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REHABILITATION OF COGNITIVE IMPAIRMENT WITH THE REHAMOB

The aim of the study was a continuation of previously provided research on the tablets usability in the rehabilitation of old patients with cognitive disabilities after a brain stroke. First, the analysis of the pilot research results was provided. It gave a hope for possible rationalization of the rehabilitation process after proper improvement of the proposed mobile solution. Prototype examples of mobile rehabilitation applications were extended and integrated in the *RehaMob* - a single mobile solution. The mobile application includes six different types of tasks, which can be useful for stimulation and rehabilitation of language functions, short-term memory, etc. The *RehaMob* was made available again to the therapists in the rehabilitation center. Finally, the mobile application is used with good results in the therapy of patients with cognitive disabilities. The mobile solution is useful support for traditional rehabilitation process, but its influence to the rehabilitation progress is difficult to assess, because the *RehaMob* can be used only as additional tool.

1. BACKGROUND

This document was prepared from a survey carried out with the *RehaMob* - a mobile application developed for patients with cognitive impairments after brain strokes. Such patients take part in a psychological rehabilitation using many exercises to stimulate different cognitive functions: memory, concentration, language functions, etc. The neuropsychological therapy in a common practice mostly uses exercises in a traditional form - printed sheets of paper containing various textual, graphical tasks. However, a major part of patients has additional effect of brain stroke - partial paralysis of motor organs. They have a problem with movement and handwriting. The mobile application prepared for tablets with touch screens is one of the simplest form of interaction requires the only one finger to operate. We predicted that the use of tablets with proper application could significantly support the therapy process. At the first phase of the research, we analyzed the content of memory exercises. Although, there are many exercises available in the Internet (i.e. [1]), tasks used for patients of a particular nationality, should be prepared by authors, they are professionals from the same country, because a lot of them (tasks) have a language form. We contacted the *Upper-Silesian Rehabilitation Center "Repty"* located in Tarnowskie Gory (Poland), where therapists use a special kind of workbooks [6], [13], [19], [21]. Numerous tasks presented on the pages of those exercise packages were analyzed and classified. Separated categories were depended on the exercise content and trained

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cognitive function. In each type, there was assessed level of adaptation for tablets, complexity of interaction, and the need of additional resources - dictionaries, images etc.
At the start, we expected that each category of tasks requires a different mechanism of implementation, but the analysis showed that different types of exercises can often use the same types of interaction on tablets. Such approach simplified the development of prototype applications and had a good influence on the efficiency of applications. However, sometimes direct adaptation of exercises to the form of mobile applications were not possible i.e. traditional exercise mechanism as words handwriting was replaced by a multiple-choice test, which is a big help for many older patients having problems with the virtual keyboard displayed on the screen.
Finally, after the preliminary analysis of exercises and therapists suggestions, chosen tasks were realized in a form of software application to mobile devices. The prototype versions of mobile applications were used in the *Silesian Rehabilitation Center* for a pilot studies [5].
The aim of the current study was the analysis of results of the mentioned research, the improvement of previously prepared mobile applications, and the evaluation of its use in the rehabilitation process.

2. RELATED WORKS

Exercises provided during rehabilitation of cognitive impairments include various tasks assigned to chosen cognitive functions [1]. Frequent repetition reduces the effort of the brain during the collecting and processing of information and improves all cognitive functions [12], [17], because these operations are becoming faster and more automatic [2]. Additionally, every type of cognitive exercises can make long-term memory improvement [23]. A lot of traditional cognitive training programs use face-to-face contact between a therapist and a patient. For patients treated at home that approach can be expensive, because an individual therapy program often requires special appropriate meeting location, organizing timetables, includes therapist's travel time etc.
Computerized approach of cognitive therapy could offer more flexible and personalized treatment than traditional cognitive training programs. That allows for easier access and distribution of rehabilitation applications to persons with access to the Internet. Computerized rehabilitation process can also provide a real-time feedback, and can be customized to the patient's ability level. Therefore computer support is often included to the traditional cognitive training programs [20].
Every process of cognitive rehabilitation needs a constant repetition of exercises. Unfortunately, often repeated the same exercises are boring and discouraging. They therefore need to be diversified, e.g. by performing tasks with randomly generated content. This is done by computers. Computerized cognitive training with elderly nowadays is widely used. Hundreds of publications touch this problem [14]. The results of computer-based cognitive therapy have assessed during many studies. The role of computer in the rehabilitation of cognitive disability remains discussible [15], because effects are largely determined by computer application design, supervision during at-home training, and frequency of training [16].
Another problem is the design of the user interface. The mobile applications used in the rehabilitation process should be easy for use for older people [18], because they are the majority of patients with cognitive impairments. Regardless of diagnosed cognitive disability, we should be also aware that for older people both absorption of information (i.e. task contents) and reaction time, takes more time [11].
Exercises realized with a tablet should be carried out step by step, so that does not discourage older people too much by the complexity of the longer tasks [7]. On the other hand, too many

small steps can lead the user to be lost [22].
Additionally, elderly with cognitive impairments very often have also various physical disabilities, particularly problems with sensory and physical fitness. Moreover, the biggest role in the use of applications play the eyesight. While designing the graphical user interface, we should remember about the contrast of used colors [3], the size of the screen buttons [8], [9] and the intervals between them [10]. Next, the hearing problems can cause problems with the proper recognition of audio feedback within the application. This is the reason, why multimodal interfaces should be designed [4] for the older people with disabilities of various senses.

3. REQUIREMENTS

Describing technical expectations of software application, we need to indicate separately functional and non-functional ones. The functional requirements include fundamental functionality: choice of the task category, running exercises, presentation of patients results. The non-functional requirements are the result of the preliminary analysis and the evaluation of prototype applications used during rehabilitation process in the rehabilitation center by patients with cognitive impairments. The last part of the pilot studies was the evaluation done by therapists conducting rehabilitation activities with patients. The main conclusions are following:

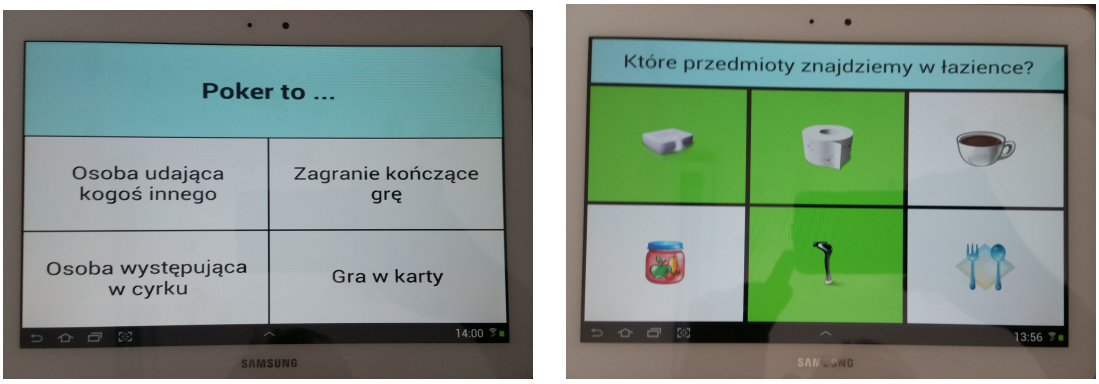
- prototype applications must be improved by the introduction of difficulty levels separately for each tasks category,
- patients have problems entering text with the virtual keyboard displayed on the screen,
- sound feedback is necessary for better signalization of correct and wrong answers,
- prototype applications should be integrated into one single mobile solution,
- simple and large sized graphics must be in proper contrast,
- adaptation of the application to the most popular tablets with 10” of diagonal is needed,
- mobile solution using touch screen is a big help for patients with partial motor disabilities, which prevents the traditional method of solving tasks using paper.

4. THE REHAMOB

The set of several tablet exercises is completed in the frame of the current studies, and they are integrated in the one mobile application under the name *RehaMob* working on the Android Operating System. The application is designed for the Polish speaking patients, so the language of the user interface is Polish as well. The *RehaMob* includes six types of exercises. Choosing any, the user must indicate a proper level of difficulty: easy, normal or hard.

First two types of tasks have a form of quiz. They are used to stimulate the patient’s memory by remembering the meaning of certain words and associating images. The first one has a textual form (Fig. 1(a)). Its objective is to indicate correct definition for a given word. The user sees four definitions on the screen, but only one is correct. The user must touch the screen area containing correct answer. Then it lights up green. Incorrect answers blink red the indicated subarea, and the user has the next trial.
The user interface of the second type of tasks is very similar to the previous one (Fig. 1(b)). Task objective is described by a short text, but answers are given in the form of images and, unlike the previous exercise, a few answers of six presented can be correct. The task is finished, when the patient will highlight only correct answers.

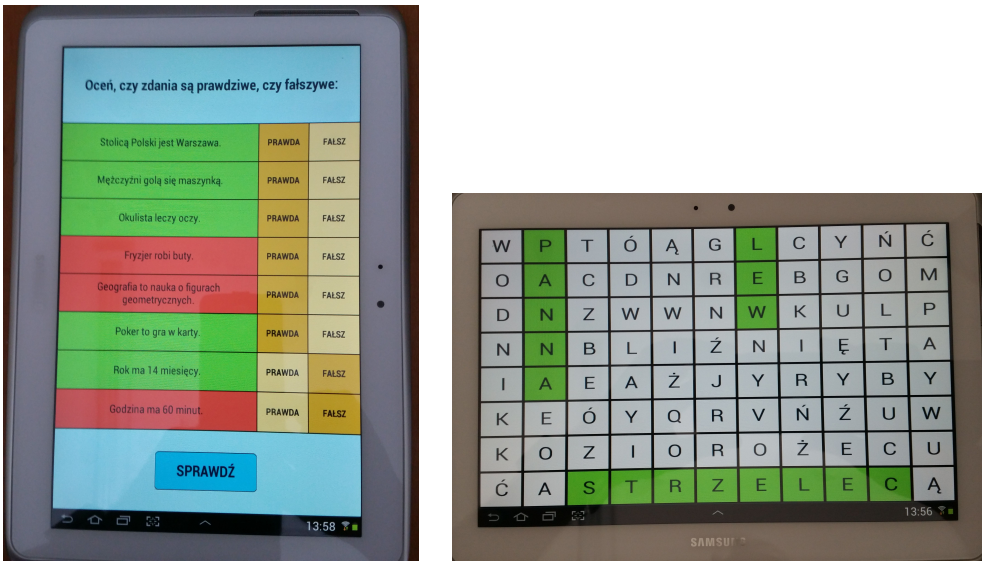
The aim of the next task (Fig. 2(a)) is indication of the logical correctness of short sentences. Single task consists of eight sentences, which should be identified as true or false. After



(a) Textual quiz (b) Graphical quiz

Fig. 1. Tasks: understanding of definitions and classification of concepts.

indicating the answers, the correct ones highlight green, incorrect - red. The graphical user interface in the task is oriented vertically to make better use of touch screen surface.
The next task is a kind of language exercise. The screen is a matrix of letters (Fig. 2(b)). The objective for the user is to look for the words belonging to the given areas, i.e. names of animals, zodiac signs, months, etc. The user has to drag a finger starting from the first character of the discovered word to the last one. Words are randomly placed in horizontal or vertical orientation. They can also be crossed containing a common character or reversed in dependence on the chosen exercise level.

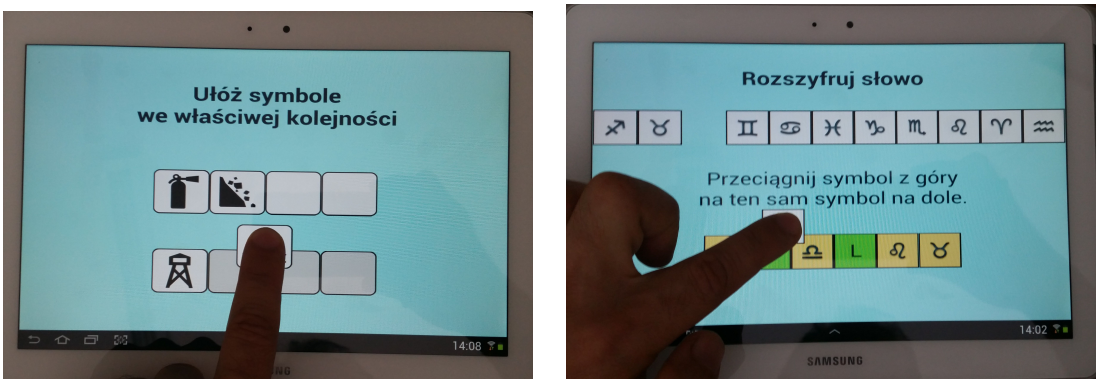


(a) True//False sentences (b) Finding words

Fig. 2. Tasks: logical thinking and perception.

The *RehaMob* also includes exercises for short-term memory training. During several seconds the user has to remember the order of shown symbols. Then, his task is to restore that order (Fig. 3(a)). Higher level of the exercise makes longer the length of the sequence to remember. The last of the implemented types of exercises is the comparing of the simple images (Fig. 3(b)). The user has to identify shapes on the need to decode a hidden word. The higher level of the task makes slighter the differences between symbols shapes.
The user working with two last exercises has to interact dragging chosen graphical symbol to a proper empty place.

In all the exercises, sequence of tasks and the order of the answers are drawn, so patients



(a) Putting in sequence (b) Decoding a word

Fig. 3. Tasks: short-term memory and attention.

do not memorized the placement of correct answers on the screen. Tasks use a thesaurus with words grouped in categories, which were prepared by therapists.

5. TEST RESULTS

The *RehaMob* was used in the *Upper-Silesian Rehabilitation Center "Repty"* in the hospital ward. 12 men and 4 women in the age range 51-84 participated in the research. All of them took part in the neurological rehabilitation. Only two patients had previous experience with mobile devices as tablets, but most of them had used only basic functions of smartphones.
Upon finishing each therapy session, participants completed a questionnaire about the *RehaMob*. This questionnaire was composed of a five-point Likert scale with ten sentences about usability of the mobile application. Due to the nature of patients disability, it was impossible to complete a questionnaire independently and to evaluate the suitability of the mobile application. Moreover, the contact with several patients was difficult because of their partial dementia. Therefore, therapists supported patients completed the questionnaire. The table (Table 1) shows questionnaire sentences with the results as a median value.

Table 1. Result of the questionnaire.

Opinion	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	median	standard deviation
	1	2	3	4	5		
Tasks content is understandable	0	0	0	2	14	5	0.342
Colors are well chosen (contrast)	2	7	0	3	4	2	1.506
Interaction is easy and intuitive	0	0	0	4	12	5	0.447
Sound design application is sufficient	0	0	0	0	16	5	0
Voice reading is not necessary	4	0	0	2	10	5	1.746
Difficulty levels are properly defined	0	0	4	2	10	5	0.885
Tasks solutions are clearly presented	0	0	0	2	14	5	0.342
The patient wants to re-use the app.	0	0	0	1	15	5	0.250

High values for seven sentences can be interpreted that the *RehaMob* in its current form can be successfully used in the rehabilitation of cognitive functions. The only one result, related to used colors, indicates the dissatisfaction of patients. Although colors of tasks screens seem to be well chosen, but the main screen of the *ReahMob* consists mainly of light blue and dark blue colors. That screen presents menu including varicolored buttons representing particular tasks and can make users to be disoriented.
The average value is not calculated for the Likert scale because of its non-discrete value, but the

standard deviation shows significant dispersion of answers for two sentences. First one concerns colors. Two shades of blue used on the main screen are acceptable for 7 persons (mainly older patients), but 9 of patients did not like such color composition. Second ambiguous opinion is on the sentence about the need of voice reading of the tasks content. Support in the form of synthesized voice reading seems to be helpful for some patients, but others can be disturbed. Therefore a good idea is to make optional such application feature.

6. CONCLUSIONS

Tablet-based cognitive therapy is certainly interesting form of rehabilitation. The use of the mobile application developed in the frame of the project, shows that tablets can be successfully used in the process of rehabilitation of cognitive disabilities. For most of patients the tasks in the form of mobile application are more attractive than the traditional (paper) equivalent.
However, we cannot clearly identify a progress in the therapy with the *RehaMob*. Cognitive disabilities are not separated from each other. Rehabilitation tasks do not stimulate single cognitive functions. These two facts caused impossibility to prepare exercises dedicated to chosen cognitive deficits. In addition, many of patients 80+ after brain stroke have already partial dementia. Hence, it is important to get information about cognitive deficits prior to a brain stroke. Thus, more studies should be provided with a greater group of older patients and in longer time interval.
Long-term rehabilitation can be a boring process for many patients, so introducing exercises on tablets may activate patients and encourage further training. First of all, the same exercises are repeated many times. Therefore the sequence of tasks in all the exercises, and the order of the answers must be drawn, because the user can remember the placement of correct answers on the screen. Developers of applications for a cognitive therapy should also remember that patients are characterized by different levels of cognitive impairment, so the difficulty level has to be configurable for each type of task separately. Apart of cognitive disabilities, very often people also have partial motor disability, especially manual problems. Therefore computer-supported language exercises should not use handwriting, virtual keyboard, and sophisticated gestures on the surface of the touch screen. The best approach is simple interaction using the only one finger and one touch point. Synthesized voice reading also seems to be helpful support for some cognitively disabled people.
One of potential further research on the use of mobile applications in the rehabilitation of cognitive disability is introducing game elements. We might predict that gamification will make the application more attractive, particularly for non-elderly.

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