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Enhancing Mobile Game Accessibility: Guidelines for Users with Visual and Dexterity Dual Impairments

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Abstract. Software accessibility has recently become a legal requirement in most countries. Minimal guidance into the legalities of this matter has been provided, leaving most software engineers to adapt software they write to "skim" the surface of what is acceptable, such as providing simple screen reading capability. Even less information is available for users with two disabilities. In this work, we provide a user-centered designed game example, with a participatory design approach, to address not one but two disabilities, vision and dexterity impairments, concurrently. We show how entertainment and interaction can take priority in the development process while not compromising on the usability and accessibility of the games. We provide the reader with seven guidelines from our findings to create accessible mobile games that can be entertaining for people with dual disabilities and non-disabled individuals equally.

Keywords: Accessibility · Games · Guidelines · Disabilities

1 Introduction and Motivation

As of March 2021, 84% of adults above 16 possess a smartphone [18]. With this widespread of smartphones, mobile gaming is more accessible to a broad audience. However, the current state of game accessibility remains a significant concern, with more than 94.8% of Android applications containing accessibility violations [1]. Research has shown that most developers ignore accessibility guidelines due to two main reasons, the lack of awareness and the lack of tools to support them in the requirement specification and the implementation stages [3].

Researchers have surveyed 836 papers published in ASSETS and CHI venues and have found that only 1% of the published research have targeted users with multiple disabilities [15]. Multiple disabilities involve people with more than one disability in "cognitive, physical and/or functional abilities" [16]. Meanwhile, the majority of accessible games focus on rehabilitation purposes [23], [28], [17]. In a recent systematic analysis of video game accessibility, it is concluded that

entertainment is not targeted as much and that future research should have more accessible games in the entertainment genre [8]. Indeed, it is important that we target entertainment rather than pure educational, rehabilitation, or therapeutic purposes. There is a clear call for future research projects for users with multiple disabilities or complex needs [24], which highlights the necessity for more inclusive guidelines for mobile application development.

Although specific statistics around users with both vision and dexterity impairments are limited, affected people are more than one could expect. For example, there are an estimated 1.6 million people with complex disabilities in the UK, which is projected to increase to 2 million by 2029 [22]. Complex disabilities involve individuals having two or more sight, hearing, or learning disabilities [21]. Similarly, conditions, such as cerebral palsy, multiple sclerosis, or certain stroke experiences, affect speech and dexterity. 764,000 people have at least one symptom of cerebral palsy in the U.S. [20], and 130,000 adults in the UK [13].

Lazar has proposed a framework for "born-accessible development" [14]. In this approach, "accessibility is considered as a primary design goal from the start, and people with disabilities are included from the start" [14]. Our work aims to develop a framework for mobile game development accessible to users with dual disabilities addressing the need apparent in this area. We utilize Artificial Intelligence (AI) to enhance accessibility and entertainment. This paper presents the initial prototype of our ongoing project focusing on different dual disability combinations. We present one dual disability combination, limited vision and dexterity impairments. We plan on creating new prototypes targeting other dual disability combinations in future projects. We propose seven guidelines for mobile game development to ensure that the game is "born-accessible" for users with limited vision and dexterity. The proposed design guidelines were concluded by developing an accessible mobile game using a user-centered participatory design process. "Cell Escape" is available for anyone to explore and try out suitable for adults with computer literacy.

2 Related Work

WGAG [27] and other guidelines, such as Android Developers [7] and IBM [11] are available for developers. WCAG guidelines cover a range of disabilities, such as vision, hearing, movement, and speech along with combinations of these [27]. For example, part of the guidelines suggested by the UK government include ensuring that the service works with assistive technologies, such as screen readers [26]. Indeed, this guideline helps users with visual and speech dual disabilities, but it would not ensure accessibility for users with vision and movement impairments because screen readers heavily rely on tapping or keyboard use. Guidelines are limited to complex disabilities or less common disabilities.

Similarly, games accessible for dual disabilities are limited. Theil, Buchweitz, et al. have presented one of the first game design recommendations for users with dual sensory loss, particularly deafblind users [25]. They propose user-driven game design recommendations based on different categories, such as tim-

ing, turns, instructions, etc. [25]. Nevertheless, they focus on hearing and vision impairments with an ability-based design framework rather than disability.

Binaural sound [4], haptic feedback [12], and audio-based approaches [5] are used effectively in research projects to enhance game accessibility for blind users. Nonetheless, these games are not compatible with users with limited dexterity due to their dependency on tapping and swiping on phones. Similarly, Google has developed the TalkBack feature embedded into the Android platform, a great tool for visually impaired users. Many mobile text-based games using this feature are accessible for the blind, such as the Zork series adventure game [2]. Nevertheless, these games rely on tapping or keyboard keys to play are not applicable to people with limited hand dexterity.

Meanwhile, there are tools and research projects around enhancing accessibility for users with limited dexterity on mobile devices. Google's Voice Access allows users to navigate using voice commands [6], which benefits those with dexterity issues. Yet, it is not accessible for blind users because it numbers the user interface elements requiring users to say the number of the element they want to tap.

The games mentioned rely on visual elements or tapping to move forward. Future endeavors should focus both on technological innovations and ensuring that these advancements contribute to a gaming environment accessible to users with multiple disabilities.

3 Developing the Cell Escape Game Prototype

The Cell Escape Game is a mobile game offering an entertaining experience without the need for tapping on the screen or relying on visual elements. Speech is used as the main input. Sentiment analysis is used for the processing stage and deciding upon where to divert the user. With no visual elements implemented, the game relies on audio files as the main output to communicate with the user. Therefore, the game is accessible for users with both dexterity and visual impairments with speech input and audio output. User input is only taken when the player is asked a question or expected to do a task. It is timed at three seconds because constant consideration of user input is not viable in this instance, as it would result in a disorganized experience due to the nature of the game's input/output process. Figure 1 shows the game's architecture with the devices needed for each operation. The game does not have visual elements as they are not necessary.

In this game, the main character has recently been brought to a prison cell. There is a man in his next cell asking for help to escape. The non-playable character (NPC) gives different options and answers based on what the player says. However, the game story has a linear progression, and the NPC will try to convince the user to help them if the user disagrees to help. This will help and move forward in the game accordingly as shown in Figure 2. Fixed options with no sentiment analysis needed include "start game" and "end game". While "start game" is available only in the introduction scene. The "end game" option

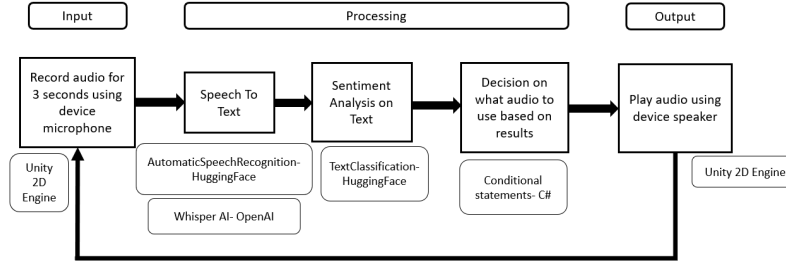


Fig. 1. I/O operations for the game prototype with the technologies used for each process. No visual elements are used.

is available throughout the game. In the final scene, the story will conclude and the user will be notified that they have reached the end of the prototype. The application will automatically exit afterward. Finally, targeting ethical considerations, permissions are taken from the player to use the microphone from the beginning of the game.

We developed the game using a participatory design approach involving ten user experts, two of whom were legally blind. The experts were user experience and accessibility specialists with extensive professional or academic research backgrounds³. The initial requirements were set, and the game went through multiple design iterations. The user experts provided constant participation and support throughout the design and development process. We received comments on the inclusion, entertainment, and efficacy of the accessibility and AI integration in each iteration. This will help with refining the stories and technologies for our upcoming projects. The initial requirements included accessibility for visual and dexterity impairments, entertainment as an essential aspect of the game, and ethical considerations for microphone permissions.

The game is developed using Unity 2D game engine version 2021.3.2f1. The source code is written in C# (version 7.3). We have

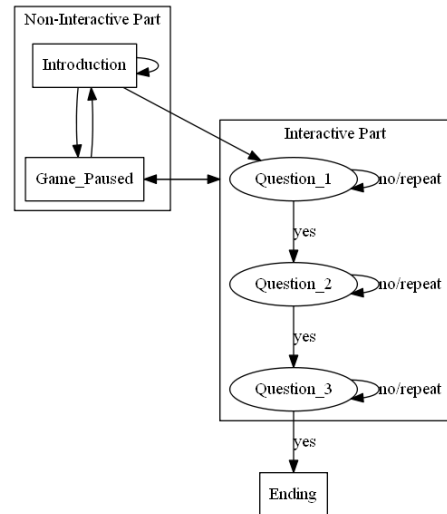


Fig. 2. Linear progression for the first prototype

³ The participants were part of the design and prototyping processes. They do not include the authors.

used speech-to-text AI libraries. The experimental nature of our prototype led us to employ two distinct AI libraries in separate scripts for a comparative analysis of their efficacy. Whisper [19] is used in the introduction scene and HuggingFace is used in the second and third scenes [9]. Moreover, the TextClassification library [10], developed by the HuggingFace community, is used for sentiment analysis to progress in the game accordingly. Some of the audio files were AI-generated. They were enhanced and edited using Audacity and Logic Pro for binaural effects. The audio files are pre-recorded and edited. They are not generated in real-time. Figure 1 shows the technologies used at each stage.

4 Guidelines

The prototype was developed with constant input from ten user experts, during which we observed their interactions and solicited feedback regarding the game’s inclusivity and entertainment. The participants found the game approach feasible for our target disabled users. They also found the game entertaining with positive feedback, highlighting the game’s potential. Using participant feedback and developed prototype, we have concluded seven guidelines in Table 1 for developers to follow. These guidelines address accessible games for users with visual and dexterity impairments. The ultimate goal is to encourage inclusion for dual disabilities in mobile games by facilitating developers without compromising the entertainment.

The first guideline listed in Table 1 is concluded from the user’s limitation with changing the game’s accessibility settings. The game shall be accessible if it is "born-accessible" and not leave it to the user to make it accessible for themselves. The second guideline comes from another input from our expert participants with their uncertainty about what the question or task was in the gameplay. With our audio-based game that takes speech as its main input, we programmed the "repeat" command to repeat the question or task asked. The third guideline shows the significance of letting the user know when input is taken to minimize confusion or unnecessary input. The user cannot see the screen. Audio feedback (a beep sound) was considered an efficient way to communicate when speech input was accepted. The fourth guideline is implemented in the majority of games. It is worth noting that an accessible game shall have these options equally as most players expect them. This is necessary regardless of the length of the game, and users shall have the option to pause the game and get back to it later. Tagging a game with the necessary accessibility tag helps others find their desired accessible games more efficiently and be recognized for its relevant accessibility category. We concluded the sixth guideline with repetitive suggestions from the end user participants for different languages and dialects. It impacts the speech recognition libraries providing the main game input, and it consequently impacts the sentiment analysis. Finally, a limitation we found was the interference of background noise. With binaural sound implemented,

the use of headphones provides a more immersive game experience. It also helps minimising background noise captured by the application.

ID	Description
1	User shall not be responsible for adjusting their settings only to provide input required for the game.
2	The game shall be tolerant enough to repeat the last audio if the user is uncertain of what the task is.
3	Feedback shall be given when the voice input starts
4	The pause and resume options shall be available throughout the entire game.
5	Published applications must be put in relevant categories with necessary accessibility tags.
6	Consider the language preferences and dialects of the target audience for voice input.
7	Recommend using a headset if it provides a more immersive experience for the players.

Table 1. Design guidelines for creating mobile games accessible to users with visual and dexterity impairments

5 Conclusions and Future Work

In this paper, we highlighted the need for research targeting multiple or complex disabilities and their impact on society focusing on blind and motor disabilities. We presented our first accessible, working prototype developed using a participatory design process with ten user experts, two legally blind. We also presented our initial guidelines concluded from the process. NLP and sentiment analysis are crucial elements of the prototype to help with accessibility and enhance entertainment. We will explore other technologies for faster and more efficient speech recognition and sentiment analysis. Similarly, we will incorporate the participants’ constructive feedback in our future prototypes. With the participants’ requests and feedback in mind, future prototypes will focus allowing the user to choose between the stories. Figure 3 shows a sample of the game story progression options we are planning to implement. It allows the story to be more personalized to the answers given by the player with different endings based on sentiment analysis results. This allows a more entertaining experience, which is one of the most essential requirements for creating inclusive games. Further work is necessary to test the game in noisy and quiet environments. More details on observational feedback will be discussed at later stages of the project. Finally, more detailed assessments of current guidelines will be published in the upcoming papers.

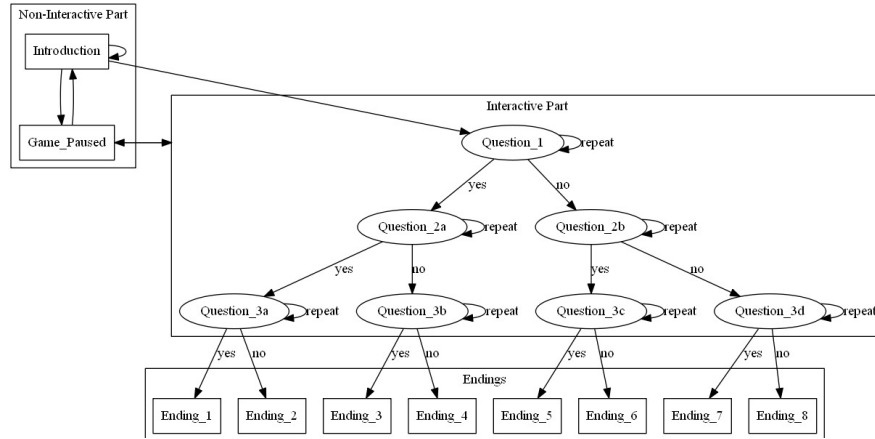


Fig. 3. Proposed future game story progression

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References

1. Aguado-Delgado, J., Gutierrez-Martinez, J.M., Hilera, J.R., de Marcos, L., Otón, S.: Accessibility in video games: a systematic review. *Universal Access in the Information Society* **19**, 169–193 (2020)
2. Anderson, T., Blank, M., Daniels, B., Lebling, D.: Zork - play online at textadventures.co.uk (2023), https://textadventures.co.uk/games/view/5zyoqrsugeopel3ffhz_vq/zork, [Accessed: 5 January 2024]
3. Di Gregorio, M., Di Nucci, D., Palomba, F., Vitiello, G.: The making of accessible android applications: an empirical study on the state of the practice. *Empirical Software Engineering* **27**(6), 145 (2022)
4. Drossos, K., Zormpas, N., Giannakopoulos, G., Floros, A.: Accessible games for blind children, empowered by binaural sound. In: *Proc. of the 8th ACM international conference on pervasive technologies related to assistive environments*. pp. 1–8 (2015)
5. GMA Games: Your resource for audiogames, games for the blind, games for the visually impaired! (2003), <https://audiogames.net/db.php?id=gmatankcommander>, [Accessed: 5 January 2024]
6. Google: Voice access: Control a device with your voice - android accessibility help (2018), https://support.google.com/accessibility/android/topic/6151842?hl=en&ref_topic=9079844&sjid=17355574717552980440-EU, [Accessed: 10 September 2023]

7. Google for Developers: Build more accessible apps (2023), <https://developer.android.com/guide/topics/ui/accessibility>, [Accessed: 3 December 2023]
8. Hassan, L.: Accessibility of games and game-based applications: A systematic literature review and mapping of future directions. *new media & society* p. 14614448231204020 (2023)
9. Hugging Face Community: Automatic speech recognition (2022), <https://huggingface.co/docs/transformers/tasks/asr>, [Accessed: 8 August 2023]
10. Hugging Face Community: Text classification (2022), https://huggingface.co/docs/transformers/tasks/sequence_classification, [Accessed: 8 August 2023]
11. IBM: Ibm accessibility requirements – ibm accessibility (2023), <https://www.ibm.com/able/requirements/requirements/>, [Accessed: 3 December 2023]
12. Islam, M.N., Inan, T.T., Promi, N.T., Diya, S.Z., Islam, A.: Design, implementation, and evaluation of a mobile game for blind people: toward making mobile fun accessible to everyone. *Information and communication technologies for humanitarian services* pp. 291–310 (2020)
13. Jones, E.: Cerebral palsy statistics uk (2023), <https://www.jmw.co.uk/blog/cerebral-palsy/cerebral-palsy-statistics-uk>, [Accessed: 1 April 2024]
14. Lazar, J.: A framework for born-accessible development of software and digital content. In: *IFIP Conference on Human-Computer Interaction*. pp. 333–338. Springer (2023)
15. Mack, K., McDonnell, E., Jain, D., Lu Wang, L., E. Froehlich, J., Findlater, L.: What do we mean by “accessibility research”? a literature survey of accessibility papers in chi and assets from 1994 to 2019. In: *Proc. of the 2021 CHI Conference on Human Factors in Computing Systems*. pp. 1–18 (2021)
16. Michigan Alliance for Families: Severe multiple impairments (2023), <https://www.michiganallianceforfamilies.org/severe-multiple-impairments/#:~:text=Students%20with%20multiple%20impairments%20have>, [Accessed: 23 January 2024]
17. Nicolaou, K., Carlton, R., Jaddoh, A., Syed, Y., James, J., Abdoulqadir, C., Loizides, F.: Game based learning rehabilitation for children with speech disabilities: Presenting two bespoke video games (2023)
18. Office for National Statistics: Percentage of homes and individuals with technological equipment (2022), <https://www.ons.gov.uk/aboutus/transparencyandgovernance/freedomofinformationfoi/percentageofhomesandindividualswithtechnologicalequipment>, [Accessed: 16 October 2023]
19. OpenAI: Introducing whisper (2023), <https://openai.com/research/whisper>, [Accessed: 15 September 2023]
20. Poinsett, P.M.: Cerebral palsy facts and statistics (2024), <https://www.cerebralpalsyguidance.com/cerebral-palsy/research/facts-and-statistics/>, [Accessed: 1 April 2024]
21. Sense: Complex disabilities (2023), <https://www.sense.org.uk/information-and-advice/conditions/what-does-complex-disabilities-mean/>, [Accessed: 2 January 2024]
22. Sense: Complex disabilities in the uk (2024), <https://www.sense.org.uk/about-us/statistics/complex-disabilities-overview/>, [Accessed: 2 January 2024]
23. Szykman, A.G., Gois, J.P., Brandão, A.L.: A perspective of games for people with physical disabilities. In: *Proc. of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*. pp. 274–283 (2015)

24. Theil, A., Anderton, C., Creed, C., Olson, N., Holt, R.J., Sarcar, S.: Accessibility research and users with multiple disabilities or complex needs. In: Proc. of the 25th International ACM SIGACCESS Conference on Computers and Accessibility. pp. 1–6 (2023)
25. Theil, A., Buchweitz, L., Schulz, A.S., Korn, O.: Understanding the perceptions and experiences of the deafblind community about digital games. *Disability and Rehabilitation: Assistive Technology* **18**(8), 1347–1356 (2023)
26. UK Government Digital Service: Understanding WCAG 2.2 (2023), <https://www.gov.uk/service-manual/helping-people-to-use-your-service/understanding-wcag>, [Accessed: 2 April 2024]
27. W3C: Web Content Accessibility Guidelines (WCAG) 2.2 (2023), <https://www.w3.org/TR/WCAG22/>, [Accessed: 2 April 2024]
28. Wästerfors, D., Hansson, K.: Taking ownership of gaming and disability. *Journal of Youth Studies* **20**(9), 1143–1160 (2017)