Investigating the Mode in Multimodal Video Games: Usability Issues for Learners who are Blind

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Abstract
This paper presents an ongoing work on methods for usability evaluation of audio- and haptic-based video games for learners who are blind. We report a Standard Usability Problem List which we envision to be the basis for comparison of the Usability Evaluation Methods (UEM) in this context. In addition, we present a preliminary analysis of evidence on what problems different UEMs can reveal by evaluating audio, interaction mode, interface adaptation, and feedback.

Author Keywords
Learners who are blind; multimodal video games; audio-haptic interfaces; interaction modes; usability.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces (D2.2, H1.2, I3.6);

Introduction: Why thinking about usability for learners who are blind?
Multimodal video games have great potential to help people who are blind to develop new abilities, learn the academic curriculum, and even to improve cognitive skills such as logical reasoning, orientation and mobility (O&M) and mental mapping [1,5,8,22,23,27,29]. There is evidence that multimodal interfaces based on

Game	Interaction	Interface
AbES	**Mode**: Keyboard **Feedback** Sonorous Visual	**Graphics** 2D **Audio**: Speech synth Iconic Spatialized
Audio Sims	**Mode**: Joystick **Feedback** Sonorous Visual Haptic	**Graphics**: 3D **Audio**: Spoken Iconic Spatialized
Audio Geometry	**Mode**: Tablet **Feedback** Sonorous, Visual Tactile	**Graphics**: 2D, 3D **Audio**: Spoken Iconic
Audiopolis	**Mode**: Keyboard **Feedback** Sonorous Visual Haptic	**Graphics**: 3D **Audio**: Iconic Spatialized
Audio Haptic Maze	**Mode**: Keyboard Joystick **Feedback** Sonorous Visual Haptic	**Graphics**: 3D **Audio**: Iconic Spatialized

Table 1: Interaction and interface dimensions of the multimodal games considered in the analysis of usability problems

audio and haptic inputs can enhance learning and cognition in young students [13,14,27]. Learners with functional or total blindness naturally use a combination of modalities to interact with their surroundings and to learn [6,32]. Therefore, multimodality can play a crucial role in acquiring complementary non-visual information for learners who are blind to interact with the video game [19,25]. Keeping in mind that learners with visual disabilities can have broadly different abilities and disabilities and may need various levels of support to learn new skills [18,19], the multimodal gaming interface should not add unnecessary complexity to the interaction. Multimodal video games for learners who are blind should be easy to play and pleasant to use**.** Otherwise, learners will not only struggle to learn how to interact correctly but also be too fatigued, distracted, confused - or even bored - to learn cognitive skills by interacting with the game [10].

Thereupon, it is necessary to ensure that multimodal game interaction and interface elements suit the cognitive purposes of the game and that learners will be able to interact pleasantly and correctly while playing and learning. For achieving this, a careful usability evaluation should be carried out considering that the applicability of general Usability Evaluation Methods (UEM) to the various domains is debatable [2,4,9] and that UEMs are mainly designed for users without disabilities [3]. Practitioners and researchers need to make sure that the UEMs and evaluation instruments administered will disclose most of the issues that recurrently affect the game interaction of learners who are blind, as well as to use the most appropriate UEMs to evaluate the desired aspects of such games. As so, the present paper makes two main contributions to the current literature in the field. First, we approach and discuss typical problems affecting the interaction of learners who are blind with audio and haptic-based multimodal video games. We introduce a Standard List of Usability Problems (SLUP) to help designers avoid recurrent usability issues in the design of such games, resulting in an initial research step towards comparing UEMs in this context. Second, we present primary evidence concerning what types of usability issues different UEMs can identify and finally show that the SLUP can be useful to create focused usability evaluation instruments.

Learners Who Are Blind meet the Standard Usability Problems

In the first step of Hartson's et al. (2001) methodology for comparing usability evaluation methods, they propose to identify a "standard" set of usability problems that occur in a target system, which will later serve as the basis for methods comparison [11]. Based on this principle, we established a Standard List of Usability Problems (SLUP) as a first step towards comparing the suitability of different UEMs to evaluate multimodal video games designed for developing cognitive skills in learners who are blind. However, instead of choosing one target application, we chose and analyzed the usability evaluation reports of five target multimodal video games, namely AbES[26], Audiopolis [24], AHM [21], AudioSims and AudioGeometry. The criteria for selection of the games were access to the usability evaluation reports, availability of the games, inclusion of distinct combinations of interaction modes, as well as feedback and cognitive abilities stimulated by the game such as O&M, mental maps, logical reasoning and spatial structures. Due to the different combinations of interaction modes and feedbacks (Table 1) which are

ID	Scholarity	Experience
E1	PhD	5-10 usability evaluations
E2	PhD	> 10 usability evaluations
E3	Master	5-10 usability evaluations
E4	Master	> 10 usability evaluations
E5	Undergraduate	> 10 usability evaluations
E6	Undergraduate	> 10 usability evaluations
E7	Undergraduate	> 10 usability evaluations
E8	Specialist Teacher	5-10 usability evaluations
E9	Specialist Teacher	> 10 usability evaluations

Table 2: Experts' profiles. The experts who proposed the SLUP **did not** answer to the questionnaire.

Age	Grade level	Ophthalmic diagnosis
8	2nd	Congenital bilateral aniridia
8	2nd	Composite astigmatism, refractive amblyopia
10	4th	Retinoblastoma, bilateral leukocoria
12	5th	Bilateral optic nerve hypoplasia
13	6th	Retinitis pigmentosa
14	7th	Bilateral aphakia, retinal detachment, phtisis bulbi

Table 3: Learners' profiles

common in this type of applications [7,28] the analysis of the usability reports revealed various issues that may occur while learners who are blind are playing multimodal games. Throughout the five reports analyzed, we first identified 22 usability problems reported by users, and 35 pointed out by experimenters. We considered a usability problem as any negative phenomenon in interaction such as user's inability to reach a goal, inefficient interaction, or user dissatisfaction provoked by a mix of user interface design aspects and context of use factors [15].

In order to validate the SLUP, seven independent experts in usability evaluation and two teachers specialized in learners who are blind (Table 2) answered to a 58-item questionnaire in which they could rate usability problems on a 7-point Likert scale of agreement and explain their viewpoint. All the respondents were familiar with conducting usability evaluations of multimodal games with learners who are blind. We adjusted the SLUP issues description and categories to agree with the nine experts' evaluation and suggestions. Then, a senior usability expert reviewed SLUP updated version. Finally, we performed usability evaluation sessions with six children (Table 3) playing with AbES and AudioSims. Four experimenters (including E9 and E5) conducted evaluation sessions using the observation [19] together with a think-aloud protocol [3], followed by a semi-structured interview, and the Software Usability for Blind Children Questionnaire (SUBC) [20]. They identified all the problems in SLUP at least once in these evaluations. The problems identified relate to the interface and interaction features that most impacted multimodal video games for learners who are blind; specifically, Audio, Adaptation, Interaction Mode and Feedback [7].

In the following, we discuss some of the most significant problems. The full version of the SLUP has 61 issues and is available at http://goo.gl/DNQQCi.

Problems related to overall usability

We identified 12 problems related to overall learnability and satisfaction, errors, and efficiency. For example, users can report perceiving the game as difficult to learn how to play (Q14); and perceiving help or extra information offered by the video game as useless (Q15, Q16). The overall satisfaction with the game can be affected when users feel that the game does not challenge them enough (Q18), or does not allow them to be in control as much as they expected (Q19). Users can also demonstrate dissatisfaction with the game controls (Q20), or feel disinterested for having difficulty to play without helping mediation (Q17). Although mediation is acceptable in the context of usability evaluation with learners who are blind [18,19], it cannot cross the line where learners are unable to perform most activities by themselves and keep making mistakes when the mediator stops explaining the game interaction and goals. On the other hand, observers can detect when users have difficulties to either move in the virtual environment (Q35) or recognize different scenarios in the game (Q37). Both issues are often related to troubles with the controls (Q20), understanding game goals (Q38), or with the quality of the game information (Q13, Q14).

Problems related to audio

Audio is essential to video games for learners who are blind because they learn to rely on their audition to compensate for their lack of vision [12]. We identified 15 usability problems related to different types of audio (Table 4). The users can perceive when iconic sounds

ID	Audio Issues	Audio Features
Q1	Difficulty to identify a sound	Iconic sound, abstract earcons
Q2	Difficulty to understand information conveyed by a sound	Iconic sound, abstract earcons, Spoken audio, Speech synth.
Q3	Difficulty to stablish relation between a sound and an action	
Q4	Difficulty to stablish a relation between a sound and user's prior knowledge	
Q5	Perceiving sounds/voices as unpleasant	
Q7	Associating a sound with the wrong action	Iconic sound, abstract earcons
Q8	Associating a sound with the wrong object	

Table 4: Partial list of the audio issues in the SLUP

Usually audio features combine sounds as iconic, spatialized, spoken, stereo, speech synthesis and abstract earcons [7].

and abstract earcons are difficult to identify (Q1); when they do not convey information properly (Q2); and when they are poorly or wrongly associated with actions or objects (Q3, Q7, Q8). They can perceive recorded voices or speech synthesis as unpleasant or unfamiliar (Q5, Q6). They can also demonstrate difficulties in relating a sound to an action, or with their previous knowledge. Alternatively, the experimenters can recognize, by observing the user interaction, whether the spoken or TTS-based information for user orientation or current location in the game is unclear (Q25 to Q28). Likewise, they can detect when the learners have a low acceptance of a sound (Q31); and have difficulties to recognize (Q29), or associate a sound to what it represents in the real world (Q30).

Frequently, the comments and questions of users lead the experts to identify multiple different usability issues. For example, the difficulty to understand the information conveyed by a sound (Q2) (reported by learners in simple comments such as "What does this sound mean?" during the observation with thinking aloud) can make the experts discover associated problems. In this case, Q1 may be related to any issue from Q25 to Q30. In situations like this, it is up to the experimenter to find the association. For instance, the learner may have difficulties in the identification of a sound because she cannot understand the accent, or does not know the words used in the spoken audio (Q25, Q26); or even because the TTS audio is too fast or too slow (Q27, Q28). Some problems are usually indirectly identified as they are a cause of another issue. For example, it is uncommon that the learner will notice she does not have the knowledge required to determine the meaning of a specific sound (Q4). Suppose that a student is playing a game and listens to beep sounds coming from a heart rate monitor. It is possible that she does not understand the meaning of the sound in the game because it does not match her prior knowledge. In these cases, to provide the correct adjustments it is necessary to identify clearly both problems: Q2 and its cause, Q4. Furthermore, we highlight the need to be attentive to accidental sounds that can cause dissatisfaction, especially in learners with total blindness, because they are more sensitive to sounds than those who can rely on some visual cues [16,17]. Two of the children who played AudioSims commented: "I don't like this sound" and "This sound is ugly" (Q5) and they both were talking about the sound of the joystick vibrating while in contact with the table.

Problems related to adaptation

Video games for people with visual disabilities should support at least the adaptation of size, color scheme, and contrast graphic elements [30,31]. Issues involving these aspects apply primarily to users with low vision. These users can still learn by using their visual modality despite the need for magnification, enhancement of contrast, and change of font type and size [32]. Initially, we listed three issues in the SLUP that commonly emerge in multimodal video games for learners who are blind failing adaptation. The initial list included difficulties in understanding the information conveyed by images (Q9); difficulties in understanding the information conveyed by colors (Q10); and problems with the sizes of figures, diagrams, or other elements (Q32). All these problems were related to graphics. However, during the evaluations with learners, we identified new issues related to audio adaptation. Two participants with low vision and who were familiar with console games complained that, although they could understand it, the spoken audio

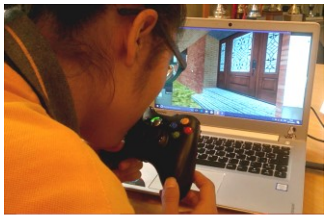

Figure 1: A child with low vision playing AudioSims

Figure 2: A child with low vision playing AbES

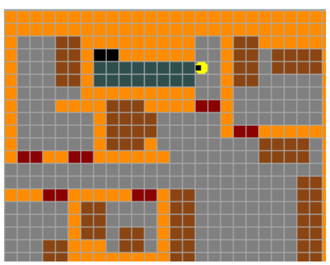

Figure 3: Partial screenshot of AbES labyrinth

The audible feedback on AbES was insufficient for two learners with low vision to understand that the area in blue was a stair, and that they could go up and down.

was too slow in AudioSims; "As if the lady is sleepy" in the words of one of them. However, this was not a problem for the learners with total blindness who were also not experienced with console games. Another learner who is legally blind and also has hearing loss could not hear well the audio feedback in AbES and constantly asked: "What did it just say?". There was no volume control in either game nor the option to adjust voice levels and TTS speed. Thus, we added to the SLUP these issues related to difficulties with the speed of spoken audio or TTS (Q11) and with the intensity of sounds and voices (Q12, Q33).

Problems related to interaction mode and feedback
Learners with visual disabilities often use tactile and kinesthetic input to learn about their surroundings and receiving information through contact and use of objects [6]. We identified 19 problems related to interaction mode and 8 related to feedback. Regarding the interaction, the users may perceive the controls as difficult to learn (Q21) and having trouble to move through the virtual environment due to poor understanding of the use of controls (Q24). In parallel, the experimenters noticed when the controls complicated the user's movement or rotation throughout the virtual environment (Q45, Q46), and when handling the haptic devices was difficult (Q23, Q47). In fact, most of the input issues could be more easily reported by experimenters because they addressed very specific aspects of the game interaction. For example, in cases where haptic devices are the game input, the experimenters could identify if the users had difficulties in recognizing a specific 2D or 3D figure or associating it with what it represents in the real world (Q48-Q51). They could also observe if the interaction techniques used were inappropriate to provide the user with the best degree of differentiation and perception of haptic elements (Q60, Q61). These issues are some of the probable causes for the textures and forms being difficult to perceive, discriminate, or recognize with the haptic device (Q54-Q57). The feedback issues were connected to audio and interaction problems. As in the example in Figure 3, experimenters could perceive whether the vibrating or audible feedback was insufficient or incorrectly applied to the execution of an action (Q41-Q44), or even inappropriate to the usage context (Q22). The users could report difficulties in identifying the actual intent of a specific feedback (Q21), and in a parallel way, the experimenters could perceive if the users understood the feedback incorrectly or were unable notice it (Q40). This situation happened a few times with AbES when the learners were sure that the sound of hitting a table was a glass breaking; and when they ignored the "monster" approaching them because they could not identify the meaning of the correspondent sound.

Preliminary results related to UEM

In the context of usability evaluation of multimodal video games for learners who are blind, the most used evaluation methods are observation, interview, and heuristics, while the most common evaluation instruments are specialized and straightforward questionnaires, and Likert-based surveys [7,28]. We analyzed the data gathered from the observation with think-aloud (in which the observers took notes and filled a checklist based on the SLUP), the videotaped observation, the videotaped interview and the answers to the SUBC, answered online by children themselves in a fun and accessible version of the questionnaire. The initial evidence is that the analysis of the videotaped observation can reveal the greater amount of usability

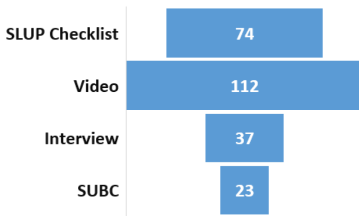

Figure 4: Usability issues found per UEM in the 6 user evaluations

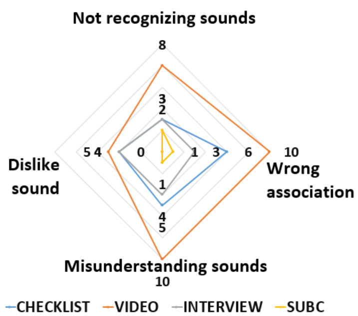

Figure 6: Types of audio usability issues identified per UEM

Overall, the issues related to audio features can be grouped as difficulties to recognize sounds, wrong association of sounds, misunderstanding information conveyed by a sound and somehow disliking a sound. The video and checklist found most of these problems, while SUBC was the less effective for this issues.

issues listed in SLUP (Figure 4) in all the dimensions analyzed (Figure 5). However, a less time- and effort-consuming analysis of the SLUP observation checklist can reveal a considerable amount of relevant usability issues as well comparing to video.

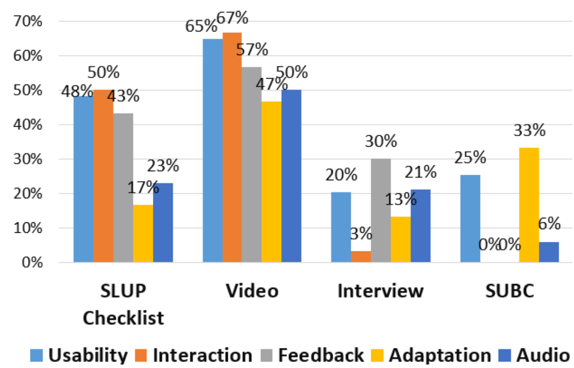

Figure 5: Comparison of usability issues dimensions disclosed per UEM in the six user evaluations

The SUBC questionnaire could not reveal any feedback and interaction problems, but it was more useful than the interview in identifying adaptation and overall usability issues (Figure 5). On the other hand, the feedback, adaptation, and audio issues found in the interview indicate that combining this method with the use of the SUBC would be beneficial for a rapid evaluation. This combination, however, seems to be insufficient to uncover interaction issues which interviews barely revealed and was absent in SUBC answers. The SLUP checklist analysis was effective in finding interaction, feedback, and overall usability issues, but much less efficient than video in revealing audio issues. Compared to interview and the SUBC, the SLUP checklist during observation was better in finding all dimensions of problems, except for adaptation. As Figure 6 exemplifies, the problems in each dimension can also be revealed at different levels, according to the method and instrument administered.

Conclusion

Planning a usability evaluation to identify relevant issues on multimodal video games for learners who are blind is not a trivial task. In this paper, we report a Standard Usability Problem List (SLUP) aiming to help researchers and practitioners in two ways. First, avoiding recurrent usability issues in the early design stages. Second, identifying and correcting real problems affecting multimodal gaming interaction during usability evaluation. We envision SLUP to be a solid basis for comparing Usability Evaluation Methods in the field. SLUP may be further expanded and used as a ground to develop specific usability evaluation instruments as shown by the literature discussed which indicated that an observation checklist based on the SLUP could help researchers to easily identify a considerable amount of usability issues. Future work will expand the evaluations made to comprise more usability methods, multimodal games, and a larger user sample. Based on the results, we will adjust the SLUP and propose a methodology for evaluating the usability of multimodal video games designed for developing cognitive skills in learners who are blind.

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