require it [2].

Although there are social security institutions in Mexico such as IMSS or ISSSTE, which provide medical care to a high percentage of the population in Mexico and government programs have been announced to expand coverage, 44% of the total of older adults is not guaranteed access to health services. In urban areas the lack of protection for older adults is 30.4%, and in metropolitan areas it is 30%. Also, 28.4% of older adults are illiterate and 63% are functionally illiterate (without completed studies) [23]. Of the illiterate group, 65% are women. There is a 69% correlation between illiterate people and people who do not have medical coverage in metropolitan areas [23].

Older adults are a sector of the population that is affected by the problem of health gap. Elderly people represent 21.5% of the population of the Mexican Republic [2] and due to their advanced age, they may suffer from physical and mental health problems [18].

The State is committed to providing health services, in order to help improve their quality of life [1]. The IMSS offers services to the elderly, in fact, in the year 2017 the population was 12.5% of the total of beneficiaries. The IMSS made a report in which it shows that the growth rate of the elderly was 45.9% in a span of 8 years, so that the demand for services by people older than 65 years old increased, but the service provided by the institute, has not increased its infrastructure and human resources proportional [2].

3 Neuropsicological Test App for Older Adults

The Soviet neurologist Alexander Romanovich Luria (1902–1977), studied the higher cortical functions in man and his relationship with the cerebral mechanisms. Functions such as perception, memorization, language, thinking, writing, reading and arithmetic can not be considered as isolated or indivisible faculties, since they are usually the result of interaction between different areas of the brain. The main purpose of these tests is to analyze and to understand the structure of psychic phenomena. This analysis helps to diagnose abnormalities of the central nervous system, and to rehabilitate superior cortical functions [6]. Luria visual perception tests are used in the diagnosis of different affections or diseases, for example visual agnosia, which is the inability to recognize objects with the naked eye, but once the patient takes them and manipulates them, recognizes them. This visual condition is due to a dysfunction between the brain and the vision that makes everything around the individual continually new. For example, if a tennis racket is shown to a patient with visual agnosia, he will not know what that object is or what it is used for. Only when using it, the patient will know that it is a racket and that serves to hit a ball. This visual disability is associated with a brain injury caused by traumatic brain injury or stroke and even meningitis.

The application of these tests is carried out by mental health specialists and are usually applied with the help of printed images, audio tracks, interviews, text analysis and even body movements.

In this paper we describe six Luria tests: Poppelreuter 1, Poppelreuter 2, Raven, Words learning, Visual afterimages and Mediate memory. The images used for their description come from the book by Luria [14] and Raven's progressive matrix manual [20].

Poppelreuter Test 1. This test begins by showing the patient the image of the outline of an object, later it will be shown more images containing the original object, but now the outline is mixed with strokes or lines that can confuse the patient. The specialist will request that the outline of the original object be marked, ignoring the additional lines, which are classified as visual noise. The test consists of displaying different images, with different objects and different types of visual noise. Figure 1 shows an example of test images where the original object is a bottle and next to it we see two images with visual noise, the extra strokes can be straight lines or curves.

Poppelreuter Test 2. This test consists of displaying images that contain the outline of different objects. Unlike Poppelreuter 1, this test uses visual noise, but it does overlap the contour of different objects. In this test, there are various objects, all the strokes displayed belong to a general drawing and all objects must be identified. The specialist will ask the patient to distinguish objects. In case the patient shows problems to list them he can use his finger and try to point them out. Figure 2 shows four examples with objects that are easily identified.

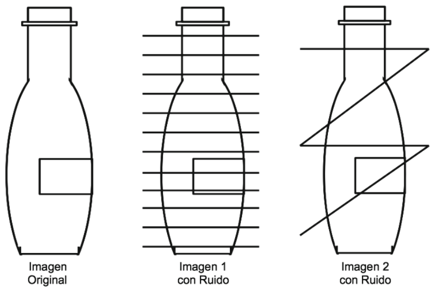

Fig. 1. Example of the Poppelreuter 1 test.

This is important because if uncommon objects are included, the patient will have trouble naming objects and the cause is not a visual disability [17].

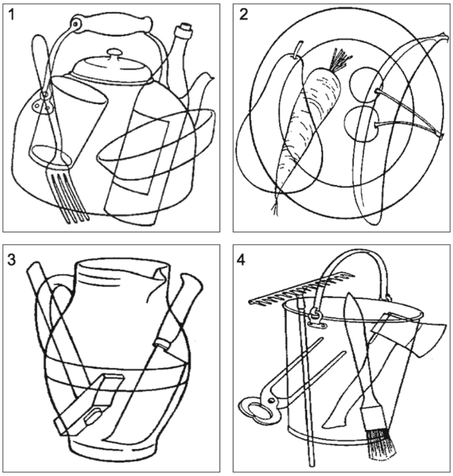

Fig. 2. Example of the Poppelreuter 2 test.

Raven Test. The Raven test is used to evaluate visual abilities and cognitive abilities. It consists of the patient observing a certain visual structure, which is incomplete. The patient can choose between six or eight possible options, but only one is correct. In some cases, the specialist will ask the patient to differentiate the answers from the others. To do this, the patient must identify the pattern of each option.

The complete Raven test consists of three series, each with twelve different test matrices whose difficulty progressively progresses. The advantage of employing Raven to evaluate cognitive abilities is that no grammatical knowledge or complex mathematical ability is required. For this reason, this test is used in children and adults [21,22]. Figure 3 shows an example for Raven test matrix.

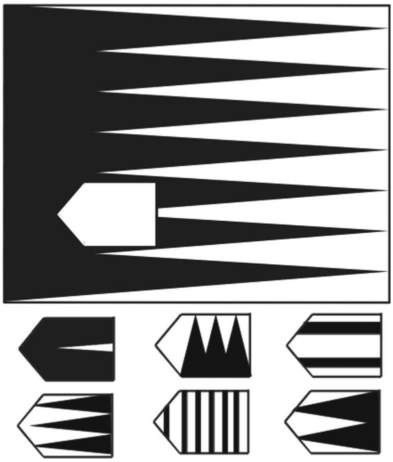

Fig. 3. Example of the Reven test.

Words Learning. In this test, 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 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 min, the specialist must ask to the patient the series of words without mentioning it to the patient again.

Mediate Memory. 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 min, the specialist should show to the patient the selected pictures and asked to mention the word that associate with that image.

Visual Afterimages Test. Consists in presenting the patient with 3 or 4 bright red geometric figures over a heterogeneous background (white or gray) for 15 or 20 s 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 s 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.

3.1 Older Adults Computer Interaction

GUI Design for Older Adults. Interface design for seniors considered possible natural damage they may have. These impairments are visual, auditory, movement and cognitive.

Vision. Physiological changes to the eye related to aging result in less light reaching the retina, yellowing of the lens (making blue a difficult to discern color), and even the beginning stages of cataracts result in blurriness. The eye muscles are also affected; it can be more difficult for older adults to quickly change focus or get used to fast-changing brightness. Some solutions for design include: conspicuity can be enhanced by enhanced contrast and taking advantage of preattentive processes, and effortful visual search can be lessened through application of Gestalt laws.

Effect of vision. How the visual aspects of the web can interact with aging to produce difficulties.

Background images should be used sparingly if at all because they create visual clutter in displays. High contrast should be maintained between important text or controls and the background. Older users vary greatly in their perceptual capabilities; thus interfaces should convey information through multiple modalities (vision, hearing, touch) and even within modalities (color, organization, size, volume, texture). Within a website, consistency should be the highest priority in terms of button appearance and positioning, spatial layout, and interaction behavior. Older users are likely to have a reduced tolerance for discovery and quit instead of hunting.

Information should be presented in small, screen-sized chunks so that the page does not require extensive scrolling. If this cannot be helped, alternative ways of navigating (such as table of contents) or persistent navigation that follows the user as they scroll be provided.

Hearing. A wide variety of changes can occur to hearing. A good auditory design considers both the physical changes in sound perception and the cognitive changes in the comprehension that comes from initial perception. Keeping informational sounds above background noise requires a study of the display environments. The loudness of a sound is truly individual, but can be approximated through the sound pressure levels (dB) and frequencies typically maintained in the aging ear. When hearing loss is severe enough that users wear an aid, consider how those aids interact with the interface.

List of general design guidelines that can be used to improve the design of auditory menus. Calculate loudness levels. Consider potential background noise For tones, use low-tom-mid-range frequencies When designing a display device, consider physical proximity ti the ear and interactions with hearing aids. Avoid computer-generated voices Use prosody Provide succinct prompts Provide context.

Cognition. The main objective in the design of displays is that they are easy to understand. It is intended that the interface is effective, that is, to help users to complete tasks with less confusion and less possible error. To achieve this, we consider some user skills such as: working memory, spatial skills and perceptual speed. Working memory allows the user to recall situations or things in a short period of time. Spatial ability refers to the user to have a location-based representation of the environment where it interacts, in our case, the state of the application. The perceptual speed indicates the rate at which it perceives and processes information. It is known that these skills decline with age, so the design should not be confused with the instructions or the information presented.

For this reason they have only information related to the test. It ensures that each task selection, display, are associated with their own display. Generating an intuitive workflow. In each display the action to take as a central element occurs, this allows the user to hold the attention.

Movement. The movement is an essential part of many means of interaction, because a series movements, perform an action to complete a task. Motion control refers to the accuracy and response time of a movement of a human. The accuracy and response time decay with age, for various reasons, mainly due to illness, such as Parkinson or arthritis. From [18], it is suggested that there is sufficient time for inputs, have feedback by other means (auditory, visual, haptic). Simplifying the number of target elements with which the user must interact. And use words instead of images.

3.2 Design Considerations for Tablets of Neuropsychological Tests

Following the ideas of design for older adults, the designs of the tests were made with a linear navigation, example of this is the Mockup of the application of the Word Learning test that is shown in the Fig. 4.

Applications development considers orientation in landscape and portrait. However, once the test is initialized in an orientation it can not be changed until the test is completed. Luria's memory test applications have two o more combinations of interaction modalities.

Vision-Haptic. In this combination of modalities, the application presents the series on the touch screen and after the presentation, the user must type the words or figure using the virtual touch keyboard.

Vision-Voice. In this case, the application displays the words or the test format on the touch screen and the user indicates the words by voice.

Audition-Haptic. In this combination, the applications says the series and the user must type the series using the virtual touch keyboard.

Audition-Voice. In this case, the applications says the words and the user indicates the words by voice.

Vision-Touch. In this combination of modalities, application shows the format and the users use the finger to draw an image on the touch screen.

Vision-Stylus. In this combination of modalities, application shows the format and the users use the stylus to draw an image on the touch screen.

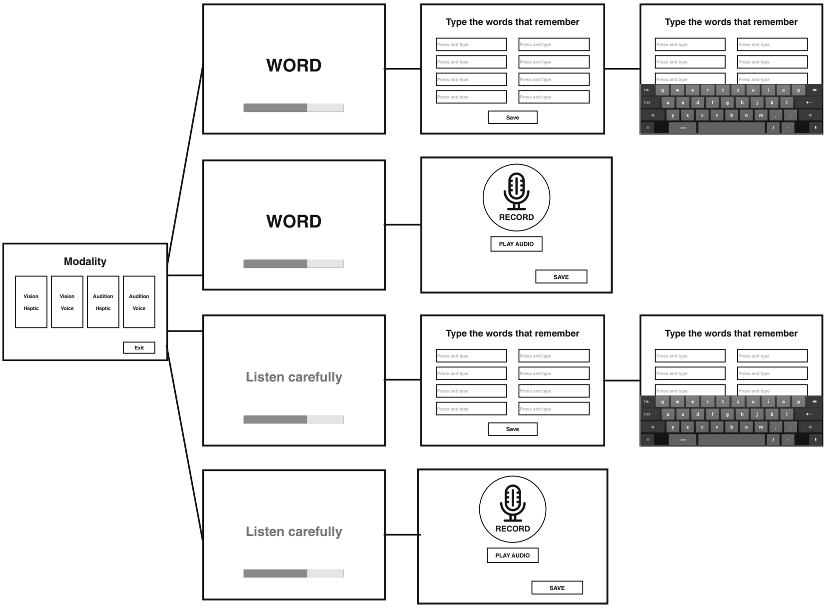

Fig. 4. Mockups for Word Learning tests with interaction modalities.

4 UX Evaluation

According to [25] the relationship between user experience and usability is very close. Usability is more objective because it evaluates the execution of tasks by the user in an interface. UX is more subjective and try to study the experiences lived. From this point of view we can see that the usability evaluation methods help to obtain credentials and understand the UX for a specific problem.

Although it has been about usability and UX, usability and UX are closely linked to the evolution of software, from the point of view of prototypes. The types of dynamic GUIs that appear on devices such as tablets make textual descriptions and diagrams insufficient for a properly designed GUI. Rapid prototyping with user participation is appropriate for the development of these applications. The end user evaluates the prototype using usability questionnaires based on the Likert scale [13] and semantic differential [12]. In this way, we obtain quantitative data for usability and UX in the development of prototypes. The development by prototypes would basically have two or three iterations before an evaluation of UX.

Afterwards, the tests are carried out with the groups of end users. The objectives of the tests are explained to them, a demonstration of the application is made and each user is asked to perform different tasks. In the end, they are given a questionnaire with questions with Likert and semantic differential scales.

5 Experiments

The tests of the applications were made by different groups of the third age. The neuropsychological tests that were done on tablets were: Words learning, Visual afterimages test, Mediate memory, Poppelreuter 1, Poppelreuter 2 and Raven. In all tests, user instructions are by voice and text.

All the tests were developed using a prototype methodology. In the first iteration, the prototype was presented to the specialist to obtain feedback and make corrections. In the second iteration, the tests were done with groups of older adults to determine the usability of the user interface and the effectiveness of the interaction modalities. In the last iteration the tests were applied to groups of the third age and their effect was validated (Tables 1, 2, 3, 4, and 5).

Table 1. Problems with the presentation of instructions.

Test	Text	Audio	None
Word Learning	20.5%	2.5%	77%
Visual afterimage	20.5%	2.5%	77%
Mediate memory	20.5%	2.5%	77%
Poppelreuter 1	12%	4%	84%
Poppelreuter 2	12%	4%	84%
Raven	12%	4%	84%

The memory tests applications for learning words, visual afterimages and mediate memory were applied to 39 seniors with an average age of 70 years old. The 90% is female and 10% is male. In this group, 12% have a some vision problem, 2.5% have a audio problem, 7.6% have arthritis, 2.6% have Alzheimer y and 12% are illiterate. Raven, Poppelreuter 1 and 2 were applied to 25 seniors with an average of 74 years old. In this group, 22 people are female and 3 are male. Three member of this group have a vision problem (12%) and 1 senior have a audio problem (4%).

Table 2. Preferences in the orientation Tablet.

Test	Landscape	Portrait	Both
Word Learning	100%	0%	0%
Visual afterimage	100%	0%	0%
Mediate memory	100%	0%	0%
Poppelreuter 1	64%	28%	8%
Poppelreuter 2	68%	28%	4%
Raven	88%	8%	4%

In all tests, user instructions are by voice and text. As show in Table 2 the groups present a similar behavior in the different tests. The reader can see that the users who performed the Word Learning, Visual Afterimage and Mediate Memory tests have greater difficulty when presenting the instructions by text. The correlation of people who presented this difficulty and who have problems with vision or who can not read and write is 98%. The correlation of users who perform Poppelreuter 1, Poppelreuter 2 and Raven tests with difficulty with text instructions and users with vision problems is 100%. In all test, the users with problems with Audio modality. The correlation, in all the tests, of the users with problems with the modality of interaction of audio and hearing problems is 100%.

Table 2 shows the preference in the orientation (portrait or landscape), of the Tablet to make the tests. Clearly it is appreciated that Landscape orientation was the best acceptance among users.

To evaluate the usability, measurements were obtained through questionnaire qualification using Likert scales and semantic differential scale. Both scales allow us get an evaluation about UX. The questionnaire assesses the understanding of the instructions, the interaction and response of the application. For the questionnaires of all the tests, we asked about the size of the images, buttons, the easy identification of them, preference for interaction modalities and preferences in the use of the application. The possible results are in the range of 4 to 18, and 11 is de medium value. This medium value (11) allows us to divide the results into two sectors, on the left values that indicate less usability and on the right those that reflect good usability levels. In Table 3 we notice that Median and Average are far to the medium value and we can conclude that applications have a good usability for older adults.

For the analysis of time, we only consider the Poppelreuter tests, since they involve a drawing action. From Table 4, we can notice that when the interaction

Table 3. Values of usability.

Test	Minimum	First quartile	Median	Average	Third quartile	Maximum
Word Learning	12	13	16	16.1	18	18
Visual afterimage	12	14	16	15.8	17	18
Mediate memory	11	13	16	15.7	17	18
Poppelreuter 1	11	13	16	15.4	18	18
Poppelreuter 2	12	14	16	15.8	18	18
Raven	12	13	16	15.8	18	18

mode is by voice, the time is very short compared to the modalities of touch and stylus. This behavior is due to the fact that in the touch and stylus modes the user must identify and highlight the figure through a drawing. This makes the user consume more time. Also its possible see that the use of stylus consume more time for older adults because they can have a better definition and try to do it in more detail.

Table 4. Performance for Poppelreuter 1 and 2.

Test	Minimun	First quartile	Median	Third quartile	Maximum
Poppelreuter 1	16.7	26.6	43.2	54.5	145.7
Poppelreuter 2 with voice	9	10	12	15	19
Poppelreuter 2 with touch	69.3	107.7	108.2	145.2	148.7
Poppelreuter 2 with stylus	108.7	143	166.9	192.7	250.1

Table 5 shows the preference interaction modalities. With the exception of the Raven test, the other tests have two or more modes of interaction. The combination of interaction modalities easier to implement is that of Vision-Haptic, however for Word Learning, Visual Afterimage and Mediate Memory tests, it was not the preferred combination of modalities. It is observed that there is a strong preference for the combinations Vision-Voice and Audition-Voice, that is, the interaction between the participant and the tablet through the voice is the most preferred. The interaction through Stylus in the Poppelreuter 1 test has greater acceptance, mainly because this modality allows having a greater definition in the identification of the objects that are presented to the user. The relationship between participants who did not like any modalities of interaction with illiteracy is 40% and with people with vision or hearing problems is 86%. Interestingly, people with arthritis did not think negatively about modalities, they prefer hearing and voice and voice vision. In the Poppelreuter 1 and 2 and Raven tests, people with visual or hearing impairment did not have problems with the interaction modalities. There were participants who could not finish some tests of Word Learning, Visual afterimage and Mediate Memory. These people have Alzheimer or have two problems in vision, hearing, illiteracy or arthritis.

Table 5. Preferences in the orientation of Tablet.

Test	Vision haptic	Vision voice	Audition haptic	Audition voice	Vision touch	Vision stylus	None
Word Learning	0%	38.4%	12.8%	38.4%	—	—	10.25%
Visual afterimage	0%	38.4%	15.38%	38.4%	—	—	12.8%
Mediate memory	0%	38.4%	12.8%	38.4%	—	—	10.25%
Poppelreuter 1	—	—	—	—	20%	80%	0%
Poppelreuter 2	—	80%	—	—	4%	16%	0%
Raven	100%	—	—	—	—	—	0%

6 Conclusions

There is a problem of health gap in Mexico. Older adults are a vulnerable sector of the population and a high percentage of this group does not have access to health services, although they live in urban areas. The increase of health services in Mexico is not proportional to the growth of the population that requires its services. IT services, through e-Health can help increase health coverage in older adults for certain conditions.

In the clubs of the third age of the DIF and INAPAM there is more participation of women of the third age than of men. And a 10% of illiterate people was detected.

Older adults have presented a favorable acceptance to the use of neuropsychological test applications in tablets. Not all users who used the test applications had previous experience with the use of mobile devices. The use of these applications was an incentive to use mobile devices.

Application developers should be careful with the graphic user interface designs for these tests, since the natural deteriorations of older adults should be considered. In addition to the design considerations that exist in the literature, with our exercises we could verify that older adults prefer voice and audio as interactions modalities.

There were participants who could not finish some tests. These people have Alzheimer or have two problems in vision, hearing, illiteracy or arthritis. It was proven that the tablet applications of the Poppelreuters and Raven tests are as effective as if they were done in the traditional way. Older adults take longer to perform some tests when they are digitized, mainly because they are focused on doing things well, rather than finishing them in short times.

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