DOI:10.34918/87340

Krzysztof DOBOSZ[1,*], Aleksandra MUSIAŁ[1]

Chapter 14. PROVIDING ACCESSIBILITY IN THE REHABILITATION MOBILE GAME

14.1. Introduction

The rehabilitation of people with cognitive deficits, due to the ageing population in Europe, is a major challenge. The number of elderly people continues to increase, and one of the consequences is an increase in stroke cases. According to [1], the number of stroke-related hospitalizations in Poland is constantly increasing (2019 – 14241 patients, 2020 – 14536 patients, 2021 – almost 14985 patients). The duration of hospital neurological rehabilitation after brain stroke is between 6 and 16 weeks [2]. After returning home, patients often continue rehabilitation, sometimes individually.

Taking the above into account, there is no doubt that tools are needed to support the effective therapy and rehabilitation of neurological patients. At the same time, let us remember that neurological patients often have motor and often visual deficits in addition to cognitive disabilities. Therefore, it is also important that the tools are developed in such a way as to ensure accessibility for users with different special needs. At the same time, the tools should be common enough so that the person being rehabilitated can also practice on their own wherever they are. Therefore, rehabilitation tools can take the form of mobile applications that can be used on smartphones.

The aim of the study was to analyse how to make a rehabilitation tool in the form of a mobile game accessible to people with cognitive deficits. By analysing the state of art, existing solutions and guidelines, a prototype rehabilitation tool was developed and its accessibility was assessed against other similar applications.

[1] Department of Algorithmics and Software, Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology, Gliwice, Poland.
[*] Corresponding author: krzysztof.dobosz@polsl.pl.

14.2. Related work

Personalized medicine is used in the field of treatment of neurological disorders [3]. However, due to the variety of possible deficits resulting from e.g. a brain stroke, we should focus on the individual characteristics of each patient [4]. Therefore, it is important to match the forms of rehabilitation to individual deficits, which can bring more benefits. The positive impact of personalized therapy is also confirmed by clinical trials [5]. Effective therapy of neurological patients can also be achieved using solutions based on virtual reality. Such solutions can help in the rehabilitation of the motor and cognitive functions [6, 7]. However, it should be remembered that rehabilitation exercises can also be realized at home using common devices. This is where smartphones can be very useful. Mobile devices provide a number of solutions that make them better suited for use by people with disabilities than, for example, desktop computers, which often require the provision of specially adapted hardware. In addition, smartphones have a small size and the ability to operate without charging. Therefore, there are great candidates to become a target group of devices to support the development of applications for people with disabilities [8]. Touchscreens have great potential to enhance and speed up navigation on a mobile device due to their ability to recognise various gestures. In addition to existing screen readers or applied commands, further techniques are emerging to improve the use of smartphones by defining a customised set of gestures [9], where each gesture is assigned a function. It is also important to be aware of any options provided by mobile operating systems so that the application under development does not interfere, but works with them.

14.3. Mobile games accessibility

14.3.1. Embedded mechanisms

Mobile devices have many built-in mechanisms that are helpful in daily use by people with disabilities. Every mobile application developer should be aware of the built-in facilitation that mobile devices provide, as some of these eliminate the need to implement some user interaction requirements. In special cases, the developer does not need to include additional code to ensure full accessibility for people with special needs. Smartphones' built-in facilitation mechanisms include [10]:

- Screen reader – gives audible descriptions of the text and images on your screen,
- Font size – allows the user to change a font size of the text on the screen,
- Display – the user can choose to turn on High Contrast Text, Dark Theme, Color Inversion, or Color Correction to make everything more visible.
- Magnification – the user can pinch with two fingers on the screen to adjust the magnification,
- Lookout – relies on computer vision to recognize an object or text, then describes it to the user,
- Voice access – users can provide spoken commands to do everything from opening apps to typing messages to placing a call,
- Voice input – allows users with physical or visual impairments to type text messages, emails, and other notes by saying the words out loud,
- Live transcribe – provides real-time speech-to-text captions in many languages, and many common sounds like applause or laughter, for people who are deaf or hard of hearing,
- Switch access – allows users to navigate their phones with a designated "switch" like a keyboard key or mouse button instead of tapping,
- Sound notifications – alerts users when it hears sounds like fire alarms, doorbells, crying babies, and more.

Developing software for mobile devices, dedicated to the disabled group, requires familiarization with all the functionality that smartphones or tablets offer. Useful features include Speech-To-Text and Text-To-Speech mechanisms, a built-in gyroscope and accelerometer, vibration, volume up and down buttons, and support for multiple touchscreen gestures. In mobile applications, all of these features can be used to prepare an alternative control method.

14.3.2. Game accessibility

The awareness of mobile application developers is growing every year. The number of people with disabilities who speak publicly about their limitations and aspects of their lives that could be made accessible to them with the use of appropriate assistive technologies is also increasing [11]. Thanks to the collaboration of IT teams and people with disabilities, many applications and ways of adapting software to inclusivity have been developed.

There are a few standard and simple rules that can and should be applied to any game or mobile application without much effort. All over the world, associations have been set up to collect information on the limitations that exist and together with a group of people with disabilities, to explore ways of eliminating them. Thanks to the cooperation of many specialists and university representatives, accessibility guidelines for game developers have been prepared [12]. In Poland, the Poznan Gamers Guild Association has been active on this topic for many years and has also made its guidelines available [13]. However, one of the most important issues is simplifying the application interface to the bare minimum [14]. We should also note that sound games are starting to become increasingly popular [15, 16]. They take advantage of auditory acuity in people with other sensory impairments and also allow them to exercise their imagination based on the sounds they hear.

Cognitive disorders refer to problems with, among other things, memory, attention and information processing. Board games are often part of cognitive rehabilitation for patients with neurological problems. Among the widely available materials on the development of accessible mobile applications, you can find separate guidelines addressed directly to developers of mobile games. Paper [17] specifies the field of research for card games. The authors of the article [18] also undertook an analysis of recommendations for board games. There are also wider interpretations and refinements of existing recommendations [19].

14.3.3. Accessibility guidelines

The Memory game, although often using cards, is classified as a board game because of the need to use a flat surface, e.g. a table, to lay out all the guessing pieces. From a set of approximately 120 accessibility guidelines [12], we selected only those that are closely related to mobile board games and are intended for players with cognitive disabilities. These guidelines are collected in three levels: *basic*, *intermediate* and *advanced*. These levels are based on a balance of three elements: reach (number of people who benefit), impact (the difference made to those people), value (cost to implement). The set of *basic* guidelines contains:

- Allow the game to be started without the need to navigate through multiple levels of menus.
- Use an easily readable default font size.
- Use simple clear language.

- Use simple clear text formatting.
- Include interactive tutorials.
- Allow players to progress through text prompts at their own pace.
- Avoid flickering images and repetitive patterns.
- Offer a wide choice of difficulty levels.

Intermediate guidelines are as follows:

- Include contextual in-game help/guidance/tips.
- Indicate/allow a reminder of current objectives or controls during gameplay.
- Include a means of practicing without failure, such as a practice level or sandbox mode.
- Ensure no essential information (especially instructions) is conveyed by text alone, reinforce with visuals and/or speech.
- Give a clear indication that interactive elements are interactive.
- Provide an option to turn off/hide background movement.
- Provide separate volume controls or mutes for effects, speech and background/ music.
- Ensure sound/music choices for each key objects/events are distinct from each other.
- Allow difficulty level to be altered during gameplay, either through settings or adaptive difficulty.

Advanced guidelines include:

- Allow all narrative and instructions to be replayed.
- Provide an option to turn off/hide all non-interactive elements.

The set of analysed guidelines was enlarged, keeping in mind that the deficits that often accompany cognitive disabilities are motor deficits (due to paresis after strokes) and visual deficits (due to the often old age of neurological patients). Due to possible motor deficits, the following *basic* guidelines were selected:

- Ensure controls are as simple as possible, or provide a simpler alternative.
- Ensure interactive elements/virtual controls are large and well spaced, particularly on small or touch screens.
- Include a toggle/slider for any haptics.

Intermediate guidelines:

- Make interactive elements that require accuracy (eg. cursor/touch controlled menu options) stationary.
- Ensure that all key actions can be carried out by digital controls (pad/keys/presses), with more complex input (eg. analogue, speech, gesture) not required.

- Include an option to adjust the game speed.
- Allow interfaces to be resized.

And two *advanced* guidelines:

- Allow play in both portrait and landscape.
- Include a cool-down period (post acceptance delay) of 0.5 second between inputs.

Taking into account accessibility for visually impaired users requires the implementation of additional guidelines. Set of basic guidelines covers:

- Use an easily readable default font size.
- Ensure interactive elements/virtual controls are large and well spaced, particularly on small or touch screens.
- Use simple clear text formatting.
- Provide high contrast between text/UI and background.
- Ensure no essential information is conveyed by a colour alone.

The set of *intermediate* guidelines includes:

- Provide volume controls or mutes for sound.
- Ensure sound/music choices for key objects/events are distinct from each other.
- Allow interface to be resized.
- Provide an option to turn off/hide non-interactive elements.
- Ensure screen reader support for mobile devices.

Advanced guidelines include:

- Provide pre-recorded voiceovers for all text, including menus and installers.
- Ensure that all key actions can be carried out by voice commands.
- Use distinct sound/music design for all objects and events.

Some guidelines are similar, for different categories of deficits. However, during the study we decide not to merge them, because the application of each guideline group will be analysed separately.

14.4. Methodology

Testing the accessibility of a mobile application can be achieved through various methods. An approach proposed by those working on the Android operating system is to identify four ways of verifying applications [20]: manual testing, the use of dedicated tools, automated testing and testing with people with disabilities. Our study focused on

manual testing, using a screen reader mechanism and the Switch Access application. The next step will be to use the Accessibility Scanner tool to test contrast.

According to the guidelines in WCAG 2.2 (Web Content Accessibility Guidelines) [21], the minimum contrast ratio (AA level) is at least: 3.0 for large text, 4.5 for small text. The enhanced contrast ratio (AAA) is a minimum of 4.5 for large text and 7.0 for small text respectively, where the border between small and large text is 24 pixels.

Then we will propose our own *AccessibleMemory* game, in which we will try to implement as many guidelines as possible. We will compare it with other simple board games: those with the highest number of downloads, and those for which the authors have declared accessibility in the description. Each application will be verified to meet the guidelines for mobile board games for people with cognitive, motor and visual deficits, according to the guidelines indicated in the previous chapter.

In an article [22] on inclusive gaming in relation to cognitive disorders, it was proposed that the accessibility index should count as the sum of the guidelines met. However, in order to obtain a normalised accessibility ratio, the sum of implemented guidelines must be divided by the sum of all guidelines. The overall accessibility ratio *AR* will be calculated using a formula that takes into account the weighting of each level of the guidelines:

$$AR = \frac{a_b \sum g_{bi} + a_i \sum g_{ii} + a_a \sum g_{ai}}{a_b \sum g_b + a_i \sum g_i + a_a \sum g_a} \quad (1)$$

where:

g_{bi}– number of implemented guidelines at *basic* level

g_{ii}– number of implemented guidelines at *intermediate* level

g_{ai}– number of implemented guidelines at *advanced* level

g_b– number of all guidelines at *basic* level

g_i– number of all guidelines at *intermediate* level

g_a– number of all guidelines at *advanced* level

a_b– weight of guidelines at *basic* level

a_i– weight of guidelines at *intermediate* level

a_a– weight of guidelines at *advanced* level

We noticed that the *basic* level guidelines had a fundamental impact on the accessibility of the application, hence they were given the greatest weight ($a_b = 4$). They are extended by *intermediate* level guidelines ($a_i = 2$). The guidelines from the *advanced* ($a_a = 1$).) level have the least impact on the overall assessment related to the widest possible accessibility.

14.5. Prototype of the mobile rehabilitation tool

The author's task was to develop a fully accessible Memory mobile game. Note: the rehabilitation game was developed without prior knowledge of the selected guidelines. In this way, it was possible to later identify the elements that caused the most problems for the developers. The tool developed for cognitive rehabilitation is called *AccessibleMemory*. Figure 1 shows the main screen, the choice of difficulty level and the help screen. In addition to the rules of the game, the help screen also provides information on the available ways to move around the board. It also explains the number of cards in each difficulty level. Five levels are available: very easy (2x2 board), easy (2x3 board), medium (2x4 board), difficult (3x4 board) and professional (4x5 board).

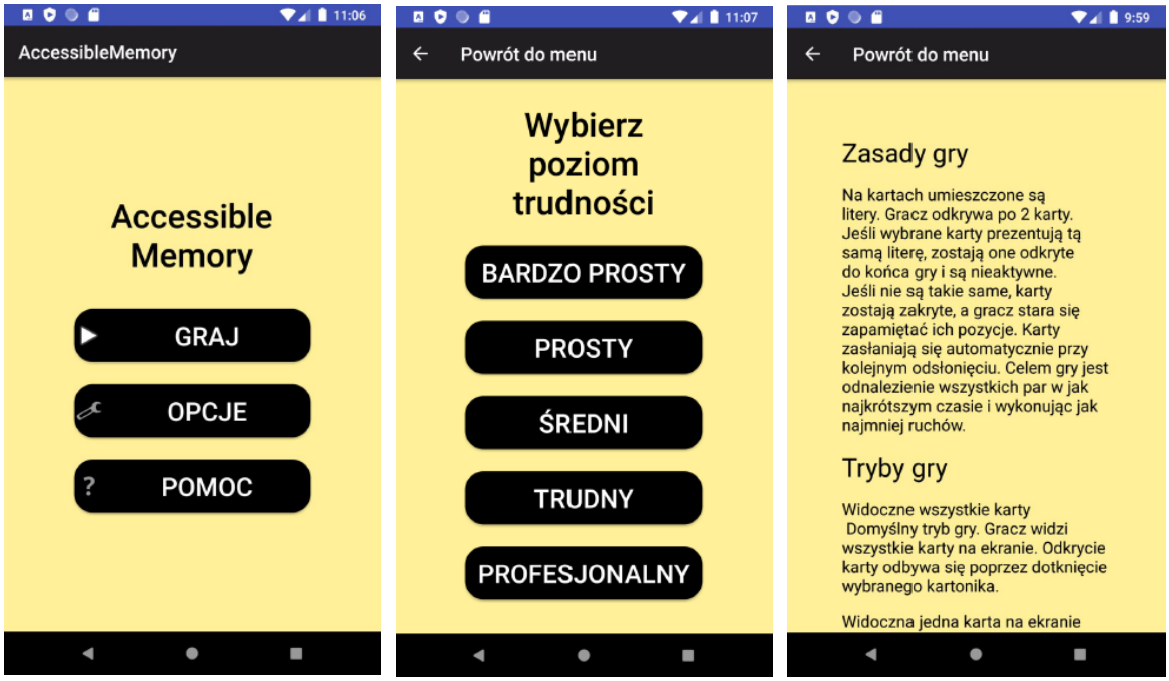

Fig. 1. *AccessibleMemory*: main screen, difficulty level screen, help screen
Rys. 1. *AccessibleMemory*: ekran główny, ekran poziomów trudności, ekran pomocy

Figure 2 shows the options panel and the two modes of presentation of the card board. The options panel (Figure 2) is divided into two sections. The top section refers to general settings. The first option is to enable sounds, while the second allows the user to change the gameplay mode. *AccessibleMemory* uses two modes to present the board. By default, the user sees all the cards on the screen (classical view). In the case of blind users and a system-enabled screen reader, they can explore the board with the cards by moving over them with a pointer, such as a finger. The second mode is related to the

presentation of only one card on the screen. It is dedicated to users with severe visual deficits who do not wish to use the support of the system screen reader. When the single card view is selected, additional settings become available. The first is to enable vibration when the user wants to move beyond the edge of the board. The second allows the user to change the control from swiping to changing the position of the smartphone.

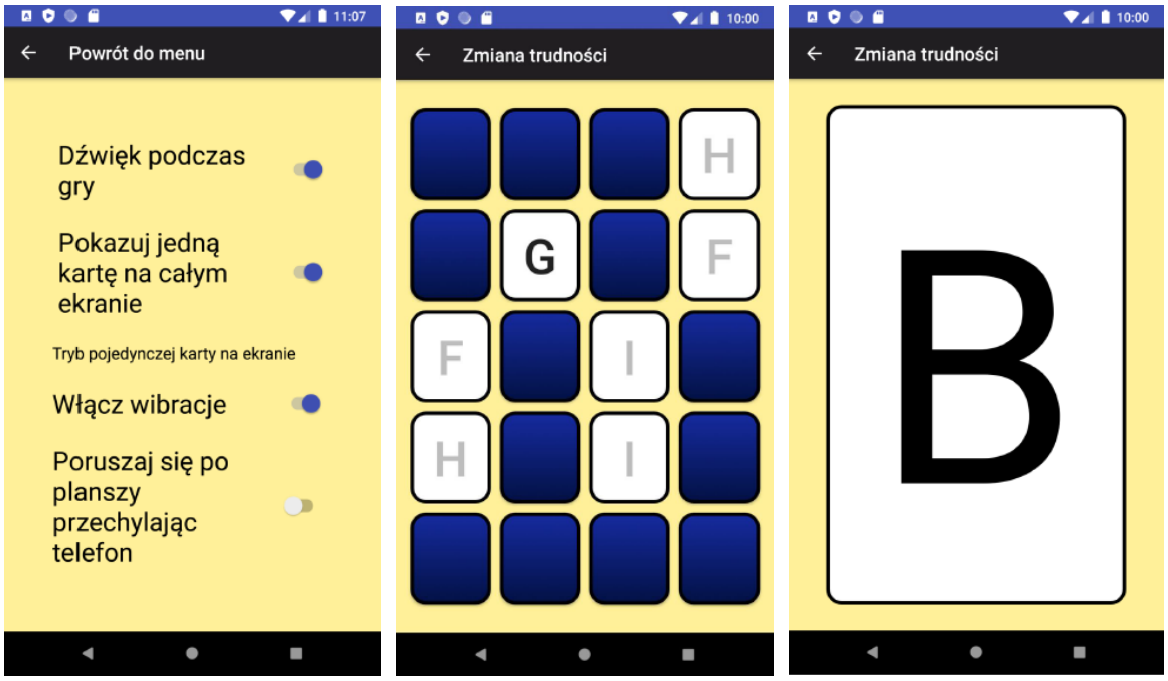

Fig. 2. *AccessibleMemory*: option screen, classical view, single card view
Rys. 2. *AccessibleMemory*: ekran opcji, widok klasyczny, widok pojedynczej karty

14.6. Results and discussion

After the prototype was developed, it proceeded to evaluate it against other simple board games. For the research purposes of this work, three games from the Google Play store with the largest number of downloads and with the highest ratings were selected:

- *Checkers Online* (100M+ downloads, rating 4.5)[1].
- *Backgammon* (10M+ downloads, rating 4.4)[2].
- *Mills* (1M+ downloads, rating 4.8)[3].

[1] https://play.google.com/store/apps/details?id=pl.lukok.draughts
[2] https://play.google.com/store/apps/details?id=uk.co.aifactory.backgammonfree
[3] https://play.google.com/store/apps/details?id=com.donkeycat.mill

The authors of these games have not declared accessibility. The selected set was extended with three accessible mobile applications. However, this time, there was little choice among the board games with declared accessibility. Selected applications include:

- *Accessible Memory* (100+ downloads, rating 4.3) – the application allows two forms of gameplay: traditional (i.e. using a touch screen) or accessible – with an external switch (Switch Access option)[4]; in our assessment we will call it Memory I.
- *Accessible Memory Trial* (1K+ downloads, rating 3.8) – description contains the information that applications is fully accessible for Talkback users; all provided functions of the game are accessible for blind and visually impaired users[5]; in our assessment we will call it Memory II.
- *Chessback* (10K+ downloads, rating 4.0) – blind and partially sighted chess players have been identified as a target group.[6]

It should be noted that no information about accessibility for users with cognitive deficits was found in the description of any application. The study included six selected applications and a proposed prototype solution. It was verified that each of the guidelines selected for mobile board games was implemented. Then the accessibility ratio was calculated according to equation (1). A comparison of the results (AR value) obtained for each of the applications assessed and the set of guidelines is shown in Figure 3.

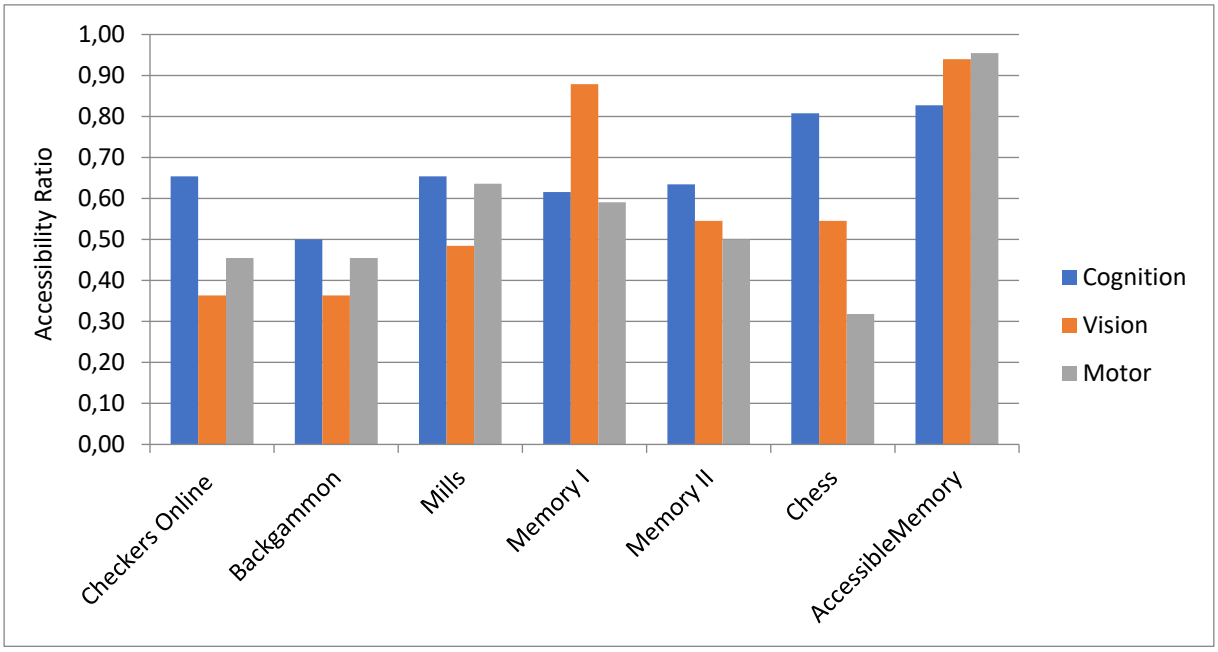

Fig. 3. Comparison of calculated Accessibility Ratio (AR) values
Rys. 3. Porównanie obliczonych wartości Współczynnika Dostępności (AR)

[4] https://play.google.com/store/apps/details?id=com.mouse4all.memory
[5] https://play.google.com/store/apps/details?id=hu.gersoft.accessiblememory
[6] https://play.google.com/store/apps/details?id=vnspeak.android.chess

The results for the number of implemented guidelines in games without an accessibility declaration (*Checkers Online, Backgammon, Mills*) were surprisingly positive. As expected, none of the advanced level recommendations were included, while every game contained at least one intermediate suggestion implemented. However, it should be noted that, despite a relatively high AF value of 0.5 to 0.65, none of them use an easily readable default font size, iterative tutorials, reminders or practicing without failure, which for users rehabilitating cognitive function is a major shortcoming. The degree of implementation of the other requirements (guidelines for visual and motor disabilities) for these applications also oscillates around a value of 0.5.

When analysing the applications declaring accessibility (*Memory I, Memory II, ChechBack*), it was found that they implement some of the recommendations from the advanced level. It is noticeable that the implementation of the guidelines for cognitive deficits in the case of Chess and the guidelines for visual deficits in the case of Memory I is correct. However, this does not change the fact that, despite a little better performance, the results are not satisfactory. Applications claiming accessibility still have deficiencies in the implementation of the guidelines, even at a basic level.

The *AccessibleMemory* rehabilitation game developed best implements recommendations for visual and motor impairments (value around 0.95). Some advanced level guidelines were omitted, but all recommendations of the basic and intermediate levels were implemented. However, for cognitive guidelines the AF value is only 0.83. Unfortunately, of the cognitive guidelines, four were not included: interactive tutorials, contextual in-game help/tips, practice level, repetitive instructions.

14.7. Conclusions

Although the topic of accessibility in mobile games and applications is not unknown, however, there are still many software developers who overlook the needs of people with disabilities. However, accessibility is very important, especially for people with disabilities who want to use them for rehabilitation purposes. Hence, there is a need to prepare sets of accessibility guidelines for mobile applications with a well-defined purpose. Note that even the developer's awareness of the need for accessibility did not allow all the guidelines selected to be included. Attempts to ensure general accessibility may not be sufficient when we need, for example, a specific rehabilitation tool to exercise cognitive functions for neurological patients. Moreover, even for cognitive

rehabilitation, a set of guidelines will be a little different for short-term memory exercises, another for attention or language fluency exercises. We therefore conclude that there is a need to define sets of accessibility guidelines for a certain group of mobile app applications and then disseminate them. Then evaluating the apps, using the proposed accessibility factor, will lead to an effective selection for specific rehabilitation exercises. Finally, we indicated a general need to prepare sets of accessibility guidelines for mobile applications with a well-defined goal, e.g. games for cognitive rehabilitation.

Bibliography

1. E-zdrowie. Liczba hospitalizacji związanych z udarem mózgu. https://ezdrowie.gov.pl/9157, [accessed: 10 April, 2023].
2. Narodowy Fundusz Zdrowia. Rehabilitacja lecznicza. https://www.nfz.gov.pl/dla-pacjenta/informacje-o-swiadczeniach/informacje-o-pozostalych-swiadczeniach/ [accessed: 10 April, 2023].
3. M. Semprini, M. Laffranchi, V. Sanguineti, L. Avanzino, R. De Icco, L. De Michieli, M. Chiappalone, Technological Approaches for Neurorehabilitation: From Robotic Devices to Brain Stimulation and Beyond, *Frontiers in Neurology* (2018) **9**:212.
4. J. Zielińska, Sprofilowana i spersonalizowana terapia pobudzana (sterowana) danymi, *Niepełnosprawność – zagadnienia, problemy, rozwiązania* (2017) **23**:132–148.
5. A. Stasieńko, I. Sarzyńska-Długosz, Zastosowanie rzeczywistości wirtualnej w rehabilitacji neurologicznej, *Postępy Rehabilitacji* (2016) **4**:67–75.
6. RehaCom, https://www.treningmozgu.pl/doc/metody/katalog_rehacom.pdf, [accessed: 20 April, 2023].
7. CogniPlus, https://cognific.pl/produkt/cogniplus/, [accessed: 20 April, 2023].
8. K. Dobosz, Designing mobile applications for visually impaired people. *Visually Impaired: Assistive Technologies, Challenges and Coping Strategies* (2016) 103–126.
9. S. Kane, J. Bigham, J.O Wobbrock. Slide rule: making mobile touch screens accessible to blind people using multi-touch interaction techniques. *Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility* (2008) 73–80.
10. B. Nelson, 25 Smartphone Accessibility Settings You Need to Know About, https://www.rd.com/article/accessibility-settings, [accessed: 20 April, 2023].

11. B. Yuan, E. Folmer, F. Harris. Game accessibility: a survey. *Universal Access in the information Society* (2011) **10(1)**:81–100.
12. Game accessibility guidelines. http://gameaccessibilityguidelines.com, [accessed: 10 April, 2023].
13. Dostępność gier wskazówki dla twórców gier. https://gildiagraczy.pl/wp-content/uploads/2019/04/Dostepnosc-gier-wskazowki-dla-tworcow-gier.pdf, [accessed: 10 April, 2023].
14. K. Dobosz, J. Ptak. How to control a mobile game. *15th International Conference on Computers Helping People with Special Needs, Proceedings Part I* (2016) 523–529.
15. O.T. Borges, M. de Borba Campos. "I'm blind, can i play?" recommendations for the development of audiogames. *International Conference on Universal Access in Human-Computer Interaction, Springer* (2017) 351–365.
16. G. Johnson, S. Kane. Game changer: Accessible audio and tactile guidance for board and card games. *Proceedings of the 17th International Web for All Conference*, New York, NY, USA (2020) 1–12.
17. K. Dobosz, A. Adamczyk. Accessibility of mobile card games. *17th International Conference on Computers Helping People with Special Needs, Proceedings, Part I* (2020) 217–224.
18. M. Heron, P. Belford, H. Reid, M. Crabb. Eighteen months of meeple like us: An exploration into the state of board game accessibility. *The Computer Games Journal* (2018) **7(2)**:75–95.
19. G. Mahardhika, A. Kurniawardhani, D. Yolhanda. Mobile games interaction design for people with visual impairment using participatory design approach. *IOP Conference Series: Materials Science and Engineering* (2019) 482:12–39.
20. Test your app's accessibility. https://developer.android.com/guide/topics/ui/accessibility/testing, [accessed: 10 March 2023].
21. Web Content Accessibility Guidelines (WCAG) 2.2, https://www.w3.org/TR/WCAG22/#contrast-minimum, [accessed: 10 March 2023].
22. A. Jaramillo-Alcázar, S. Luján-Mora, L. Salvador-Ullauri. Inclusive education: Mobile serious games for people with cognitive disabilities. *Enfoque UTE* (2018) **9(1)**:53–66.

PROVIDING ACCESSIBILITY IN THE REHABILITATION MOBILE GAME

Abstract

In the article, we presented how to ensure accessibility for the mobile rehabilitation application. First, we demonstrated the need to develop mobile applications that can act as rehabilitation tools for neurological patients. We then listed a number of accessibility mechanisms provided by modern mobile operating systems. As a next step, we looked at accessibility in mobile games and proposed three sets of guidelines for accessibility for people with cognitive, motor and visual disabilities. Then we proposed our own rehabilitation application and compared its accessibility with similar applications with the highest number of downloads and three more for which the authors declared availability. For the assessment, we recommend a new method of calculating the accessibility ratio.

Keywords: cognitive impairment, rehabilitation, accessibility, mobile application, card game