Dimensions to Analyze the Design of Multimodal Videogames for the Cognition of People Who Are Blind

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ABSTRACT

Multimodal serious video games are relevant tools to enhance the cognitive skills of people who are blind. For this purpose, it is necessary that designers and developers be able to create user interfaces and interactions using the multimodal components properly. Thus, there is a need to know the key components to be considered for such applications, as well as to understand their roles and relationships. In this paper, we propose and discuss a 4-dimension classification: Interface, Interaction, Cognition, and Evaluation, to analyze the design of multimodal videogames for the cognition of people who are blind. Such classification was assembled from features related to the design and evaluation of a number of multimodal video games and virtual environments, identified via literature review based on systematic review methodology. We also classify and discuss multimodal applications within the proposed categorization.

Author Keywords

Multimodal Interfaces, Virtual Environments, Serious Videogames, People with Visual Disabilities, Design, Evaluation

ACM Classification Keywords

H.5.m. Information interfaces and presentation: Miscellaneous.

INTRODUCTION

One of the most significant cognitive issues for people who are blind is the development of orientation and mobility (O&M) skills so that the individual can become autonomous and independent. For an efficient navigation and the development of orientation skills, a person needs to construct a mental representation or metal map of the surrounding environment. However, the absence of vision adds more complexity to easy tasks that require spatial representation [11]. It happens because the visual channels handle to collecting most of the information needed to assemble such a mental map [13, 23]. Therefore, a person who is blind needs to use complementary non-visual stimuli to perceive the environment and construct mental maps.

Receiving space information via complementary sensors collaborates with the creation of an adequate mental representation of the environment. There is evidence that multimodal interfaces, mainly based on audio and haptic stimuli, can enhance learning and cognition in children who are blind [14, 22]. There are several experiences with the design and use of video games for stimulating the development of various skills in people with visual dissabilities [52, 53]. In fact, multimodal serious games have been widely used as tools to improve various spatial and O&M skills in children and young people [13, 35, 4, 37, 39, 38, 36, 34, 49]. This type of applications has particularities and must consider the limitations of users as well as ensure the cognitive goals. Even so, important issues are frequently neglected in the development and evaluation of these applications. Using a development cycle that do not consider the particularities of the target audience, and/or the desired cognitive skills, or not performing a proper and trustable evaluation, are recurrent situations in the design of such video games [27].

There is a need to promote a better understanding and an adequate, relevant and meaningful use of the multimodal elements in a serious game. Academics, software engineers, developers or simply interested end users lack a comprehensive overview of the development and evaluation of multimodal videogames aiming to improve cognition. To the best of our knowledge, there are no studies addressing these issues. For this reason, the present work seeks to fill in some of these gaps.

The overall goal of this paper is to give readers a comprehensive overview of the multimodal video games for the cognition of people who are blind works to date. Also to provide necessary insights for the practical understanding of the issues involved in their design and evaluation. As such, we performed a bibliographic review based on the systematic review approach [10] to investigate the role of multimodal elements in the development and evaluation of games and virtual environments, aiming to enhance cognitive skills of people who are blind [27]. In this paper, we propose a classification based on the significant features identified on the 21 studied multimodal video games. Derived from these characteristics, we discuss the challenges and open issues in the development and evaluation of multimodal video games, in the context of enhancing cognition of people who are blind.

METHODOLOGY

We performed a bibliographic review from July to November in 2014, based on the steps proposed on the systematic review approach [10, 19]. The systematic review consists in a secondary study method that reviews existing primary studies in-depth and describes their results [19]. In this research approach, a set of search strings correspondent to the research questions is posed to suitable sources. Then, the obtained papers are filtered according to a set of exclusion and inclusion criteria. The resulting papers are analyzed in order to answer the initial research questions. There are three main phases of a systematic review: planning, conducting and reporting the review [10]. To support the realization of the three stages of the study, we used the tool StArt [5]. As a reference manager, we relied on Mendeley [44].

For the planning phase, we defined a protocol that guided the research objectives and clearly defined the research questions, the query sources and the selection methods. Two researchers and two experts performed incremental reviews to the protocol. The research questions are: Q1: What strategies have been used for the design of multimodal games for learners who are blind to enhance cognition[1]? Q2: What strategies have been used to evaluate usability and quality of multimodal games for learners who are blind? Q3: What technologies have been used for the development of multimodal games for learners who are blind, to enhance cognition?

For the conducting phase, we posed the search string addressing the research questions Q1, Q2, and Q3 to eight sources. The sources were the following digital libraries: ACM Digital Library, Engineering Village, IEEE Xplore, Scopus, Science Direct, Springer Link, PubMed, and Web of Science. The result of submitting the search string to the eight selected bases was an initial set of 446 papers. Then, using the snowballing sampling technique [16] we manually added a set of 52 papers to the original sample. Snowballing sampling is a technique for gathering research subjects through the identification of an initial subject which is used to provide other related subjects. In this research from the initial set of 446 papers we also gathered 52 relevant related research works cited in these papers. Thus, the total of papers obtained was 498. From this amount there were 48 papers from ACM (9.6%), 136 from IEEE (27.3%), 28 from Scopus (5.6%), 181 from ScienceDirect (36.3%), 50 from Springer (10%), 4 papers from Web of Science (0.8%), 1 paper from Pubmed (0.2%) and 52 added manually (10.5%). It is important to note that, although ScienceDirect had the higher number of papers, there were not many outcomes related to the desired area. It happened because this source returned a vast amount of articles related to cognition and/or people who are blind, but under the medical point of view.

```
(
    ((Evaluation AND (usability OR quality)) OR Design OR
    Development)
     AND
    (Serious AND (Videogame OR Game))
)
AND
(
        ("blind learners" OR (("eyes-free" OR "visually
        impaired" OR blind) AND ("education" OR "learning")))
    AND
        (Multimodal OR haptic OR audio OR auditory OR
        vibrotactile OR device OR "I/O" OR gadget OR
        technology)
    AND
        ("cognition" OR "Cognitive spatial structures" OR
        "Navigation Skills" OR "Mental map" OR "Walking
        Simulation")
)
```

Figure 1. Search string submitted to the eight selected sources.

To choose the most suitable studies to answer the research questions, we filtered the papers according to the inclusion and exclusion criteria (Figure 2). The inclusion criteria helped us selecting studies describing multimodal serious video games, some specific entertainment video games and navigational virtual environments, whose goal was to enhance cognition. The inclusion criteria also selected studies describing no application but introducing a model for the design or the evaluation of multimodal games or environments for people who are blind. The exclusion criteria helped us to eliminate papers related to audiences other than people who are blind and those unrelated to mental models, navigational and similar cognitive skills.

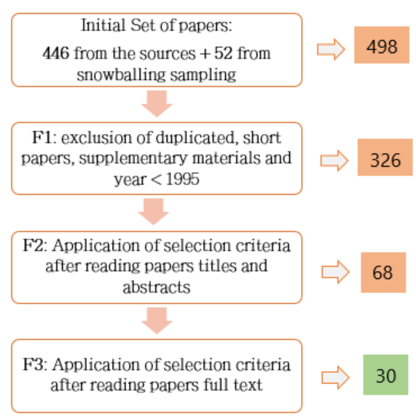

Figure 2. Filtering process

The first filter (F1) consists of removing the duplicated and short papers (i.e. less than four pages) and secondary studies

[1] Concerning to mental models, cognitive spatial structures, and/or navigation skills.

or those published before 1995. F1 excluded 172 papers (34.5%) so that 326 studies went to the second filter. The second filter (F2) consists of the application of the specific exclusion criteria and the inclusion criteria, after reading the papers' title and abstract. F2 excluded 216 papers (43.4%) and included 68 papers (13.7%). These papers went to the third filter (F3), intending to refine the initially accepted set of studies. F3 consisted of the examination of the full text of the 68 articles and the review of the assigned inclusion and exclusion criteria. F3 excluded 34 articles by criteria and four duplicated papers (7.6%) and included 30 papers (6%). Most of the papers eliminated were related to cognition, but not to multimodal games for people who are blind. From the 30 papers finally selected for data extraction, one paper was from ACM, two from IEEE, four from Scopus, two from ScienceDirect, two from Web of Science. Finally, 19 papers were added manually, through a snowballing sampling.

The relevant papers are from 1999 to 2014, being 80% of the papers from 2008 on. The selected papers were: [13, 51, 2, 35, 3, 4, 8, 15, 12, 17, 18, 41, 42, 24, 25, 30, 28, 29, 32, 33, 31, 37, 39, 38, 40, 36, 34, 47, 48, 49]. Among these, 25 papers described 21 distinct applications: 17 multimodal games and four multimodal navigation virtual environment. Some papers discussed the same application, but from another point of view.

CLASSIFICATION OF FEATURES

We analyzed the 21 applications and reported the answers to the aforementioned research questions in a previous work [27]. In the present work, we analyze the characteristics related to design and evaluation of the 21 selected applications. Based on this analysis, we identified that the studied multimodal applications differentiate mainly in the interface and interaction characterization, along with the cognitive aspects and the evaluation performed. Therefore, we propose a classification of the features existing in the multimodal video games and environments in four dimensions related to Interaction, Interface, Cognition, and Evaluation. It is important to highlight that the features we describe are those found on the applications' papers. The proposed classification shows some trends in interface characterization and the interaction style, as well as instruments and activities for evaluation of usability and cognitive impact. Figure 3 gives an overview of the identified features, discussed in detail in the next sections.

Several elements are common to the design of multimodal applications aiming to enhance cognition of individuals who are blind [27]. The video games and environments combine those elements according to the target cognitive purpose. The Interface dimension has three kinds of features: Graphics, Audio and Adaptation. The main features related to the Interaction dimension are Feedback and Mode, i.e., the way a user can interact with the application. Table 1 provides an overview of the applications studied and their classification, according to the Interface and Interaction dimensions.

Furthermore, we can distinguish the applications by the type of skill they aim to improve and by the kind of evaluation performed. The main feature in the Cognitive dimension is Skill, with six types present in the studied papers. Although only part of the applications carried out a proper evaluation, this process usually focuses on the interaction and interface features that are meaningful to the cognitive enhancement proposed.

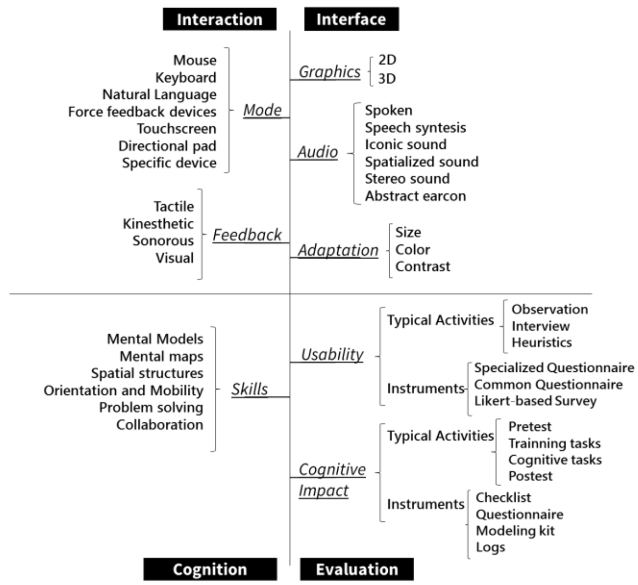

Figure 3. Classification of the key features in multimodal video games for the cognition of people who are blind

The evaluation concentrates on the aspects of usability and cognitive impact verification. Even though there is no model for usability evaluation of multimodal games and no formal standardization about the elements to evaluate, it is possible to identify the most used tools and methods. As so, the features on Evaluation dimension are Usability and Cognitive Impact, both related to Typical Activities and Instruments.

DIMENSION 1: INTERACTION

According to the information available in the analyzed video games and environments, there are seven modes through what the user can interact, providing input to the application. The chosen input device determines the style of interaction available in the application. It also influences the type of feedback that the application provides to an interaction. The Interaction Mode comprehends mouse, keyboard, natural language, force feedback devices, touchscreen (with or without a stylus), directional pad, and specific devices, designed for a particular application. The Interaction Feedback can be either haptic (kinesthetic or tactile), sonorous or visual. Some applications combine two or more interaction modes and feedback types.

The keyboard requires no specific learning and allows direct interaction since it is a familiar input device, common to diverse kinds of systems and technologies. In fact, 71% of

		INTERACTION										INTERFACE										
		MODE							FEEDBACK			AUDIO						GRAPHICS		ADAPTATION		
									HAPTIC	SONOROUS	VISUAL	SPOKEN	SPEECH SYNT	ICONIC	SPATIALIZED	STEREO	ABSTRACT	2D	3D	SIZE	COLOR	CONTRAST
MULTIMODAL VIDEOGAME OR ENVIRONMENT	e-adventure [48]	x		x						x	x	x	x					x				
	My First Day at Work [47]		x	x						x		x	x					x		x	x	
	AINIDIU [8]		x							x	x		x					x				
	MOVA3D [35]		x					x	x	x				x	x				x			x
	AudioGene [24]					x	x			x		x		x	x			x				
	AHM [42]		x		x				x	x		x		x	x	x			x	No graphics		
	Audio Space Invaders [18]		x		x				x	x		x		x	x			x				
	AudioDoom [17]	x	x		x				x	x					x			x				
	Virtual Environment [13]				x				x	x				x					x			
	AUXie [3]		x							x		x	x				x		x			
	Tower Defense Game [4]				x				x	x		x		x	x	x		x				x
	Audiopolis [33]		x		x				x	x				x	x				x			x
	AbES [36]		x							x			x	x	x			x				
	The Natomy's Journey Game [39]		x							x				x	x	x		x				
	AudioNature [31]					x				x		x	x	x				x				x
	AudioChile [37]		x		x				x	x				x	x	x			x			
	Virtual environment [12]				x				x	x		x		x				x				
	AudioMetro [38]		x							x		x		x		x		x		No graphics		
	AudioVida [34]		x							x				x					x			
	Terraformers [51]		x							x		x		x	x				x	No graphics		x
	PowerUp [49]	x	x							x			x	x					x	x		

Table 1. Classification of the studied applications according to the Interface and Interaction Dimension

the researched applications use the keyboard as a primary or secondary interaction mode, in the desktop paradigm. The interaction via the keyboard is associated with a sonorous or visual feedback. The keyboard is a low cost, accessible and straightforward device, but it provides no sense of touch or volume during the interaction. Nevertheless, it may be a desirable feature in a navigation context to provide non-visual stimuli that help perceiving the environment physical characteristics.

Force feedback devices allow the haptic feedback (tactile and kinesthetic). These devices measure the positions and contact forces of the user's hand, displaying contact forces and positions to the user [44], even without visual clues. The applications using force feedback devices allow manual interactions with the multimedia environment through touch. It allows the user to explore the environment to extract information, through the tactile feedback and manipulation for modifying the environment, via the kinesthetic feedback [9]. The applications use various devices to allow the function of haptic feedback. Gamepads and joysticks are the second most used interaction form, present in 33% of the studied applications. The applications that use gamepads focus on the tactile feedback, providing sensations of vibration, pressure, touch, and texture. The tactile feedback allows the user to perceive contact force, the geometry of an object and temperature [9]. The applications that utilize joystick provide kinesthetic sensation, dealing with forces resulting from position and velocity of the hand motion and simulating the force and torque [9]. Those applications that employ specialized joysticks, e.g. 3D touch controllers, usually combine tactile and kinesthetic, providing haptic feedback. The force feedback device always has an alternative interaction mode, usually the keyboard. It assures the availability of the game, even without the force feedback. The most common force feedback device is Novint Falcon, a 3D USB haptic device used in four applications. However, Novint Falcon has a high cost, about $250 for the standard version. So, lower cost devices have also been utilized, such as OWL joystick, Wiimote, and SideWinder joystick.

The use of mouse and touchscreen with stylus configures a style of interaction that uses a directional pointer to select items on a display screen. Due to the visual limitation of the audience, these are the less frequent interaction modes identified. Two applications (9%) allows the use of mouse along with the keyboard and one uses the mouse as the primary interaction mode. However, this last application main audience is partially sighted users. The use of mouse relates to a sonorous-only feedback while the stylus also provides a tactile feedback. The natural language is still an underutilized feature (found in two applications). The feedback to this kind of interaction is sonorous. Unlike the mouse, we expected a wide use of the natural language in this type of application, as an easier and instinctive way to interact. However, the accurate and efficient recognition and processing of the human language is still a challenge in computer science. A single application uses the directional pad, a four-way directional control with one button on each point, found on most video game console gamepads. In this context, the directional pad interaction occurs in a mobile application and its feedback is sonorous.

Another option is the development of specific devices to allow for the interaction of the users who ae blind with the multimodal video game. For instance, the Digital Clock Carpet [35] is a device based on a usual cane and a simple digital carpet that inform the user about directions to a destination point, based on the hour system. In this particular case, the feedback is both sonorous and haptic, but adapting a device to interaction and feedback specific to the context of a multimodal video game brings a bunch of new possibilities.

DIMENSION 2: INTERFACE

The interface features that impact most the design of the studied multimodal video games and environments are Graphics, Audio and Adaptation (Figure 3). The Graphics and Adaptation features are directly related since all the interface adjustments refer to graphical elements. Regarding Adaptation, the interfaces may support the adjustment of the size, color or contrast of the graphical elements. The features include the resize of the elements, the possibility of choosing a high contrast mode and the presentation of relevant information in colorblind safe colors. The resizing relates mainly to text elements, which can be resized with no loss of content or functionality. The high contrast is to provide enough contrast between the content and its background so that people with low vision can read it. The use of colorblind safe colors is to assure the interface presents the visual elements in color combinations that are perceivable by people with any colorblindness.

The Graphical User Interface (GUI) is a vastly utilized feature in this kind of applications, allowing the user to interact with graphical elements through direct manipulation. In their exploratory study [50], the prevalence of visual over other senses in video games is highlighted and compares the vastly used option of "turn off sound" with the option to turn off the graphics. They state that it is uncommon to turn off the game graphics in a way that it can still be played and enjoyed. Our results corroborate partially to that conclusion in the context of multimodal gaming for cognition in players who are blind since we identified no video game with a sound-only interface. However, 14% of the applications studied do allow the users to choose navigating exclusively through sound, by using a graphic interface for configuration only.

The reason all the applications studied have a graphic interface, despite the visual impairment of the main audience, is to increase the interaction options for users with visual loss. The interface's graphics can be either 2D or 3D combined with icons, images, and text. The association of such elements helps filling some gaps on the interaction. For instance, children with residual vision have difficulties recognizing certain 2D icons and not always associate them with the designed actions, so the use of 3D icons helps increasing the fidelity of the representation [37]. Besides, having a graphical interface a facilitator can support the interaction with the video game, observing the navigation and the cognitive aspects [26].

Although the graphics are substantial features to the interfaces of the studied multimodal video games, the essential interface feature is the Audio. The papers showed 6 types of audio that can be used solely or combined to provide sonorous feedback in a multimodal interface: iconic sound, spatialized sound, spoken audio, stereo sound, speech synthesis and abstract earcon. All of the analyzed applications use at least one aural interface element, although most of the cases combine two or more aural elements. The prevailing combination is between iconic and spatialized sound, in 3D environments. Figure 4 illustrates the use of each audio feature in the considered applications.

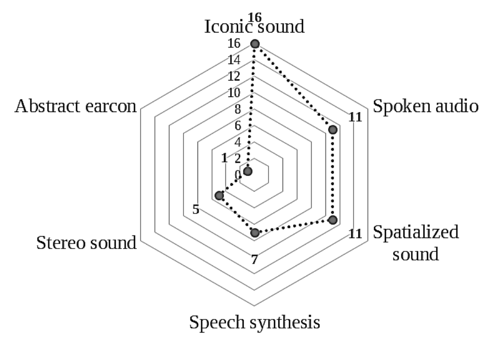

Figure 4. Distribution of the audio features found in the 21 studied applications

Iconic sounds are specific sounds associated with each available object and action in the environment. Every time the user executes a certain action or interacts with a particular object, the corresponding representative sound is heard, for example, distinct steps sound for different kinds of floor. It is the most common audio feature, occurring in 16 applications (76%). Spatialized or 3D sounds are stereo sounds that are digitally processed to appear to come from particular locations in the three-dimensional space, aiming to simulate the acoustic experienced by a listener within a specific environment. A 3D sound navigable environment can serve as an aural representation of the space and surrounding entities, helping the players who are blind to assemble a mental image of an environment [17]. It was the second most used audio feature, present in 11 (52%) applications. Spoken audio refers to the use of sentences pre-recorded in a human voice, usually describing the game status or relevant information about the actions and objects. The spoken audio occurs in 11 applications (52%) while the speech synthesis, which is the artificial creation of the human voice, appears in seven (33%). Five applications combine these two approaches. Stereo sound consists in the mixing of two channels of sound recorded in two separate sources, with the distinction of left and right channels. Stereo sound is present in five applications (23%) and can provide information regarding the nature and location of objects, using intuitive associations (e.g. the sound of flowing water representing a fountain). Abstract earcons appear in only one application, using music/tones to represent different objects. It refers to the use of sounds unrelated to the elements they represent. The use of abstract earcons requires the user to learn with what they are associated. However, it is possible to represent a much wider range of concepts than by using iconic sounds [3].

DIMENSION 3: COGNITION

The studied multimodal video games and virtual environments meticulously combine the Interaction and Interface Dimensions' features, not only for entertainment but also for learning and stimulating cognitive processes [35, 3, 4, 8]. The Cognition dimension deals with which cognitive skills an application aims to improve. Some of the applications help the development of more than one skill. Besides, some skills are secondarily stimulated while playing. The Table 2 summarizes which are the main skills the studied applications aim to improve. We defined six types of skills that compose the Cognition dimension: mental models, mental maps, spatial structures, orientation and mobility (O&M), problem solving and social collaboration. Some of the multimodal games for players who are blind did not specify how they improve cognitive skills. Most of the applications work O&M skills (44%). It is a set of techniques that helps visually impaired children and adults to develop and master the concepts and competencies necessary to be able to move safely and efficiently within their world. While navigating the video game environment, people who are blind can perceive the audio and haptic elements and use them as references for orientation and mobility [42].

Mental models are constructs that can explain human behavior and the internal mechanisms that allow people to understand, explain, and predict the behavior of objects and systems [20]. The improvement of mental modeling can involve the user adopting and restructuring a mental model of spatial dimensions, based on audio and haptic cues after interacting with a video game [42]. The adequate orchestration between audio and haptics can also help the user who is blind to build up a model of a fantasy world and of how a game works [18, 51]. Specific mental models are stimulated by 27% of the studied applications.

Mental maps are mental representations of the space being navigated and its defining features, e.g., overall structure, spatial components, landmarks, dimensions, and relative positions [12]. Having a mental map of space is fundamental to the efficient development of orientation and mobility techniques [35]. From the applications that improve cognitive skills, 27% help developing mental maps. Cognitive spatial structures stimulated by 16% of the applications studied, relates to spatial and temporal reference frames, implying the connection between visual and haptic space [6]. The spatial properties include location, size, distance, direction, separation and connection, shape, pattern, and movement. Humans acquire spatial knowledge and beliefs directly via sensorimotor systems that operate as they move about the world [45]. While navigating in multimodal environments, players who are blind can acquire spatial knowledge indirectly through the maps and images, 3D audio and graphics models, and the language.

GAME / ENVIRONMENT	MAIN COGNITIVE SKILL						
	MENTAL MODEL	MENTAL MAP	SPATIAL STRUCTURE	O&M	PROBLEM SOLVING	COLLABORAT	NON SPECIFIED
e-adventure [48]							x
My First Day at Work [47]							x
AINIDIU [8]					x		
MOVA3D [35]		x		x			
AudioGene [24]					x	x	
AHM [42]	x			x			
Audio Space Invaders [18]	x						
AudioDoom [17]			x				
Virtual Environment [13]		x		x			
AUXie [3]	x						
Tower Defense Game [4]		x			x		
Audiopolis [33]			x	x	x		
AbES [36]			x	x	x		
The Natomy's Journey Game [39]		x					
AudioNature [31]					x		
AudioChile [37]				x	x		
Virtual environment [12]		x		x			
AudioMetro [38]				x			
AudioVida [34]		x	x				
Terraformers [51]		x					
PowerUp [49]		x					

Table 2. Classification of the applications according to the Cognitive Dimension

Problem solving can be understood as the act of consciously apply rules and procedures to bridge the gap between the initial problem state and a solution state [7]. Working this skill while playing multimodal video games involves navigating and interacting, while solving tasks, challenges and issues [37, 8]. Besides, it may include other competencies such as learn and interpret points on a two-dimensional plane [3], and searching, mobilization, localization and designing strategies [37]. Skills concerning to social collaboration refers to help multiple people interact and share information to achieve a common goal. These skills can be improved while multimodal gaming when users who are blind and sighted users solves collaborative tasks [24]. It creates an inclusive learning context where users can work together collaboratively and achieve commonly shared objectives.

DIMENSION 4: EVALUATION

The last dimension we defined to classify the analyzed games is Evaluation, which concentrates on two main aspects: usability and cognitive impact verification (Table 3). It is important to point out that both evaluations are necessary to assure the quality of multimodal video games with cognitive enhancement purposes. According to the ISO/IEC 9126 (2001) quality, relates to "[...] all the features of a product or service that exert their abilities to meet the stated or involved needs." It makes clear that usability is an important aspect of the game's quality. However, without a proper cognitive impact evaluation one cannot assure that a particular application can develop or enhance any cognitive skills for people with visual disabilities [27].

GAME / ENVIRONMENT	EVALUATION	
	USABILITY	COGNITVE IMPACT
e-adventure [48]	no	no
My First Day at Work [47]	yes	no
AINIDIU [8]	no	no
MOVA3D [35]	yes	no
AudioGene [24]	yes	yes
AHM [42]	yes	yes
Audio Space Invaders [18]	no	no
AudioDoom [17]	yes	yes
Virtual Environment [13]	no	yes
AUXie [3]	yes	no
Tower Defense Game [4]	yes	yes
Audiopolis [33]	yes	yes
AbES [36]	yes	yes
The Natomy's Journey Game [39]	yes	no
AudioNature [31]	yes	no
AudioChile [37]	yes	no
Virtual environment [12]	no	yes
AudioMetro [38]	yes	yes
AudioVida [34]	yes	no
Terraformers [51]	yes	no
PowerUp [49]	yes	no

Table 3. Types of evaluation performed on the considered applications

The usability evaluation is the most frequent type of end quality (users and expert user's acceptance) assessment in this context, performed more often than cognitive impact evaluation. Among the applications analyzed that aim to enhance cognition, only 50% performed a cognitive impact evaluation while 64% carried out at least one type of usability evaluation. However, in this context both evaluations are essential. Table 3 shows the evaluations performed on the set of the video games and environments analyzed. There is no particular model for the cognitive impact and usability evaluation of this kind of multimodal games. However, we identified the most used instruments and activities for the usability and cognitive impact evaluation.

For the usability evaluation we identified three types of commonly applied instruments: Specialized Questionnaires, Common Questionnaires, and Likert-based Surveys. The specialized questionnaires are validated and reusable instruments, prevailing in the formal evaluations. They consist of some context-specific sentences, for which the users can define the degree of fulfillment on a scale. The specialized questionnaires[2] identified are the Software Usability for Blind Children Questionnaire (SUBC) [43]; the End User and Facilitator Questionnaire for Software Usability (EUQ) [21]; the Software Usability Elements Questionnaire (SUE), which quantifies the degree to which the sounds of an application are recognizable; the Open Question Usability Questionnaire (OQU); and the Initial Usability Evaluation (IUE). The common questionnaires and the Likert-based surveys are developed and used circumstantially, to evaluate a particular application and consist of a set of factual, opinion, and attitude questions. In both cases, the authors themselves created the instruments, and they do not disclosure the validation process or a particular formalization. The surveys are mainly based on the context of the application and are applied face to face or via email [4, 47]. These instruments are prevalent in non formal evaluations.

The typical activities executed in the usability evaluation of the multimodal games and environments analyzed are Observation, Interview, and Heuristics Evaluation. The observation is direct and involves an investigator viewing users as they use the application, and taking notes on usability aspects [17]. The interviews are semi-structured and occur after the user interacts with the application. The questions intend to establish the subject's previous experience, identify aspects of the interface that were helpful or problematic, and prompt for suggestions on improving the experience [3]. In the heuristic evaluation, usability experts inspect the application's interface and compare it with usability principles in a checklist. For example, the Heuristic Evaluation of the Videogame (HEV), based on Schneiderman's golden rules and Nielsen's usability heuristics, and the Heuristic Evaluation Questionnaire (HEQ) [35]. The evaluations often combine such activities and instruments.

For the cognitive impact evaluation, the instruments most commonly used are Logs, Checklists, Questionnaires and Modeling Kits. The four sorts of instruments can be used throughout the assessment's activities, combined with observation and interviews. The goal is to collect data that will allow an investigator to observe, compare, analyze and measure the skills and the development of the subjects. The typical activities identified relates to the research structure of

[2] None of the papers presents a bibliographical reference to these instruments, except for SUBC and EUQ.

the quasi-experimental design of non-equivalent groups [1], considering experimental and control groups and a two-sample test analysis (pretest-posttest).

The four typical activities identified are Pretest, Training Tasks, Cognitive Tasks and Postest, performed in this order. The pretest involves the users executing an activity under observation so that an investigator can establish the subjects' initial skills [42, 38]. The training tasks refers to the skills that the users need to have before using the video game [33]. Through the training tasks, the user can be familiar with the gameplay [36]. The cognitive tasks focus on developing the specific desired skills based on the software interface [33]. Through the utilization of the video game, each skill in Cognition dimension can be worked on, to strengthen the development of these skills by using the video game. Once the cognitive tasks are completed the posttest takes place, to determine whether or not there was any impact on the previously evaluated skills [33, 17, 42]. In the posttest, each subject is asked to represent in an adequate way the learned skills. The representation can be either a graphic or physical model, an oral description, a test or another suitable approach. Besides, the representation data can be gathered from, for example, logs and in-depth or structure interviews. All the generated data is analyzed and compared with the pretest and cognitive tasks data, determining the cognitive impact of the application.

CONCLUSION

Multimodal interfaces through video gaming can help to improve cognitive skills and thus to make that the playful aspects of the game and their associated technologies positively influence the motivation of end-users [26]. While developing these applications, one must carefully consider several factors, such as the context of use, the desired skills to be developed and the severity of the audience's visual impairment [27]. The analyzed papers show trends in interface characterization and the interaction style, as well as instruments and activities for evaluation of usability and cognitive impact. However, there are some gaps related to when and how to employ the interface and interaction elements to fulfill the application's cognitive requirements. Significant issues remain neglected in the evaluation of multimodal video games for blind learner's cognition enhancement. This paper aimed to help reducing the problems aforementioned by presenting necessary insights for the practical understanding of the issues involved in their design and evaluation of such applications. We proposed a classification of the features for design and evaluation of multimodal games for cognition of people who are blind, considering four dimensions: Interaction, Interface, Cognition, and Evaluation. Besides, we provide readers with a comprehensive overview of the multimodal video games for the cognition of people who are blind works to date. As future work we intend to propose a methodology for evaluating the usability and the cognitive impact of interface elements and interaction components in this kind of games. The results will allow us to analyze and discuss the impact of interface elements on cognition and to propose guidelines for the better practical use of such elements.

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