Virtual Environment Interaction through 3D Audio by Blind Children

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ABSTRACT

Interactive software is profusely used for learning, cognition, and entertainment purposes. Educational entertainment software is not very familiar among blind children because most computer games and electronic toys do not have appropriate interfaces to be accessible without visual cues. This work applies the concept of interactive hyperstories to blind children. Hyperstories are tried out in a 3D acoustic virtual world. In past studies we have conceptualized a model to design hyperstories. The study illustrates the feasility of the model as well as introduces to the field of entertainment software for blind children. As a result, we have designed and field tested AudioDoom, a virtual environment interacted through 3D Audio by Blind Children.

AudioDoom is also a software that enables testing non trivial interfaces and cognitive tasks with blind children. We explored the construction of cognitive spatial structures in the minds of blind children through audio-based entertainment and spatial sound navigable experiences.

Children playing AudioDoom were exposed to first person experiences by exploring highly interactive virtual worlds through the use of 3D aural representations of the space. This experience was structured in several cognitive tasks where they had to build concrete models of their spatial representations constructed through the interaction with AudioDoom by using Lego blocks.

We analyze our preliminary results after testing AudioDoom with chilean children from a school for blind children. We discuss issues such as interactivity in software without visual cues, the representation of spatial sound navigable experiences, and entertainment software such as computer games for blind children. We also evaluate the feasibility to construct virtual environments through the design of dynamic learning materials with audio cues.

Keywords

Virtual acoustic environment, space representation, blind children, audio-based navigation, hyperstory, 3D sound, audio interface.

INTRODUCTION

Interactive computer games have been used for entertainment purposes for some time. However, it has been during the last years that these games have been available to a wider population of children. Today, most youth worldwide have had some type of experience with computer games delivered mainly through video-based devices [6]. This scenario is not the case for children with disabilities [1] who do not have interactive entertainment software available in quantity and variety. The case turns more critical with blind children, because they cannot take advantage of visual games.
This study reacts to this growing need through a two-fold approach: present a way to introduce interactive and immersive “edutainment” for blind children, and demonstrate that 3D auditory experiences can render spatial environmental images.

An image is a two dimensional representation of an n-dimensional referent; it is not visual by nature. Since vision plays a preponderant role in our knowledge of the world, the majority of image representations are created from visual perception. This seems to exclude people who lack the sense of vision. A small number of psychologists do research in the field of drawings and spatial image representation for the blind. Kennedy [10] let blind individuals draw spatial scenes and concluded that they do not represent images with perspective, maintaining a flat bidimensional projection in their drawings. Burton developed a system called Rose [3] that imitates children’s drawings based on spatial models. However until now no systematic approach has been developed to design perceptual image maps of three-dimensional objects and scenes without visual cues.

Our approach tries to extend these concepts by testing the hypothesis that a 3D sound navigable environment can create some mental images and serve as an aural representation of the space and surrounding entities such as the ones explored in previous studies [13,15,16,20]. Kobayashi [11] explo-res the idea of sound-space association to enable simultaneous speaker listening, but spatial navigation is not included. To deal with this topic we have created a framework to describe and implement virtual acoustic navigable environments.

The application introduced here stems from a design model for generic hyperstories. A hyperstory is defined by the combination of a navigable virtual world, a character manipulated by the user, a set of dynamic objects and characters, and traces of interaction among these entities given by the plot of the story [14].

The main research question underlying this work explores how audio-based entertainment and spatial sound navigable experiences can create cognitive spatial structures in the minds of blind children. We also propose a model to describe an acoustic navigable environment. In addition, we asked whether spatialized acoustic modality combined with haptic manipulation of the environment may allow blind children to construct mentally associated structures such as haptic/acoustic correlation, spatial navigation without visual cues, or object permanence in time through the hyperstory metaphor. Furthermore, we examined interface and usability issues related to interactive software for blind children.

WHAT IS A HYPERSTORY?

A hyperstory is a story that occurs in a hypermedia environment. It is the hypermedia version of literary stories. The concept of hyperstory is derived from MUDs (Multi-User Dungeons), their variations (MOO, MOOSE, etc.) and adventure games. Our model extends these ideas by including the elements of a story. These elements are: plot, roles, and characters. The main idea is to capture these elements in the hyperstory representation [8]. Plot is a temporal sequence of actions involving a set of individuals. A plot and its constituent actions may be quite abstract, i.e.: A meets B, A loves B, A loses B, A wins B. Role is the class of individuals whose prototypical behaviors, relationships, and interactions are known by both actors and audience. This plot is ordinarily illustrated with alternative roles, for instance: the boy in love and the girl he loves. Character is a personality defined as a coherent configuration of psychological trait, for instance, any of the characters in the present scenario might be shy and sensitive, silly and affectionate.
We first introduce the definition of a Story Virtual Environment (SVE) as:

SVE : = navigable world + dynamic objects + characters *Eq. (1)*

The navigable world is composed of several environments (nodes) connected by physical links. Each node of the virtual world represents a container of objects and a potential scenario of the hyperstory [5]. Physical gates, portals and doors represented as links render the connectivity. Dynamic objects are in charge of representing objects within the virtual world. They are entities that have behavior in time and react to the events produced by the user or other virtual objects. The characters are special cases of dynamic objects, which are critical to the central plot and elicit the content of the story. The characters are entities carrying on the main course of events involving a complex behavior. For example, in a film the most interesting events happen to the characters and trigger the actions that emotionally impact the audience. There is also a distinguished character called the protagonist manipulated by the child and representing the user-system connection. Due to the sound rendering, the protagonist is acted in a first person representation.

But at this point an adventure computer game could be in some way similar to the previous definition. We add a narrative component to SVE. This is a necessary condition for a HS which is not so in the case of adventure games. Then a Hyperstory (HS) is an extension of a SVE and structurally can be defined as:

HS = SVE + narrative *Eq. (2)*

As depicted, our model extends the idea of a SVE by introducing the idea of narrative. Differences of hyperstories from standard MUDs rely on an intentional sequence of events based on plot, roles and characters. Also, a HS differs from a MUD because the design includes a closure or an explicit end, described as a good feature of a narrative [12].

The added value of hyperstories

A hyperstory is an interactive story guided by an intentional argumentative structure rather than a casual scenario. The plot in a hyperstory is not linear, it is a hyper-plot; here, action, object activation and dialog can trigger a change in the flow of the story. Thus, we borrow ideas from hypertext/hypermedia technology by including narrative in a virtual environment context [2]. Hyperstories have improved conventional literary stories by allowing a "dynamic binding" between characters, the world in which they move, and the objects they act upon [19]. The child develops this binding through a greater flexibility in the learning/ exploration process. In other words, a hyperstory is a combination of a navigable virtual world, a set of interactive objects, and the pattern of interaction between entities [14].

In a particular execution of a hyperstory, two children may experience different views of the same virtual world, extending the ideas of Joiner [9]. Slight changes introduced by a child to the object's behavior can produce different hyperstories in the same world. Children when manipulating a character can also interact with other characters to solve a given problem. Familiar environments such as schools, neighborhoods, squares, parks, and supermarkets can be interesting metaphors for building virtual worlds. It is important to note that conventional computer authoring tools do not provide an adequate set of facilities for building acoustic hyperstories as we have conceptualized them here.

THE MODEL

Our model is a design model based on object oriented concepts, providing a framework to describe the diverse building blocks of the hyperstory. The model supplies a framework composed by four foundational classes as described in Object Oriented Design techniques [18]. These classes are context, link, entity, and channel. Contexts model the static world and links model the connectivity between contexts. Entities are the abstract class that capture any object or character definition, and channels work as a broadcast media of events in a fan-in or fan-out fashion to the subscribed entities. The definition of these classes allows a scheme for designing virtual worlds. Environments such as Virtual Reality Modeling Language, VRML, does not inherently include these high level concepts.

Each fundamental class has a predefined behavior and a set of attributes that makes them different from each other (e.g. a link knows about the transportation of entities between contexts). Another example of specialized behavior arises from contexts: if an entity sends an event to a context, it does so to all contained objects. Thus, a context works as a diffuser of events. All these fundamental classes have behavior, based on modal programming. We used ObjectCharts as the formalism to specify behavior [4]. ObjectCharts are a well-suited tool to describe environments based on events and actions as in hyperstories.

The structure of the world

Hyperstories with several scenarios organize them according to their physical linking or connectivity. For this purpose, we can describe the virtual world as a type of nested context model. A virtual world is defined as a set of contexts that represent different environments. Each context contains an internal state, a set of contained contexts, a set of objects, links to other contexts, and a specific behavior. Different relationships may be held between two different contexts, such as:

- Neighborhood (there is a link from one context to the other),
- Inclusion (one context is included in the other), or
- None (contexts are "disjoints").

Different "real world" metaphors such as a town, a house, houses within a town, and rooms within a house can be described easily with this simple model. All these metaphors are built in such a way that can be freely navigated. Another important concept about context is perception: a context is a spatial container that can be perceived as a whole rendered as a unity at the interface level. In the case of an acoustic HS the context presents some attributes as echoes, background music or atmosphere sound. At this point of the design we are dealing with the navigable world, the first term of the Eq. (1).

The activity in the world

In order to bring life to the hyperstory, we populate the environments with objects, some active and some passive. This is the behavioral dimension. Another dimension is the navigational one. To avoid confusion we briefly define some terms concerning objects in a virtual world.

- **Passive**: the object answers only to simple events such as "Who am I?"
- **Active**: the object has a noticeable behavior while the time progresses -continuous or discrete- or they respond to events with some algorithm that reflects some behavior.
- **Static**: the object always belongs to the same context.
- **Dynamic**: the object can be carried between contexts by some entity or travel autonomously.

Any object or character (even the protagonist) is a subclass of an entity. Therefore we need to extend the basic attributes and behavior of the entity class. Basically, an entity can be viewed as an object with a set of attributes that define an internal state and a behavior. Using especially made state-based scripts we are able to describe the object's behavior. In each state there are a set of rules containing a triggering event, a pre-condition, and a list of actions that must be performed when the event arrives and the pre-condition is satisfied. Each rule plays the role of a method in OOD. But, if we try to capture the nature of the narrative and the diverse branches of a hyperstory, the model must consider this requirement: certain entities in a story can respond to the same event (message in Object Oriented Design) in a different way according to the story stage. For example, according to the stages of the hyperstory a character can respond "fine" or "tired" related to the question "How are you?" In short, an object can behave differently to the same message received depending on its life stage. This concept is called programming with modes [21] or state-based programming. To capture this feature the rules are not specified in a standard way. Instead they are blocked and grouped according to the entity's life stage. In short, we use state-based scripts in order to deal with a variable response to the same event. By embedding narrative in the behavior of entities we are satisfying the components of a HS as depicted in the Eq. (2).

AUDIODOOM: A HYPERSTORY FOR VISUALLY IMPAIRED CHILDREN

Visual imagery may be loosely defined as visual mental processing that resembles the perceptual mental processing normally induced by the eyes. AudioDoom tries to test the hypothesis that claims that a 3D sound interactive, navigable aural environment can create these mental images in the absence of direct sensory stimuli from the eyes.

Sound serves as the output media of the system. However, the transient nature of the sound imposes a bias in the interface design, leaving it tightly linked to temporal constraints. For this reason, the conceptual idea of an interactive narrative combined with challenging features of game and story must be organized and rendered in a very simple way to model our target user, blind children between 8-12 years old.

AudioDoom is the prototype designed to test our ideas about interactive hyperstories for visually impaired children. With AudioDoom the child can navigate in a set of corridors where he obtains and interacts with virtual objects, resembling in some way the classic Doom game. AudioDoom is based on a fantastic story about an extraterrestrial invasion to the earth, developing the action inside an extraterrestrial flying-source. The child must save the planet in order to get a successful story ending. While playing AudioDoom, the child encounters characters, objects, and challenges that may change the plot of the story.

The structure of the flying-source is presented as a set of perpendicular corridors of different lengths (see Fig. 1). These corridors are connected by doors that can appear at the end or at the side as an optional exit to other corridors. In each case the user can activate the desired door in order to access a specific corridor. The user is allowed to move in the forward direction step-by-step in order to physically navigate inside a corridor. Certain entities can appear suddenly after a current step has finished. If this happens, before progressing the user must solve a challenge depending on the type of entity found. For example, the monster is simple to destroy -three shots- but the mutant moves in the space jumping between neighborhood voxels, minimal discrete units of volume. This type of behavior enforces the child to localize the entity as soon as possible and then shoot immediately. It must be clear that each user action or entity appearance is rendered with spatialized sound.

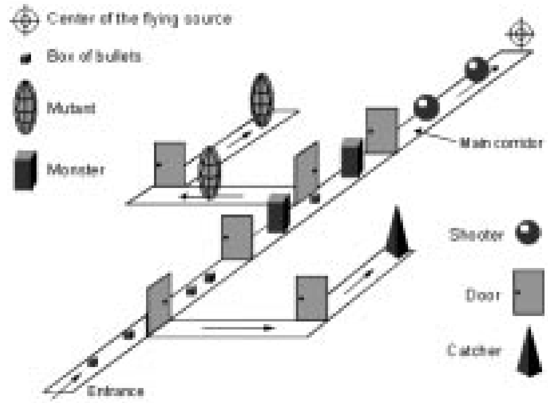


Fig 1. Graphical representation of the spatial environment rendered by AudioDoom

Typical actions in AudioDoom involve getting objects (box of bullets), shooting an entity (monster and mutant), or localizing and interacting with a determined character (the catcher) in a position of the space. The soul of the story presents multiple branches, but some of them are not deterministic, because some story entities may or may not be encountered, depending on the casual user-entity encounter. This scenario brings new alternatives in each session with AudioDoom. The spatial sequencing of the space enables the user to get involved in the story, resolving challenges *in crescendo*, increasing the level of complexity.

The added value of AudioDoom comes from the fact that we have used the hyperstory metaphor to evaluate how a virtual acoustic representation can build a mental spatial representation in blind children. For this reason, we have built some tasks where the child interacts several times with AudioDoom and then tries to describe the taxonomy, organization, entity locations, and space organization of the environment by using LEGO blocks. In short, AudioDoom serves as an argument to test our hypothesis.

Interacting with AudioDoom

To interact with AudioDoom the child operates through the surrounding space, acting on voxels. The voxel concept determines a discreteness of the space, simplifying the surrounding positions of interaction and creating a concrete repository for an entity (see Fig. 2). For example, in a given moment a voxel can be empty or contain an entity. This entity usually is a virtual object represented acoustically, a door, a box, a character, etc. This entity can receive some events from the child depending on the entity: take, activate, open, and so on. AudioDoom presents a modal interface where the same physical event can be interpreted according to the context, mode, and entity located in the target voxel. We must take into account that an entity can have a kinetic behavior, a movement in space through time. This activity involves several voxels because a voxel is an atomic space container. This approach may appear slightly restrictive, but we can divide the environments into the desired quantity of voxels until we obtain the desired granularity.

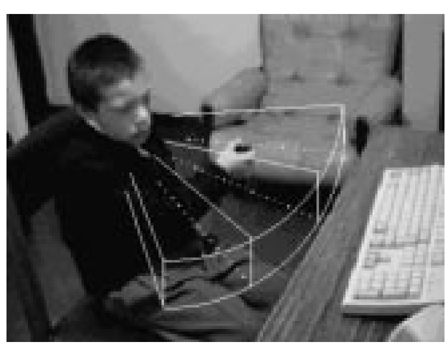


Fig 2. The child explores AudioDoom by interacting with entities located in virtual voxels (drawn artificially over the photography).

In an exploratory study with AudioDoom, first the child constructs a mental representation based on casual encounters of objects. Then, as the use of the software continues, the child tries to locate special items using a goal-directed mental navigation framework.

From the child's point of view, AudioDoom is manipulated by using a wireless ultrasonic joystick called The Owl [17]. Through this device, the child can interact and move in the environment by clicking in different voxels of the surrounding space.

According to the position of the sound, the child must coordinate the haptic/kinestetic device with the perceived sound position. This scheme of action-reaction is strongly stimulated in the child, because of the strong haptic-acoustic correlation embedded in the system. To deal with this issue we designed AudioDoom to be mainly used with both an ultrasonic joystick with 3 degrees of freedom (X,Y,Z) and spatialized sound. The child can also use AudioDoom by interacting with a standard keyboard or a mouse.

How AudioDoom works?

The basic idea of AudioDoom is to split the navigable space into small atomic environments. This is the minimal scenario of action in a given moment. In this environment the child can interact with entities in different voxels. The linear connection of the atomic environments renders a corridor. This structure organizes the space into several corridors, giving a semantic and argumentative connection of the hyperstory and the space. These corridors are modeled as contexts and the doors as links.

The child can perform different types of activities in an atomic environment such as:

- To move forward to the next atomic environment by taking a step,
- To open a door,
- To make a turn, or
- To interact with an entity in a certain way

When we consider the type of presentation media and the interaction with a strong physical metaphor, we highlight three key points to be at the interface of AudioDoom: the structuring of elements at a given moment, the location of objects, and the dynamics of selection and interaction. In general, the system presents one or several entities at a given moment, each localized in a voxel. The child then, after the acoustic localization, tries to locate the entity and elicits a reaction. According to the type of entity, the interaction can be reduced to a discrete event -take a box of bullets or hit a door to be opened. It also can be synthesized to a chain of events with a given purpose: i.e. to shoot three times to destroy an alien, to shoot several times to destroy a mutant moving randomly between contiguous voxels.

Inside AudioDoom

AudioDoom was conceptualized with the following constraints. AudioDoom must:

- Stimulate spatial relations by exploiting the physicalenvironment surrounding the child,
- Be capable of presenting disjoint and distinguishableacoustic entities, located in some point of the space,
- Clearly distinguish isolation between the input-outputmedia in order to test various concepts according to each device, and
- Reflect a real time response related to the child's action.

Our implementation follows the idea that if some entity can move between *n* possible voxels, then we can take the monophonic sound of this entity. By combining different sets of Head Related Transfer Functions or HRTF's -one pair from each position- to the monophonic sound, we obtain *n* clips of 3D sound. This processing is done off-line. The result is a large set of 3D sounds requiring only a cheap soundboard to be played. To deal with real time sound mixing -background music, sound effects, entity sound, etc.- we use the Dynamic Link Library *wavemix.dll*, included in MS Windows. Thus the execution hardware platform requires only a PC, Windows 3.1, and a stereo soundboard. In this version of AudioDoom, the sounds are only presented at ear level. This means that we do not include elevational cues.

THE EVALUATION OF AUDIODOOM

The evaluation of AudioDoom was predominantly qualitative in the sense that we tried to establish relevant usability elements of the interactive applications used by children without visual cues. This will give us enough data to determine if our hypothesis was well grounded.

The testing scenario

AudioDoom was tested with seven Chilean children aged 7-11 in a blind school setting. The children ranged from total blindness since birth to other children with light and dark discrimination (see Table 1).

Subject	Sex	Age	Blind from age	Degree of actual vision loss	Current level/grade in school
FAF	M	11	0	Total	3
JOH	M	8	0	Light/shadow	2
MAR	M	8	0	Total	2
FRA	M	8	3	Total	2
ROC	F	11	6	Total	5
EDS	M	7	0	Light/shadow	2
JOM	M	9	0	Light/shadow	2

Table 1. Profile of each child involved in the testing

After a short oral explanation about how the software works the child explored the interface and began the hyperstory. In the first session the child interacted with AudioDoom by getting confidence with the joystick and developing simple actions in the first corridor. To talk with the child we used external speakers at this stage. The localization is preferentially perceived by the sound intensity played from each speaker. The child interacted with AudioDoom several times and then we set the first evaluation. After this training the child used headphones to deliver full 3D sound.

By using LEGO blocks the child tried to represent the environment structure of AudioDoom as he imagined and perceived. To accomplish this task, each type of LEGO block had an assigned semantic: long blocks represented a part of one corridor, cubes represented mutants, small cubes represented boxes of bullets, etc. Small plastic doors represented the perceived doors (see Fig. 3).

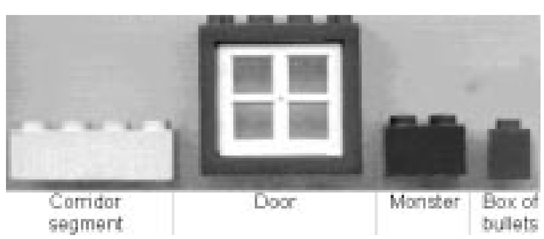


Fig 3. Each LEGO block had a specially assigned meaning in order to evaluate and interpret the structure built by the child.

The testing involved two sessions following this cycle:
1. Getting confidence with the interface of AudioDoom by running the software several times.
2. Exploring the main corridor and some hyperstory branches.
3. Building the perceived structure with LEGO blocks by following these steps:

- The child recognizes the objects separately.
- As the construction goes on, the child establishes an order of complexity (objects, scenes, contexts).
- The child constructs a model by assembling the pieces.
- The child represents the whole structure.

4. Orally describing decisions and testing errors.
5. Re-exploring AudioDoom by navigating the same path or exploring new branches.
6. Restarting the cycle in step 3.

The experiment with AudioDoom performed in the Chilean School for Blind Children consisted of two sessions of two hours each. In each session the child tried at least five times the software. Both sessions were separated by one or two weeks.

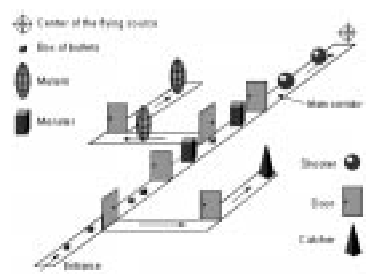
As a result, the children made a model of the environment and entity locations (see Fig. 4). It is interesting to note that when the children interacted with AudioDoom in the second session they remarkably remembered clearly the former structure built in the first session.

A very motivating aspect of this experience is reflected by the fact that the children expressed a notable satisfaction in the independent discovery of the environment. They orally communicated their feelings about this experience as a performance with self-efficacy and self-efficiency. This kind of sensation elicited in the children has few comparisons with previous experiences. Parents and teachers of the school where AudioDoom was tested assured this view.

1. After several attempts with AudioDoom, the child began the navigated space representation.

2. After trying AudioDoom at least five times, the child extended the main corridor, locating doors and singular entities.

3. This is the child's last LEGO model.



4. Compare this ideal version of the AudioDoom space with the child's LEGO model (**3.**)

Fig 4. After some back-and-forth model building, the child is able to "draw" the environment experienced. Amazingly, the child never saw the last picture.

DISCUSSION

After a preliminary user evaluation of AudioDoom with blind children we have demonstrated that it is possible to render a spatial navigable structure by using only spatialized sound. This mechanism of acoustic representation of the environment preserves with a notable precision the structure, topology, orientation, navigation, and mobility. The result is preliminary because we have not included free navigation in open places within the virtual environment. This is due to the restriction of navigating in straight corridors with divergent branches connected at 90° angles. Some children showed some difficulties, especially with mapping transversal corridors. This problem apparently arises from the fact that the turn disorientates the user, because the real surrounding space is fixed such as chair, table, etc. For this reason, we face as a key issue the representation of distinguishable milestones in the environment to facilitate the orientation of the player. The use of some artificial auditory rotational beacons may help to ameliorate this issue.

One important observation collected at the evaluation arises from the possible impact of the child´s previous experiences with testing materials on the fidelity of LEGO model. We infer that with appropriate training we can control for independent variables such as confidence with LEGO blocks and previous computer experience, leaving the intellectual ability/capacity of the children as the dependent variable without any contamination (see Table 2).

Subject	Confidence with LEGO Blocks	Previous computer experience	Fidelity of the last LEGO model
FAF	Poor	Fair	Poor
JOH	Good	Good	Good
MAR	Good	Good	Good
FRA	Good	Good	Good
ROC	Fair	Poor	Fair
EDS	Fair	Poor	Poor
JOM	Good	Fair	Fair

Key	Poor	Fair	Good

Table 2. The correlation of the child's previous experiences with the materials used in the intervention and the fidelity of the last LEGO model.

The process of building the LEGO models by the children shows that first they represent navigable structures preserving the taxonomy. Then they try to locate each entity. This process resembles the map drawing from a visually capable person: first sketch the structure and then describe the singular details. We can infer from these patterns that acoustic navigable environments recreate spatial structures similar to those acquired by first person navigation and visual environment recognition.

Even though we use 3D sound with several limitations such as no head tracking and limited quantity of voxels, children usually preferred external speakers. Children were not so clear about the reasons for this preference but one reason could be that the headphones impose the isolation, limiting the oral interaction with the evaluator. The discomfort imposed by the headphone used (a Sony MDR CD30) appears to be another reason. We detected this pattern of preference at the beginning, so we adapted the HRTFs to be used to external speakers by reprocessing the amplitude of the signal of each channel. This result triggered the use and study of transaural audio, which enabled us to spatialize sound with external speakers [7].

Furthermore, we carefully observed the mechanism of interaction in AudioDoom. We tested AudioDoom by using the keyboard as input device. Children get better confidence because there is no ambiguity of the selected voxel. The use of ultrasonic joystick presented some difficulties due to erroneous voxel selection and undetected clicking due to misalignment of the joystick related to the ultrasonic sensors. But children reported a higher level of satisfaction with joysticks. It seems that the child's arm movement increases the level of immersion. In addition, the haptic-acoustic correlation is an excellent mechanism to stimulate the available skills in visually impaired children. This result imposes opposing design decisions.

One key element in the further improvement of AudioDoom is the construction of an editor, because currently AudioDoom has a hardwired solution. The editor will help teachers and parents to adapt tasks to their own needs. Finally, we propose the possibility to go beyond the concrete construction with LEGO blocks and the mental representation of the spatial environment. We propose to the use motor skills to represent the LEGO model built by the blind child through an interactive motor skill play.

CONCLUSION

One of the most promising benefits of AudioDoom stems from the fact that virtual acoustic environments can not only serve as entertainment worlds but also can be used to deliver an ample variety of educational materials. It is well known that blind children need assistance to know and mentally map their neighborhood, school, downtown, etc. In this way we are exploring the possibility to go beyond the rendering of fantastic environments by including virtual representations of real and familiar places. These representations can be modeled with the hyperstory model by including motivating elements to capture the attention of the children. The results gathered at this point are not completely categorical but they serve as a proof-of-concept that spatialized sound environments rendered without visual cues can bring spatial structures into the minds of blind children.

We have presented a conceptual model for building highly interactive stories for blind children. Our past experiences with hyperstories indicate to us that learners tend to have control over these stories and they enjoy having free access to diverse tools and materials constructively in order to develop strategies and test hypotheses. Hyperstories were used with the implicit idea of fostering the development and use of the cognitive skills such as spatial relationships and laterality. Our preliminary results with 3D aural hyperstories support our belief that they can contribute to make the interaction with computers much more enjoyable and learnable. Children like stories and remember them easily. When children are engaged in a story, they can identify, retrieve and use relevant data to solve a challenge by having rapid and flexible access to the story sequence. From our experience with AudioDoom we have learned that hyperstories highly motivate learners, facilitate free navigation, and promote active constructivist learning by providing blind children with the power to construct virtual environments through dynamic learning materials with audio cues.

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