Assessing Presence in Virtual Reality Through a VR Escape Room for Visually Impaired Users

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Abstract. Introduction*: Not all games are accessible, as certain disabled gamers may be excluded by the game's design. This exclusion is an experience that visually impaired individuals encounter when engaging with mainstream visual games and virtual reality.* ***Objective:*** *This work assesses a designed accessible VR application with visually impaired people (VIP). This application is an escape room, a genre of game that challenges players' abilities without requiring rapid responses.* ***Methodology or Steps****: Participants were required to complete a 15-minute tutorial and a game stage session with a maximum duration of 20 minutes. Later, they were asked to answer a presence questionnaire (IPQ) to assess their sense of presence within the VR Escape Room.* ***Results:*** *A group of eight visually impaired users participated in this experience. The results show that the experience was perceived as very realistic (REAL); that the participants felt fully present in the environment (SP); and that they felt engaged with the environment (INV).*
Keywords *Presence, Virtual Reality, Visually Impaired, Escape Room, Accessibility.*

1. Introduction

According to Cairns [Cairns et al. 2021] and Guillen [Guillen et al. 2021], there is an increasing number of gamers with disabilities who are already playing games for fun, education, exercise, etc. Nevertheless, it should be noted that not all games are accessible, as some disabled gamers may be excluded by the game's design. This exclusion is an experience that visually impaired individuals encounter when engaging with mainstream visual games and virtual reality [Coronado et al. 2024a]. And the solution to this issue is not to design games exclusively for visually impaired gamers, since the evidence indicates that most games are more simplistic or less enjoyable than other games [Andrade et al. 2019].

This study employs a virtual reality (VR) game application to demonstrate that visually impaired individuals (VIPs) can engage with VR games. The chosen application is an Escape Room, a game genre selected for its suitability to the target audience: it does not require quick reflexes, involves no hostile elements, and encourages free exploration of the environment. In this type of game, players must search for objects and information within the virtual space to solve puzzles and ultimately complete the escape challenge [Fotaris e Mastoras 2019]. According to Vidergor, this genre fosters intrinsic motivation by challenging players' abilities and encouraging them to persist until they succeed [Vidergor 2021]. These characteristics make the Escape Room a well-justified and appropriate choice for this study.

It is essential to highlight that this Escape Room game was designed to be played by both sighted individuals and visually impaired players. The goal was to develop a "Game for All" by incorporating established accessibility guidelines [Grammenos et al. 2009]. These Game Accessibility Guidelines (GAG) consist of design recommendations that address the needs of players with disabilities and are well documented in the literature [Coronado et al. 2024a, Coronado et al. 2023]. By applying these guidelines, the development team implemented specific accessible features, ensuring that the game accommodates diverse user needs.

This study aimed to assess the accessibility and feasibility of the game for visually impaired individuals through a practical experiment. We considered the experiment successful if a visually impaired participant reported feeling immersed while interacting with the game. We conducted the experiment with a cohort of eight visually impaired individuals to evaluate this.

The paper is structured into five sections, beginning with the Introduction, which outlines the research context and objectives. The Background section reviews relevant literature and presents the design of the proposed virtual reality escape room. In the Methodology section, the authors detail the applied questionnaire and describe the experimental procedures. The Evaluation section explains the assessment process used to analyze the participants' responses. Next, the Results and Discussion section presents the findings derived from the questionnaire and offers a critical interpretation of the data. Finally, the paper closes with the Conclusion, which summarizes the main contributions and highlights directions for future work.

2. Background

2.1. Related Work

The present work was inspired by three related studies: "X-Road" [Thevin et al. 2020], "Canetroller" [Zhao et al. 2018], and "Loud and Clear" [Baas et al. 2019]. The first one is a virtual reality simulation designed to instruct visually impaired people in the proper technique for crossing a roadway. The application simulates a crosswalk in an urban environment. This training is conducted in conjunction with Orientation & Mobility professionals, who provide VIPs with instruction on the utilization of techniques for locating and navigating physical spaces [Thevin et al. 2020].

The second work developed a "mechanical cane" hardware system that simulates a virtual cane within a virtual environment. Therefore, the user can strike virtual items within the environment with the "cane". This system has three main characteristics: physical resistance when a virtual object is hit, vibrotactile feedback when surfaces are touched, and spatial audio originating at the point of impact [Zhao et al. 2018].

The third work was designed as a virtual reality game with no visuals. Nevertheless, the game's design was intended to provide sighted users with an experience that emulates the perspective of a visually impaired individual navigating the environment. This particular work illustrates the use of the Escape Room genre, as it asks the players to navigate and locate objects solely through auditory cues [Baas et al. 2019]. The application could have been enhanced by implementing accessibility guidelines, and its testing could have included visually impaired people.

2.2. VR Escape Room

“Escape-INF-VR” is an accessible Escape Room that applies specific accessibility guidelines from the literature to meet the needs of visually impaired people, specifically blind users [Coronado et al. 2024b]. The building of the Institute of Informatics of the Federal University of Goiás inspired this game (Figure 1). The game underwent specific changes and improvements after an early version of the game was presented at an international conference [Coronado et al. 2024b, Coronado et al. 2024a].

Figure 1. Virtual Reality Environment

Before presenting the improvements, a review of the prior design features is essential. These features included: the integration of a tutorial phase, the utilization of controllers (left thumbstick for movement and right thumbstick for rotation), the incorporation of footsteps sound effects during movement and rotation, the implementation of directional audio cues during rotation, the configuration of the right controller’s ray interactor to function as a 10-centimeter cane, the addition of auditory name descriptions for all objects (activated when in contact with the ray interactor cane), and the employment of spatial sounds for locating objects and as landmarks[Coronado et al. 2024a, Coronado et al. 2024b].

Furthermore, the game added two artificial intelligence features to increase accessibility. It is important to note that previous authors have also added Large Language Models to improve accessibility through the description of environments, and by offering support to visually impaired people to move within the rendered environment [Oliveira et al. 2024, Collins et al. 2023, Collins et al. 2024]. The first feature is a speech recognizer that can provide users with predefined recommendations. The second one is an environment descriptor, which describes the environment from the player's point of view.

For the speech recognizer, the Wit.Ai service[1] was used. This cloud service provided by Meta allows people to interact with products using their voices. This service was configured to receive voice commands within the environment and recognize specific keywords such as “help” and “location”. After the service detects these keywords, it triggers a function within Unity, which plays a predefined audio file containing a recommendation of what the user needs to know or do. It is important to note that the replies are static (prerecorded audio files) and that the service requires an internet connection.

The environment descriptor incorporates a Multimodal Large Language Model: Gemini API[2]. This MLLM is a free alternative to Chatgpt[3] and other models, and it is used to provide an accessible description of what is in front of the player's point of view. To be specific, Unity takes a screenshot of the player's point of view (POV), sends the screenshot to the API along with a prompt, and returns a text description. In the final stage of the process, the Google Cloud Platform text-to-speech feature is used to generate an audio file of the description for the blind player. This work specifically used the Gemini-1.5-Flash Model. Also, Unity sends the following prompt (in Portuguese) along with the player's POV image: “Describe the virtual scenario, highlighting the main elements and characteristics. Explore the architecture and elements that make up the environment. Create an accessible description for a blind person in less than 600 characters, capturing the essence of the place. Exclude any information about the controllers.”

3. Methodology

Immersion is an essential aspect of Virtual Reality, and a method for measuring immersion in VR is through the user's sense of presence [Schwind et al. 2019]. Indeed, there are several presence questionnaires in the literature. The most cited are the WS (Witmer & Singer) questionnaire, which has 32 questions [Witmer e Singer 1998]; the SUS (Slater-Usoh-Steed) questionnaire, which has six questions; and the IPQ (Igroup Presence) questionnaire, which has 14 questions [Schwind et al. 2019]. All three of them use a 7-point scale.

Furthermore, the group of researchers who compared these presence questionnaires recommended the application of the IPQ questionnaire, because “it provides the highest reliability within a reasonable timeframe” [Schwind et al. 2019]. Therefore, this study uses this questionnaire to measure presence in Virtual Reality. To recap, the IPQ has a total of 14 questions, which are divided into four sub-scales: Spatial Presence (SP), Involvement (INV), Experienced Realism (REAL), and General Presence (GP)[Tran et al. 2024].

Nevertheless, the standard IPQ might not be suitable for assessing the immersion levels of visually impaired people. Consequently, Zhao *et al.* removed the questions related to vision [Zhao et al. 2018], and ended up with a total of 8 and four sub-scales. This adapted questionnaire was also adopted by Thevin *et al.* during their orientation and

[1]https://wit.ai/

[2]https://ai.google.dev/gemini-api

[3]https://chatgpt.com/

ID	Question	Type
Q1	In the VR world, I had a sense of “being there”	G
Q2	Somehow, I felt that the virtual world surrounded me (1 is fully disagree, seven is fully agree).	SP
Q3	I felt present in the virtual space.	SP
Q4	I was completely captivated by the virtual world	INV
Q5	How real did the virtual world seem to you (1 is not real at all, seven is completely real)?	REAL
Q6	How much did your experience in the virtual environment seem consistent with your real-world experience (1 is not consistent at all, seven is very consistent)?	REAL
Q7	How real did the virtual world seem to you (1 is about as real as the imagined world, seven is indistinguishable from the real world)?	REAL
Q8	The virtual world seemed more realistic than the real world.	REAL

Table 1. Adapted IPQ. Source: [Zhao et al. 2018, Thevin et al. 2020]

mobility study with visually impaired people [Thevin et al. 2020]. Then, this work also selected the adapted IPQ questionnaire, which is presented in Table 1.

Before the game session, participants were asked demographic questions such as gender, age, and vision level. They were also asked about their previous experience with games, technology devices, and Head-Mounted Displays.

Subsequently, participants were required to complete a 15-minute tutorial and a game stage session with a maximum duration of 20 minutes (Figure 2). The participants had to interact with six buttons: the left thumbstick to move, the right thumbstick to rotate, the button B or button Two to activate the environment descriptor, the button A or button One to request assistance through the speech recognizer, the right hand trigger or grip button to obtain and utilize objects, and the right index trigger to select a specific object (see Figure 3).

Figure 2. Participant interacting with the Virtual Environment

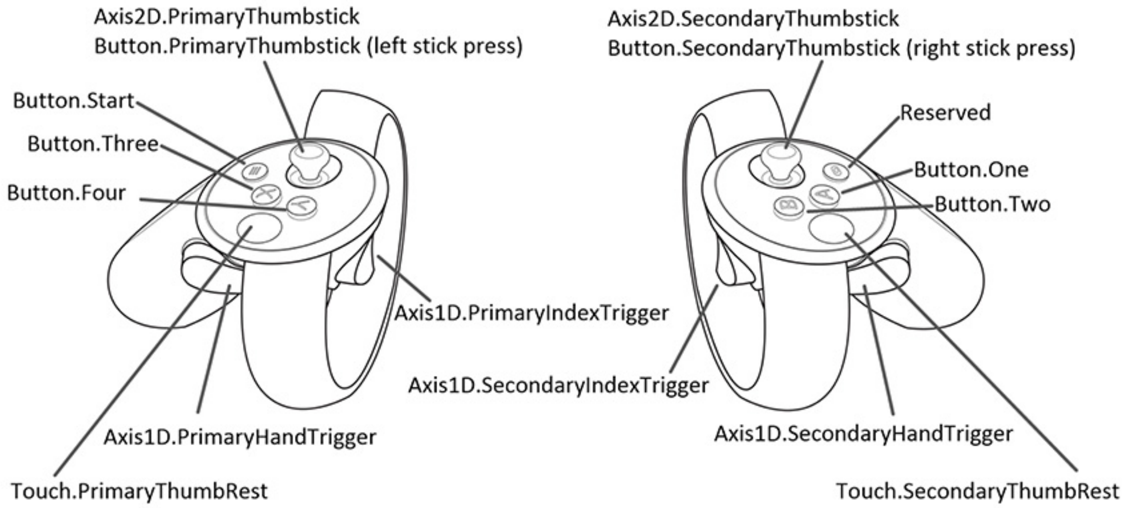

Figure 3. Meta Quest Controllers. [Unity 2019]

Following the game session, participants were invited to complete the adapted Igroup presence questionnaire (IPQ) presented in Table 1. To facilitate the experiment, the researcher asked the questions aloud, and the user provided a response using a scale from 1 to 7.

4. Evaluation

A group of eight visually impaired users participated in this study. The mean age of the participants was 26.0 years, with a standard deviation of 4.6. The gender, age, and vision level of the participants are detailed in Table 2. Additionally, Table 3 summarizes the participants' backgrounds in technology, gaming, and Head-Mounted Displays. The research was registered in *Plataforma Brasil*[4] and the project can be located through the CAAE code "67057222.7.0000.5083" and number "6.512.637".

ID	Gender	Age	Vision Level
P1	F	33	Blind from 15 y.o
P2	F	30	Low vision from 23 y.o
P3	M	27	Blind from birth
P4	M	20	Blind from birth
P5	M	28	Blind from 20 y.o
P6	M	26	Blind from 5 y.o
P7	F	24	Blind from birth
P8	F	20	Blind from birth

Table 2. Participants Characteristics

[4]Platform Brazil is a national system for registering human research studies, enabling tracking from submission to final approval by ethics committees (CEP/Conep). The system can be accessed at the following link: https://plataformabrasil.saude.gov.br/

ID	Game EXP	Tech EXP	HMD EXP
P1	No	Yes	No
P2	No	Yes	No
P3	Yes	Yes	No
P4	No	Yes	No
P5	Yes	Yes	Yes
P6	No	Yes	Yes
P7	Yes	Yes	No
P8	No	Yes	No

Table 3. Participants Background

All eight participants had prior experience with technology, as they are daily users of computers and cell phones. However, only three participants played games regularly. Similarly, only two participants had prior experience with Head-Mounted Displays: participant #5 (P5) and participant #6 (P6). Specifically, P5 had used an HMD several years ago before becoming blind, while P6 had previously participated in a beta testing phase [Coronado et al. 2024a], contributing to the enhancement of the VR application. As a result, P6 had prior experience with HMDs. Additionally, P8 mentioned using an assistive device called OrCam[5], though this device does not qualify as a Head-Mounted Display.

5. Results and Discussion

To recap, the IPQ questionnaire consists of four subscales: Spatial Presence (SP), Involvement (INV), Experienced Realism (REAL), and a general item assessing the "sense of being there" (G) [Igroup.org 2016]. In this study, the group achieved mean scores of 5.56 in Spatial Presence, 5.88 in Involvement, 5.31 in Realism, and 6.13 in General (see Figure 5). These results from the IPQ questionnaire can be compared with those from other studies, such as "X-Road" and "Canetroller". It is important to note that "X-Road" had a sample size of 13 VIPs [Thevin et al. 2020], while "Canetroller" had a sample size of 9 [Zhao et al. 2018]. The results from the IPQ questionnaire are presented in Table 4, while the comparisons are illustrated in Figure 4 and Figure 5.

ID	G	SP1	SP2	INV	REAL1	REAL2	REAL3	REAL4
P1	7	7	7	7	7	1	7	1
P2	5	6	7	7	7	7	7	5
P3	7	4	7	7	7	1	7	4
P4	7	7	6	6	7	6	5	4
P5	6	5	6	6	5	6	7	4
P6	5	4	6	6	6	4	5	1
P7	5	2	1	1	7	7	7	4
P8	7	7	7	7	7	7	6	4

Table 4. Results - IPQ

[5]https://www.orcam.com/pt-pt/orcam-myeye

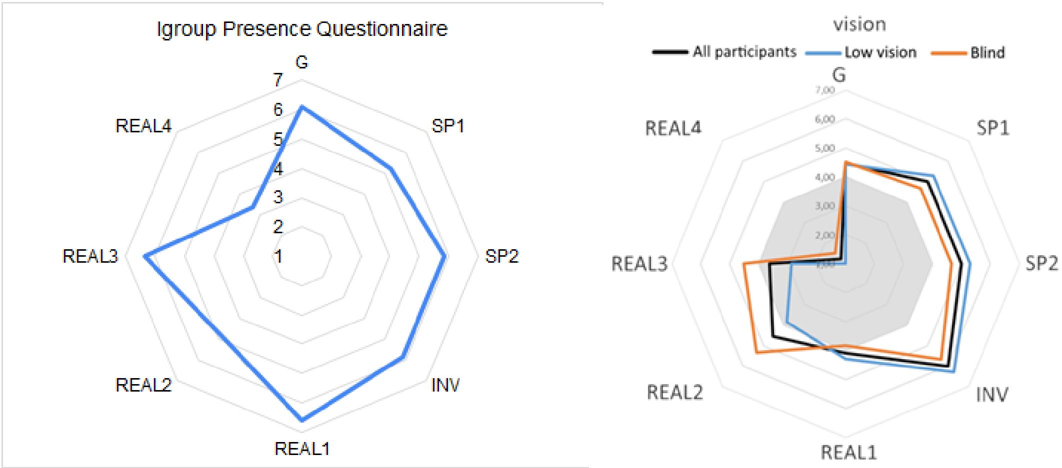

Figure 4. Comparing IPQ results: “Escape INF VR” is on the left, and “X-Road” is on the right [Thevin et al. 2020].

The results indicate that the experience was perceived as highly realistic (REAL), with participants feeling fully present in the environment (SP) and engaged with it (INV). Compared to the “Canetroller” and “X-Road” applications, “Escape-INF-VR” appears to provide a more immersive and realistic experience for the participants (see Figure 4 and Figure 5).

This study specifically utilized the Gemini-1.5-Flash Model. However, a new version, Gemini-2.0-flash, may be used in subsequent experiments [Mallick e Kilpatrick 2025]. It is important to note that using a newer or different model could potentially alter specific results, as the updated model may offer improved descriptions to the user.

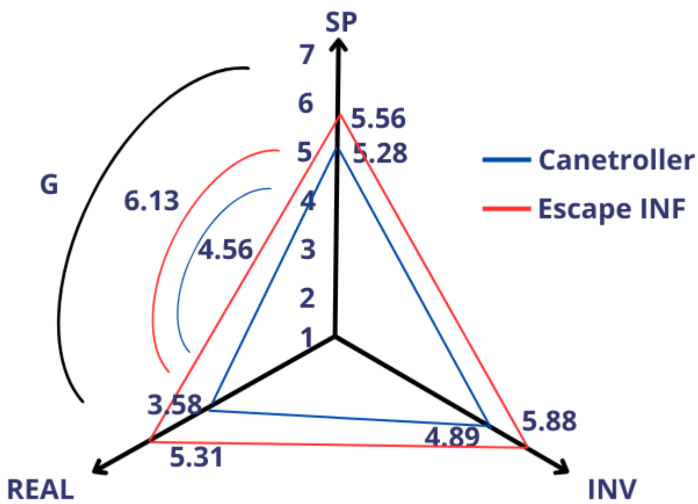

Figure 5. Comparing IPQ results through a Radar Diagram [Zhao et al. 2018]

The frequency with which users engaged with the artificial intelligence features was not considered, making it difficult to determine how these features contribute to the enhanced sense of immersion. Then, it can be theorized that the levels of immersion reached result from integrating all the features.

The following steps involve increasing the sample and recording the frequency of artificial intelligence feature usage. Such observations may provide valuable insights into the relationship between artificial intelligence and accessibility in Virtual Reality.

6. Conclusion

Escape-INF-VR offers a higher immersion level and presence than applications such as X-Road [Thevin et al. 2020] and Canetroller [Zhao et al. 2018]. These findings highlight Escape-INF-VR's strong potential as a practical and accessible virtual reality application. The experiment was also deemed successful, as participants reported significant levels of immersion and presence, as shown in Figure 4. Overall, the game provided a positive experience for visually impaired users, suggesting that Escape-INF-VR can be a practical example of an accessible Heads-up Computing application [Coronado et al. 2024a].

This study demonstrates that game accessibility guidelines can be effectively applied to virtual reality applications, expanding accessibility and promoting the creation of more inclusive and user-centered VR experiences. The findings underscore the potential of Game Accessibility Guidelines (GAG) as a valuable framework for guiding the development of accessible virtual reality applications.

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