Design of an Accessible VR-Escape Room for Accessibility Education

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***Abstract*—*Access to Escape* is a Virtual Reality (VR) Escape Room, aimed at sensitizing computer science students to the importance of digital accessibility. Since these students will develop digital content in the future, this target group is an important starting point to create awareness towards the topic. This article outlines the development of a VR game based on the viewpoints of Accessibility Education, Game Accessibility, and accessible VR to offer access to a wide range of people. The primary objective is to address the research question of what steps are necessary to create an accessible VR game and what the design process should entail to achieve this goal. The development process of *Access to Escape* showed that the Game Accessibility Guidelines (GAG) workflow offered a low threshold starting point, for example, by making the vast amount of accessibility guidelines more tangible. Here, it should be emphasized that the prioritization, as suggested by the workflow, must not lead to the exclusion of any applicable guidelines, since every guideline is needed to guarantee an accessible game experience. However, during the implementation process of our VR-Escape Room, it became apparent that many resources and a well-defined time schedule are needed to achieve a fully accessible game. To counteract this issue, more information material and open-source solutions are needed to meet all accessibility requirements.**

Keywords-Accessibility Education; Virtual Reality; Game Accessibility; Escape Room.

I. Introduction

With the increasingly digital nature of everyday life, the importance of digital accessibility moves further into focus. “The fast-growing market for making digital products and services more accessible comprises a range of economic operators, such as those who develop websites [...].” [1], making it necessary to train these operators. In consideration of that, we developed the Virtual Reality (VR) Escape Room *Access to Escape* to educate computer science students about digital accessibility. As computer science students represent the future developers of digital products, it is necessary to educate these stakeholders on the importance of digital accessibility and teach them methods on implementing inclusive software. Using an immersive learning format such as a VR game, it was aimed to sensitize the players by making barriers more tangible and thus relatable. Although gamification and VR technology offer benefits such as the mentioned immersion, they also introduce new challenges, including the need for accessible VR gaming experiences. To design an accessible VR-Escape Room, we formulate the following research question:

“What does the design process for creating an accessible VR game entail, and what implementation steps are necessary to achieve this goal?”

To address the posed research question, we will first give an overview of the related topics in Section 2 which include Accessibility Education, Game Accessibility, and Accessible VR. Section 3 will offer an overview of the implementation of *Access to Escape*. We will explain the game story and the corresponding learning goals, how we implemented the GAG workflow, and demonstrate the outcome of the implementation of accessibility features. The lessons learned and limitations of the VR-Escape Room will then be discussed in Section 4. Finally, in Section 5, we summarize our findings and formulate tasks for future work.

II. Disciplines of Accessibility

For a successful implementation of the introduced VR-Escape Room, it is necessary to consider different disciplines of digital accessibility. *Access to Escape*, for one, represents a tool for learners to grasp the content related to digital accessibility. For another, the VR game needs to be accessible so it can be played by every learner. In the following, the teaching of accessibility, the accessible design of a game, as well as of the VR application itself will be examined, which are needed to achieve the mentioned goals.

A. Accessibility Education

Accessibility Education is a broad field in which learners are supposed to acquire various competencies: Initially, they need to develop theoretical understanding and procedural knowledge regarding accessibility [2]. Only with the aid of this foundational knowledge, learners can build technical skills in this discipline.

To teach these skills, educators need resources that can teach accessibility while considering the current knowledge and skill set of students [3]. As digital accessibility is still not a widespread mandatory subject at every university, it is necessary to create such learning materials that provide a low-threshold introduction to the subject, so even students who do not have any prior educational knowledge about digital accessibility can have an easy access to the content.

In order to provide a simple introduction to the topic, it is beneficial to make barriers tangible and thus provide learners with a realistic experience [4]. For example, Kletenik and Adler [5] developed three games in which the players are confronted with simulated disabilities to generate awareness of the topic accessibility. It became apparent that students who played these games increased their empathy for people with impairments or disabilities and also their motivation to design

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more accessible content.

To simulate barriers even more immersive, VR technology has the potential to create such experiences and make them as tangible as possible [6].

B. Game Accessibility

Game Accessibility describes the subarea of game development that addresses the removal of barriers for people with impairments or disabilities [7]. It should be emphasized that removing the barriers, and by that, creating an accessible game, is limited by the game rules as games often include intended barriers which represent the challenges of the game story. If those challenges would be removed, the intention and / or the entertaining character of the game could be compromised.

For the development of accessible games in accordance with the corresponding game rules, the Game Accessibility Guidelines (GAG) [8] by the International Game Developers Association (IGDA) have been established in different elaborations [7], [9], [10], [11]. The GAG [8] are guidelines which are based on an online survey that gathered methods to make games more accessible to different user groups. The current version (May 2021) includes 122 guidelines that can be classified according to motor, cognitive, visual, auditory, linguistic, and general barriers. Each of these six groups is again classified into three subgroups (basic, intermediate, and advanced). The classification into these subgroups depends on the following three factors:

Reach: The number of people who benefit from meeting the corresponding requirements.

Impact: The qualitative difference this adjustment makes for players.

Value: The cost incurred for implementation.

The *basic guidelines* [8] describe accessibility features that make playing easier for a large number of players and are also easy to implement. The *intermediate guidelines* [8] include features that require additional planning and resources, but are still easy to implement and reach many players. Finally, the *advanced guidelines* [8] involve complex modifications and high costs. Although only a few specific players benefit quantitatively from these modifications, they have a very high qualitative value for those players.

The need for each guideline of the GAG is emphasized by a realistic use case, making the traceability of a barrier easier for developers [8]. Further support provided by the guidelines are the listed best-practice games that have particularly well implemented the respective guideline.

Regarding the implementation of accessible games, the following workflow is recommended by the IGDA [8]:

1) *Familiarize:* Before the implementation phase begins, the guidelines must be considered, since a variety of requirements can already be met through simple design decisions in the conception phase.
2) *Evaluate & plan:* In the second phase, it must be investigated which guidelines will be relevant and applicable in the context of the planned game to create a reduced subset of requirements to be implemented.
3) *Prioritize & schedule:* The chosen requirements from the second phase are prioritized with respect to the available resources and scheduled in the development plan.
4) *Implement:* To achieve the best results, experts and players with a disability or impairment should also test the game during the implementation phase.
5) *Inform:* Players should be made aware of the implemented guidelines in tutorials and loading screens, as there is a risk that they will go unnoticed in various menu settings.
6) *Review & learn:* Information on how often players have used accessibility features helps future projects when conducting the third phase, especially when prioritizing requirements.

C. Accessible VR

The use of VR is steadily increasing and is becoming a more prevalent tool in education. This makes the access to VR technology even more important. The developer manual of the company Oculus emphasizes that accessible VR applications can reach a wider range of users [12]. VR applications are considered accessible when people with different types of visual, auditory, mobility, perceptual, and cognitive impairments can interact with the given content. The manual presents procedures for seven application areas of a VR application, which partly overlap with the GAG and the Web Content Accessibility Guidelines (WCAG) [7]. The sections of the manual are presented in the following:

User Experience (UX) and User Interaction (UI) [12]: To achieve an inclusive UX, game developers must first become aware of exclusive UX design. As an example of such an exclusive design, the chosen size of the play area is mentioned: Players with a limited movement area could experience a below-average or even unplayable user experience. Only when the game can be completed without blockages or external help, an inclusive UX design is achieved. It must be constantly tested to see if this is the case. For example, it is useful to play the game with disabled sound or color filters. Also, the use of auditory, visual, and haptic interaction possibilities makes the UX more inclusive.

Controls and Interactions [12]: The predefined controls of a game can hinder players, for example those with motor impairments, in interacting with the game. To improve this situation, selection options and alternative types of interaction should be presented. Modifications help not only people with disabilities but also all players. For example, the ability to re-assign control keys not only helps players who cannot fulfill the default input requirements due to motor impairments but also benefits habitual players who prefer a personalized interaction.

Movement and Locomotion [12]: In order for the movement of players in the virtual world to be feasible for everyone, among other things, developers must consider how a person who cannot move in the real world could still move around in the virtual world. For example, navigation via joysticks eliminates the barrier for players who cannot move freely in the real world.

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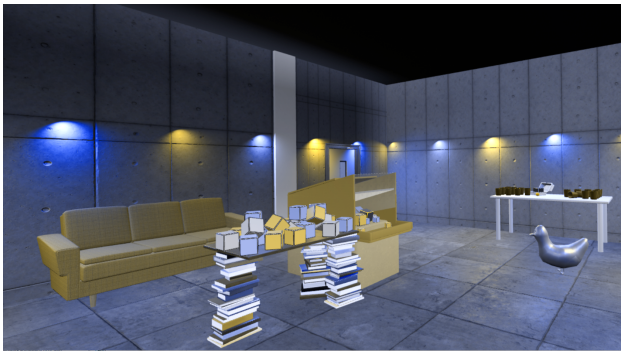

Fig. 1. Puzzle 3: Using a color filter, the player experiences the perception of a person with a color vision deficiency (deuteranopia)

Display [12]: Personalizing screen displays, such as variable brightness settings, is now standard on many devices. In VR applications, this personalization is even more important because the complete occupancy of the visual space and the proximity to the human eye pose a risk of sensory overload. A personalized display prevents this danger for all players, with and without impairments. For example, the ability to enlarge text elements or objects in the virtual world can support people with visual impairments.

App Design [12]: Elements of app design can support the accessibility of VR applications. For example, a clear and mandatory tutorial at the beginning of the game provides the opportunity to become familiar with the game mechanics. Clearly defined rules and objectives help players stay focused on the game. Through such methods, the basic understanding of the game can be simplified for all players. Additionally, the game can be made more accessible by adding a guiding character. For players who were unable to process auditory, visual, or haptic signals, these characters can, for example, provide additional hints.

Audio [12]: In addition to the possibilities of visual and haptic interaction, audio offers another form of communication. Short and simple audio tracks can signal actions and processes. However, despite the advantages of sound, the option should be kept open to deactivate it without loss: People who, for example, have difficulty concentrating and therefore choose to turn off the sound, must not experience any loss of information.

Captions and Subtitling [12]: Captions refer to the textual reproduction of spoken dialogues. Whereas, subtitling refers to the translated textual reproduction of spoken foreign-language dialogues. These forms of information transfer help a variety of people: players with hearing or cognitive impairments, players who do not understand the game language, and players who prefer to read dialogues instead of hearing them.

III. Implementation

The implementation is divided in different sections: First, we introduce the VR-Escape Room *Access to Escape* and its learning objectives. They specify what skills and knowledge the learners are supposed to gain. Next, the application of the GAG workflow is presented, which exemplifies how the workflow can be integrated in the development process. Finally, the implemented accessibility features are presented and categories for clustering them are proposed.

A. Access to Escape

At the beginning of the game, the player is in a university building and has to find a certain auditorium. Initially, the person playing is on the first floor were a training room is located. As soon as the player is ready, they can use an elevator to go to the desired location but because of a defect, the elevator crashes shortly after. Finally, the player lands on the basement floor where five puzzles, each representing a barrier, need to be solved to get the elevator running again.

- Puzzle 1: The player is faced with an incomprehensible speaker announcement that is caused by an incorrect language setting. The learning objective of the first puzzle is based on the *WCAG guideline 3.1.1 Language of Page (Level A)*. This requires the ability to programmatically determine the language of the content at hand. People who use a screen reader will encounter this barrier, for example, when a web page has no or an incorrect language tag. If the screen reader pronounces text in a different sound than the language in which the text is written, the read-out text is very difficult or even impossible to understand.
- Puzzle 2: An important code which is needed to move on within the game is displayed via an extremely blurry image. By that, the player is introduced to the difficulties caused by inaccessible graphics which are mentioned in the *WCAG guideline 1.1.1 Non-text Content (Level A)*. Here, it is described that non-text content needs an alternative textual access point.
- Puzzle 3: The player enters a room that contains a color-dependent puzzle but can only see a limited set of colors due to a color filter (see Fig. 1). The player is introduced to the content of *WCAG Guideline 1.4.1 Use of Color (Level A)*, which states that color should not be the only way to convey information. If content is conveyed through color alone, people with limited color perception may not be able to assimilate this information. Therefore, the player is introduced to other ways in which information can be conveyed, such as patterns.
- Puzzle 4: A cliff has to be crossed by choosing the correct order of labeled buttons which represent heading levels (see Fig. 2) and by that the player becomes familiar with the content of *WCAG Guideline 1.3.1 Info and Relationships (Level A)*. This guideline requires that the structure of (web) content must be programmatically determinable. If the correctness of the heading order is not given, the comprehensibility of the digital content is limited.
- Puzzle 5: To reactivate the elevator, the player is confronted with buttons of insufficient size (see Fig. 3). Based on the *WCAG guideline 2.5.5 Target Size (Level AAA)* it is necessary to maintain a minimum size for buttons (and other interactive elements) in order to guarantee their operability for all users.

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Fig. 2. Puzzle 4: Three button options next to the magic carpet, each representing a different heading level

Fig. 3. Puzzle 5: Inaccessible target size of the ON-Button making it impossible to select the element

B. Implementation of GAG Workflow

The development process of the VR-Escape Room follows the phases of the IGDA workflow for an accessible implementation:

Phase 1 - Familiarization: The structure and content of the GAG and the presented Oculus manual were considered.

Phase 2 - Evaluate & Plan: The GAG are provided in form of an Excel spreadsheet in which each row represents a guideline whereas the Oculus manual contains various texts, which are spread over several pages. To allow a structured evaluation, we converted the content of the Oculus manual into an organized Excel spreadsheet. The further evaluation of the now prepared guidelines was approached together with the following phase.

Phase 3 - Prioritizing & Scheduling: The prioritization of the guidelines has been carried out in several steps. First, it was decided that, in addition to the Oculus manual, only the basic GAG guidelines would be considered. These do not require a complex implementation and yet help a large number of gamers, making them a suitable basis for the first prototypical implementation. In the next step, the Excel spreadsheet from phase 2 was extended by two additional columns, “Importance” and “Ease”, which take a value between 1 (important resp. easy) and 3 (rather unimportant resp. difficult) for each guideline (see Fig. 4). “Importance” is used to indicate how necessary a guideline is for the concrete game experience of *Access to Escape*. Thus, the guideline to use a readable text size is associated with the importance of ’1’, whereas

Guideline	Importance	Ease
Hearing		
Basic		
Provide subtitles for all important speech	1	1,5
Provide separate volume controls or mutes for effects, speech and background / music	1	2
Ensure no essential information is conveyed by sounds alone	1	1

Fig. 4. Excel spreadsheet with rating of guidelines

the guideline to inform about accessibility features during the game is rated with an importance of ’2’. The latter policy aims to improve the game experience by providing information; the former policy aims to provide a basic perceptible game experience, which is why it is considered more important. “Ease” describes how complex and time-consuming a potential implementation of the policy is estimated. After determining whether a policy is applicable to the game (see Phase 2), the values of “Importance” and “Ease” were discussed and recorded. By looking at the final scores, a prioritization of the guidelines or features could be performed.

Phase 4 - Implementation: Throughout the development process, the game was evaluated by usability and accessibility experts. Because of these evaluations, an implemented puzzle could be identified as a trigger for simulator sickness and thus as non-accessible. Therefore, an alternative path to the game was developed, which avoids the sickness indicating factors.

Phase 5 - Informing: Game-internal informing was not considered in the context of the prototypical VR-Escape Room. *Access to Escape* does not have any settings that can be accessed by the players but the implemented policies represent features that are inevitably encountered in the game anyways.

Phase 6 - Assessing & Learning: The testing phase of *Access to Escape* included 11 participants with connections to the study field of computer science [13]. We were present throughout the testing, which made it easy to observe how the participants reacted to the accessibility features. Here, it became apparent that the implemented features were also able to provide a better gaming experience for players without impairments or disabilities. They showed positive reactions to multiple access possibilities. Examples are the textual content conveyance through subtitles, the auditory signaling of events via sound effects, and the haptic feedback in form of different vibration patterns of the controllers.

C. Implementation of Accessibility Features

This section sketches the implemented and discarded guidelines and presents different categories in which these guidelines can be clustered. The respective categories are not to be considered disjunctively; thus, a guideline that is assigned to one category may also be part of another. In the following, the categories and exemplary associated guidelines are presented in ascending order of effort.

1. Implementation by the game engine: Besides guidelines which have to be implemented manually, there are also accessibility features which can be implemented by pre-developed templates of the chosen game engine (in our case

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Unreal Engine), such as: “Representation of the controllers in the virtual environment” [12]. In order for the players to have a reference to the real controllers during the game and to simplify their use, a virtual copy of the controllers should be displayed (see Fig. 3). This not only shows the position of the buttons on the controllers, so that the players do not have to remember them, but also marks the position of the controllers in the real space, and thus simplifies their findability [12]. The game engine Unreal also provides this feature in the engine’s own VR-template.

2. Implementation based on prior knowledge of accessibility: Further, there are such guidelines that can be implemented simply and with small expenditure, if there is knowledge of their necessity. One of these guidelines being: “Ensure no essential information is conveyed by a color alone” [8]. Since not everyone can perceive information through color, an alternative form of communication must be implemented [8]. This can be in the form of patterns, icons, or text.

In *Access to Escape*, a combination of these approaches is used. At one point, color signals the activation of a button which is additionally symbolized by sound and changing text. Another example are color-coded blocks that are equipped with patterns, so that they can be clearly differentiated without the visibility of color.

3. Implementation through elementary game design: A subset of the guidelines can be grouped under features that every common game design includes to make the application fundamentally playable, for example: “Placing UI elements in a user-friendly way” [12]. For an unrestricted gaming experience, the elements of the user interface must be easily accessible and visibly positioned, otherwise the game flow suffers [12]. The chosen position should indicate the relation of the element to the rest of the room.

In our VR-Escape Room, the guideline was planned into the visual conception of the games. The previous considerations about the positioning of individual UI elements have greatly simplified the fulfillment of this guideline.

4. Implementation through high effort: The guidelines sets also include policies that require costly implementation, such as “Provide subtitles for all important speech” [8]. Purely auditory instructions and narrations exclude persons with hearing impairments or persons who are more likely to take in written information from a full game experience [8]. To counteract this, the use of subtitles can be considered.

However, the implementation of these is not possible without further effort using Unreal Engine. The option to add subtitles to audio tracks is offered, but these are displayed in a font size that is too small and in an unsuitable position in the game. During our research, no option could be found to change font size and position, so another approach had to be taken: The subtitles are currently displayed as a separate text field based on predefined time frames (see Fig. 5). Due to the complexity of this approach, the subtitles in the prototype were only implemented as an exemplary feature in one scene of the game.

5. Implementation not possible: Lastly, there are policies that have not been implemented. In our case this had several

Fig. 5. Visualization of captions of spoken dialogue of the guiding character

reasons; for one, the guidelines may not be in accordance with the game rules or the game form: “Provide details of accessibility features on packaging and / or website” [8]. To benefit from the implemented accessibility features, players must first be made aware of them [8]. If these are implemented but not advertised, players may overlook them and, therefore, assume that the game is not playable for them. In addition, advertising the features can increase search engine traffic and distinguish the application from other games of the same kind.

However, since *Access to Escape* is only a prototype and no public deployment is currently planned, this policy was not implemented for the current application.

For another, the reason for the lack of implementation may be resource constraints, as some implementations of policies may require additional expertise or time:

“Personalization of Controller-Based Movements” [12]. For example, players who have difficulty holding a game-required arm position for an extended period of time should have the opportunity to personalize controller-based movements [12]. If a position, such as an outstretched arm, cannot be achieved in the real world, it should nevertheless be possible to personalize the parameters of size, rotation or distance, so the virtual arm can be fully extended or moved to a different position. Due to different mobility abilities, these “hand profiles” should be individually implemented for the left and right hand. This guideline was not implemented within *Access to Escape* due to its extensive implementation work and project time restrictions.

IV. Discussion & Limitations

The discipline of Game Accessibility deals with eliminating avoidable barriers for people with disabilities or impairments within the framework of game rules [7]. This creates a dilemma between adhering to the game rules and making the game as accessible as possible. Game rules typically require overcoming intended barriers that are presented in the form of game challenges.

For example, a digital chess game where each move is timed cannot fulfill the guideline of variable game speed without violating the game rules [11]. Furthermore, not every guideline is relevant to every game. For example, the guideline that requires the use of subtitles cannot be applied to a game that does not have audio. Therefore, developers must be aware that a game may not be entirely accessible due to the game rules but also that a game can still be accessible even if not every

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single guideline is met. Thus, developers are faced with the challenge of recognizing which guidelines are feasible and relevant for the game.

Within the scope of this work, the GAG workflow has proven to be a suitable approach, especially for the needed structured exploration of the guidelines. Furthermore, the transfer of this workflow to other guidelines has also been successful and can be recommended. However, developers must consider that a resource-based prioritization, as suggested in phase 3 of the GAG workflow, cannot produce an accessible application. This goal can only be achieved by implementing all applicable guidelines. The EU Directive 2016/2102 (39) also emphasizes this fact: "Only legitimate reasons should be taken into account in any assessment of the extent to which the accessibility requirements cannot be met because they would impose a disproportionate burden. Lack of priority, time, or knowledge should not be considered as legitimate reasons." Therefore, while the GAG workflow provides a structured approach to develop an application with low barriers, it is only suitable for developing an accessible application if prioritization within the workflow does not lead to the exclusion of other applicable policies. This is crucial as each guideline ensures the access to the presented content for a specific target group and further, as confirmed by our results, they have the possibility to improve the game experience for everybody. To comply with all applicable guidelines, it is necessary to schedule enough time to implement the accessibility features that were not achieved to the desired extent in the discussed implementation. In retrospect, it could be recognized that a classification of guidelines into categories is possible, which could support better time management during the development process. Another aspect that must be addressed early on during the development process is the cooperation with people affected by impairments or disabilities. Since no test person stated that they are affected, the question of inclusion can only be answered theoretically, not practically.

In conclusion, the development of an accessible VR game requires enough resources and a well-defined time schedule. To plan these factors, the GAG workflow offers a supporting guide but is not sufficient on its own which is why thorough research and more tangible implementation templates are needed.

V. Conclusion

Summarizing, the research question "What does the design process for creating an accessible VR game entail and what implementation steps are necessary to achieve this goal?" can be answered supported by the GAG workflow. It offers a suitable starting point for developing accessible games and a structured approach on working with large sets of accessibility guidelines like the GAG and the Oculus manual. The workflow is especially useful for identifying and prioritizing policies that can be implemented in a first implementation cycle. But here, the examination of the guidelines alone is not sufficient for a sustainable assessment of which prioritization these features should take. A retrospective view of the implemented features shows that preceding steps are needed, like the consideration of the features that the chosen game engine already offers, as well as the documentation of existing implementations. Here, the classification into the categories presented in this paper could benefit the development process. They offer the possibility of assessing the workload that would be needed to meet each guideline. However, since many guidelines fall under the category of "Implementation through high effort" or "Implementation not possible", our VR-Escape Room *Access to Escape* cannot meet the requirements of an accessible VR game. Our research phase indicated that there is a need for low-level solutions for accessible games and VR applications so that accessibility features that were classified under the mentioned categories can ideally be classified into "Implementation by game engine". Since this is not the case yet, the guidelines were implemented in an exemplary manner at various points in our VR-Escape Room, but not consistently, which is unsatisfactory and needs to be addressed in future design iterations. Another aspect that needs to be included in future work is the evaluation of *Access to Escape* by people with impairments or disabilities to get reliable insights on the accessibility of the VR game.

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