LEAVING THE SCREEN
NEW PERSPECTIVES IN AUDIO-ONLY GAMING

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ABSTRACT

The design of audio-based computer games possess several challenges. In this paper we discuss both, the technical perspectives in the development, as well as the aesthetics in the design of audio-only computer games. We do not restrict our target audience to the visually impaired only, and assume that audiogames can be played and enjoyed by everyone. We further think that audio-only computer games, and audio based user interfaces in general, offer huge potentials in the form of mobile devices that can be used everywhere and for nearly every application, including gaming.

For this work we played and analyzed several existing audio-only computer games regarding their structure, aim, storytelling, sonification and the possible interactions, and derived some basic rules that are important for a successful game design and development. We further added additional techniques, which we believe are necessary to achieve a higher level of immersion and which assist in the perception and play of such games. To evaluate our concepts, we designed three simple action games and one story based adventure, that we integrated into our audio framework.

1. INTRODUCTION

Playing games is an integral part of humanity and used at all times for fun and enjoyment, to compete with others and to seek challenges and boundaries. Computer games are not different and sometimes even challenge the participant in playing God [26]. What separates computer games from other software packages is their intended use: Fun and Enjoyment. If games are not designed properly, the user can easily get disappointed and quit the game. Successful games are able to immerse the player in a virtual world and communicate a true feeling of being there. They also challenge the player and one can become easily addicted and thrilled by the story and the game play.

In the last few years, besides a huge interest in game graphics, game audio received more and more attention. One point are the new surround sound systems and audio hardware, capable of rendering multiple 3D point audio sources and simulating room acoustics. Although, many users still only use very limited sound hardware, the awareness of the capabilities of a good sound equipment is present in both, the developers and the players mind.

Catalyzed through these advances in consumer audio technology, a *new* game genre has evolved: Audio-only computer games [29]. The major challenge is that these games are played by hearing only. Some of these games are developed as hybrids [10], that include an additional visual representation, but which is not necessary to play the game. Audio based games are often developed by and for the visually impaired community, but we believe that these games can be played and enjoyed by everyone. Furthermore, we think that audio-only user interfaces possess great potentials for mobile (not cellphone) and augmented gaming and communication applications.

As auditory perception varies from visual perception, alternative ways to present and commute information have to be found. A challenge in designing audio based games is to keep the right balance between functionality and aesthetics. Many techniques have been developed to assist in the navigation, orientation and exploration of virtual, auditory worlds [18]. A genre audiogames are perfectly suited for are story based adventures. In these type of games, a story is developed and explored through the game play, as the player reveals more and more mysteries and solves puzzles [5], [10]. These games can also be thought as interactive audiobooks as they combine story elements from audiobooks with the interactivity of computer games. A good reference for audiogames research is the audiogames.net website [20].

The paper is organized as follows: In the next section we discuss the technical side of designing audiogames with topics ranging from interacting with virtual, auditory worlds to object sonification. We compare the sonification techniques of existing audiogames and reference other audio based user interfaces. In the succeeding sections we review genres for audiogames as well as discuss general design issues, with the focus on the right balance between functionality and aesthetics. Along these sections we also present four audiogames, which we have implemented in our framework, and discuss their characteristics. Section four summarizes the results of a short user evaluation on playing audio-only games and section five concludes the work with a brief summary and shows possible directions for future improvements.

2. INTERACTING WITH SOUND

The main idea behind audio based user interfaces, and audio-only computer games, is that all relevant information is presented acoustically through sound and music. While it is difficult to express visual information efficiently through sound, dedicated sonification techniques have to be used. These often exaggerate the natural effects and create a non-realistic auditory environment that enhances the information perception. The goal of audio based computer games is to embed the player in an illusion of being immersed in a

virtual, auditory world. Care has to be taken in the design of these games to not break this illusion by using insufficient and nonintuitive methods for the sonification and interaction. Just as important as the technical part are the sound aesthetics and the game design and play; more on this in Section 3.

Audio based user interfaces can be found in our daily life in a large variety. They are not always used to aid in the navigation of visually impaired, but to be of assistance to everyone. Examples are telephone rings, email beeps and car navigation systems, which acoustically warn or inform, and assist us in performing our every day tasks. More difficult is the sonification of virtual, 3-dimensional auditory worlds. Much of the information contained in the visual part of the scene has to be translated to the acoustic world. As not all of this information can be easily translated, several sonification techniques have been developed to aid in the *interaction with sound*[18], [28].

Similar to the sonification of virtual, auditory worlds is the encoding of additional information to assist in the orientation and navigation for the visually impaired [13]. Many systems have been developed that utilize sound and GPS for blind navigation [7], [25]. These techniques can also be integrated into audiogames and assist the player in navigational tasks using a virtual positioning system similar to GPS [10]. They are also used for augmented audio applications, that combine a real world image using artificial acoustic environments [12]. Although, most of these wearable devices were initially developed to assist in the navigation and pathfinding of real environments [27], [19], but they also posses great potential for interesting game ideas [12], citeDemor2004. Head-tracking, which is also often employed by these systems, can greatly enhance the perception of the auditory scene and improve the sound source localization [8]. Many virtual reality systems use additional tracking devices (like the Polhemus Stylus) for pointing and *real* scene interactions [6], [16].

Many techniques have been created in the past years to make audio based games more enjoyable, to extend their depth to allow a more complex game play. Some of the techniques that were initially designed to aid in the navigation for the visually impaired can be borrowed and adopted to audiogames. Examples are radar- and sonar-like systems as can be found in the game *Terraformers* [10]. Not only audio-only, but games in general are cutting edge and often used to demonstrate and introduce new features and technology. As this is certainly true for graphics based games, many audio-only games still not utilize sound to its full capacity. Many games are simply played on a computer console through mouse or keyboard interaction, although, especially for computer games, many new and interesting input and output devices exist, such as webcams [23], force-feedback systems, virtual fishing rods [9], rattles [21] and dance mats [3]. They might not be developed with audiogames in mind, but there are certainly some interesting games possible utilizing these devices.

As for the sound rendering, most audiogames assume very simple sound hardware, and miss out the benefits offered by real 3D sound and room acoustics. Instead, they often employ stereo panning, which is capable of moving sound sources in one dimension only, along the line between the left and right ear. Many programming tools, such as OpenAL, EAX and AM:3D exist and allow an easy hard- and software rendering of 3D sounds and environmental effects. In addition, most sound hardware is able to render several 3D sound sources in realtime and process the signal using additional on-board DSP chips. A good introduction to sound rendering can be found in the book by Begault [1] and with a special focus on games by Menshikov [14]. As audiogames vary in genre and game play, many utilize music not only as emotional component to express certain parts of the story, but also to use it as factor for increasing difficulty. Louder music is more distractive in the localization of sound sources than soft, or no music at all.

All audiogames use beacons and earcons to sonify objects and points of interest. Sometimes audio textures are employed that are capable of sonifying different states of objects, like an open and a locked door [17]. Speech is often used to illustrate the game and to help in complex situations, which are easier to explain verbally. The narrator develops the narration in story-based adventure games and summarizes scenes and events at certain points during the game. As sound is perceived over time, only those sound sources that are currently playing can be observed. Although, this sounds trivial, it possess several challenges in the design of auditory user interfaces. As too many sounds will clutter the auditory display, one has to find the right balance between the number of sound sources and the information to be described. The spatiality of sound can aid to some degree, as many studies have shown that 3D sound sources are easier to separate as nonspatialied sounds. Still, sometimes not all information can be included, and as a solution a careful design of the temporal aspects of the auditory display has to be chosen.

One of the real benefits of audio is the 360° field of interaction, which can be intuitively sonified through relative simple technology including headphones, 3D sound capable hardware and a head-tracking device. Although, professional tracking equipment is still rather expensive, consumer tracking devices are already being sold [4]. The use of head-tracking allows a much more natural interaction with the acoustic environment and results in a higher degree of immersion.

To conclude this section, many useful sonification and interaction techniques exist and are already employed in many audio based games. In addition to these well established methods, other forms of interaction and acoustic scene representation have been proven to be useful, and should be included in the game design.

In our implementation we use 3D sound as well as environmental sound simulations. For this purpose we use either OpenAL or AM:3D for 3D sound rendering and EAX to model the room acoustics. We are currently working on a more sophisticated system, which will include individualized HRTF's and a more realistic environmental sound modelling. The framework we are currently using works under both, Linux and the Windows operating system, but as 3D sound rendering through OpenAL is not supported under Linux, we have centered our efforts on the Windows platform. Our final goal is a platform independent solution for Linux and Windows with 3D sound rendering and a correct environmental sound modelling. Our framework uses OpenSG as scenegraph to administer the 3D models and the scene. The environment is modelled using 3D Studio MAX and imported into the framework as extended VRML file.

3. DESIGNING AUDIOGAMES

While the last section discussed the technical perspectives in developing audiogames, this section focuses on the artistic side of the design. As mentioned in the previous sections, games are very special pieces of software, and the development of games and standard computer applications differs in many ways. Games are developed and designed for play, fun and enjoyment. From the initial idea till the final adjustments, game developers have to put them-

selves in the players position and imagine the games effects on the user. Over the last two decades the computer game industry has evolved from a small niche market into a big business and with it the developing of games. The formation of a game is nowadays the product of many contributors working on specific parts of the game only.

While this is certainly true for large audio/visual games with huge budgets, most audiogames are still developed by individuals or small groups with very little funding. This of course limits the complexity and the potential that inherits these games. Nevertheless, audio based games have some huge advantages compared to audio/visual games. The influence of the players phantasy, imagine the virtual world has not to be underestimated, as it shapes the appearance of the auditory environment. Similar to books, audiobooks and radio plays, audio-only games, especially adventures with a strong narrative background, are well suited of stimulating the players phantasy. Pictures and visual representations of a story, as they occur in movies and visual games, often limit the imagination to just the depicted scene.

As discussed earlier, many genres for audio-only games have been adopted from the visual game domain. Various audiogames are developed as narrative adventures [5] or action adventures, in which several tasks of varying difficulty have to be completed [10]. But also action games [11], [32] and adaptations of classic board based games exist with a wide variety in complexity and difficulty. Unfortunately, few games only utilize the advantage of a 360° field of interaction for real 3D or augmented audiogames. An interesting example here is the "Guided by Voices" system, which is a simple and mobile augmented audiogame [12].

For the design of audiogames, special care has to be taken in the right balance between the games functionality and sounds aesthetics. On one side, the user interface has to be supportive enough to complete the tasks, but should not be cluttered with too many information. The selection of the right number of sounds is difficult and more a form of art than science. As sound is only perceived over time, an accurate temporal design is very important. The sounds used have to be functional to the game scenario. The soundscape itself must emanate believability, and appear as natural and intuitive as possible. The goal is to communicate the illusion of being immersed in a virtual, auditory world. As images play the most important role in visual games, sound plays an even bigger role in audiogames, as it additionally has to compensate for the missing visual information. The proper design of sound and music is of the highest importance for audio based computer games. While many interaction techniques for auditory spaces exist (see previous section), the difficult part still is to chose the right methods for sonification and interaction. We found the head-tracking and the use of 3D sound sources for the design of our games most important, as they provide a better perception of the auditory environment. For the development and design of audiogames one should rather focus on the benefits of audio-only gaming, than complaining about the difficulties introduced through the non-visual interface. Many interesting true audio-only games are possible with a real 360° field of interaction.

A completely different approach is followed by Tobler [31] and Berndt [2], as they developed a music engine, which is able to render the transitions from one piece to another in the musical correct way. Berndt [2] uses this engine in computer games to describe the story completely through music and though music evoked emotions.

Games are designed to challenge the player with either quick reactions or mindboggling puzzles. In visual adventures, the important information is often hidden and has to be found. Audiogames can utilize music and other sounds as noise to hinder the detection of certain sources. This is frequently used in action based audiogames, in which music is used to mask sound signals that the player has to collect or avoid. The level of difficulty also varies with the number of objects that need to be tracked and the complexity of the puzzles.

Nearly all games feature a narrator that initially explains the game and specifies the games goal and possibilities. Speech is better suited for the transmission of large quantities of information, whereas beacons and auditory textures perform better for simple and short messages. Many games also use monologues to visualize the current situation and to assist the player in difficult situations. Also guides and other characters that provide information are frequently employed.

In order to study some effects of designing and developing audiogames more closely, we have designed four games within our framework. Three are very simplistic action games with varying difficulty and alternative interaction devices. One is a classic story-based adventure game that combines several legends and plays in our city's cathedral. All games are constructed around the spatiality perception of sound and utilize 3D sound sources as well as head-tracking for a more natural hearing. With the development of these games we wanted to motivate for the utilization of additional techniques, able to enhance the perception and game play of audio based computer games. The next sections discuss each game in detail, focussing on the techniques used and emphasizing on the game play.

3.1. AudioFrogger

AudioFrogger is a remake of the original Frogger game [22], in which a frog has to cross a street with several lanes. The player has to bring the frog on the other side of a street without getting hit by the traffic. The difficulty increases with the number of lanes and cars. Our adaptation to this game is similar, as it also stars a frog as the main character that needs to get on the other side of a busy road. The main difference is that everything is visualized through sound. The player can only move forward and backward and the cars and trucks are sonified through their respective sounds. This scenario has already been used in the design of several audiogames, but all implementations did not utilize 3D sounds, and the game was played using a standard computer keyboard [24]. We found this setup, especially through the insufficient sound design, hard to play and not very intuitive. Of course, as the cars are coming from left and right only, stereo panning can provide sufficient information to tell on which side they are, but it is still difficult to judge on which lane, at what distance and how fast they are approaching. Additionally, several studies have shown that sound sources are easier to separate if they are spatialized. Figure 1 illustrates the games concept.

In our implementation we use 3D sound, and as additional input a head-tracking device that determines the direction of view. The different cars, trucks, pedestrian etc. are represented through 3D point audio sources. Varying level of difficulty are achieved by altering the number and speed of objects as well as by increasing the loudness of the background music. The head-tracking provides a very intuitive *view* of the world and uses a natural listening cue that we often employ to resolve ambiguous acoustic situations. For playing we also use a so called force-feedback headphone [30],

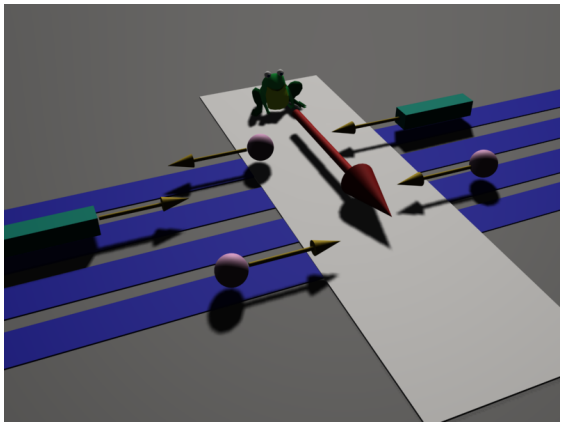


Figure 1: Principle of AudioFrogger

Figure 2: Playing Mosquitos

which is able to vibrate at low frequencies. For the AudioFrogger we use this feature to tell the player: "Hey, that was close!" in cases were the avatar nearly missed a car. The game itself is controlled using a gamepad and game options can be specified through 3D interaction by using the stylus pen from the tracking device.

The sound design for the game was relatively easy, as only sound samples for crossing objects like cars, trucks, ufo's etc. were needed. These sounds are looped and played at 3D point audio sources that move along a virtual street. The objects itself are simple geometric objects and are generated randomly depending on the level of difficulty.

We mainly developed AudioFrogger to find out if classic arcade action games can be successfully adopted to audiogames and are enjoyable to play.

3.2. Mosquitos

The **Mosquito** game is variation of AudioFrogger. The main difference is that the player is fixed at his location and can only move in a very small area. The goal of the game is to defend oneself against attacking mosquitos, flies, bees etc. with a can of mosquito spray. As in the other games, the player has to listen carefully from where the sounds are originating and then use his repellant to avoid bites. In contrast to AudioFrogger, Mosquito is a real 3D game, which is played 360° around the user and puts him in a virtual, auditory environment.

There exists a similar audiogame called *Mückenjagd*, which we have found after developing our own game [15]. This game was developed for the visually impaired and uses a good sound design and game play. Although, the game concept is the same, we have found our implementation to be more intuitive, as it is easier to locate and catch the mosquitos. This is due to the 3D sound and head-tracking used.

The setup is similar to AudioFrogger, with the utilization of 3D sound and a head-tracking device. The stylus pen, which is also connected to the tracking system, represents the mosquito spray, and the player can intuitively hold the pen in the mosquitos direction and trigger the switch. The difficulty of the game can be increased by changing the number of attacking insects and by increasing the loudness of the background music. Figure 2 shows a player in action, defending himself against virtual mosquito swarms.

Mosquitos was developed to demonstrate one advantage of audiogames over conventional audio/visual games: Real 3D perception with a 360° field of interaction. Currently, this can only be achieved for visual games by utilizing expensive head-mounted displays. Audiogames only need headphones and eventually a tracking system to enhance the perception.

3.3. MatrixShot

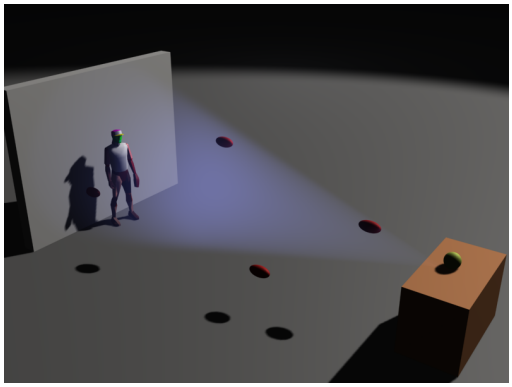
MatrixShot further extends the game play of the Mosquitos game by integrating an EyeToy [23] component into the game concept. EyeToy is a very popular and successful game idea in which webcams are employed to integrate the player into the game. This technique allows complex, full body actions to be performed by the player. In MatrixShot the user is nearly fixed at a position, but can freely move around in a small area (roughly 1 to 2 meters to the left and right). A standard USB webcam is monitoring his position and later utilized in the evaluation of the game. Virtual, acoustic bullets are now shot at the player and the goal of the game is to avoid these bullets at all cost. The player uses headphones and a head-tracking device to locate the position and the heading of the virtual bullets. He now has to avoid contacting them and move out of their pathway. This can lead to very acrobatic contortions as could be seen in the movie Matrix, which was also one of our inspirations for deigning this game. Figure 3(a) displays the games principle and Figure 3(b) shows a user in action playing the game.

The level of difficulty can be adjusted by varying the number and size of bullets as well as their speed. The bullets itself are 3D point audio sources. The webcam is used to monitor the players action and to decide whether he was hit by a bullet or not.

The game is a true 3D action sport game and our main motivation in designing MatrixShot was to combine an audio based computer game with the EyeToy feature for playing and interaction.

3.4. The hidden Secret

All of the so far discussed games can be categorized as action games, in which the player has to quickly react on certain inputs. A game genre for which audiogames are very well suited for are narrative adventure games. In these games the player explores a vir-



(a) Principle.

(b) In Action.

Figure 3: Matrix Shot.

tual world and tries to solve a hidden mystery. In the beginning of the game, parts of the story are introduced, and as the player wanders through the world and solves puzzles secrets, he reveals more and more of the story and develops the entire narration while playing the game. Many successful implementations of audio based adventure games exist, including "Der Tag wird zur Nacht" [5]. These games utilize sound and music to describe items and events, and speech for the narrators voice who explains and controls the story. These games are played on standard computer systems and a keyboard is generally used to interact with the game. Although, these methods of interaction and sonification have proven to work, they could be extended by more sophisticated techniques, allowing a finer and more precise steering of the game. Several of theses techniques are utilized in the hybrid audiogame *Terraformers* [10], which introduced methods like sonar and radar for auditory navigation.

In our implementation we use 3D sounds and an environmental sound simulation model. We further use the head-tracking system as well as the stylus pen for various interactions. The game is experienced through force-feedback headphones, that allow an intuitive representation of additional information, like bumping into a wall. The virtual player is controlled through a gamepad, which can also be employed to rotate the avatars head if no head-tracking is available. The games story is located in the cathedral of Magdeburg and constructed around several sagas that took place some centuries ago. The main character is a tourist that visits the city and the cathedral and stumbles in the middle of mysteries. As he reveals more and more information, he not only learns about the history of this place, but can also find some long lost treasures.

If the user has difficulties in orientation and navigation, several techniques can be used to assist in the game play, like a compass, a radar and a sonar. Additionally, several *guides* can be used to help in the orientation and to *show* the proper way. The virtual environment is modelled with 3D Studio MAX and imported into our framework using VRML. As discussed earlier, these games and especially this one, are well suited for an augmented audio implementation that plays in a real setting using an artificial acoustic environment.

One of our main motivations in developing this game was to find out how good all these techniques really are and whether they can be of assistance or make the chaos even bigger. As the game demonstrates, these methods are really enhancing the perception and the game play and it is on top of it even fun to play.

4. RESULTS

In a short evaluation, we have compared some of our own implementations with other publicly available audiogames. As audiogames are perceived and played in a different manner, we were mostly interested in how well the sonification and interaction supported the users in accomplishing their tasks.

The majority of our participants had non or very brief experiences with audiogames, but nearly all of them liked the idea and found the concepts of playing by ear interesting as well as challenging. One candidate had difficulties with the correct localization of the sound sources in all games and several persons reported problems with the orientation and navigation through the virtual environment in the adventure game. This is partially due to flaws in our design, and some of the sound samples used have to be replaced and enhanced. On a scale for difficulty, the games were ranked between easy to moderate for the action games, and moderate to challenging for the adventure, but everyone reported the fun factor on a high scale. All persons that had at least some experiences with audiogames found it relatively easy to achieve the games goal.

While comparing our games with existing games, we have found that especially the utilization of 3D sounds as well as the integrated head-tracking enhanced the localization of sound sources as well as the perception of the entire auditory scene. All participants were impressed by the true 360° of action possible with some of the audiogames and by the head-tracking technique.

As can be seen from the results above, audiogames are not for the visually impaired only, but can be enjoyed by everyone. With our work, we have tried to focus on the advantages of sound, moving away from the classic visual games. Care has to be taken in the game design to not overstrain the player. If the auditory environment is too complex, the player will get lost and disappointed.

More information about this work can be found online at our website[1]. A last survey that incorporates visually impaired users is still missing. At the moment the games are only available in German, but we are working on an international (English) version of the games. Once they are complete, we will upload them to our website along some additional audio samples.

[1] `http://isgwww.cs.uni-magdeburg.de/games/audio`

4.1. Rethinking Audiogames

Many interesting audiogames are already available, but only few of them are outstanding. The majority of existing games are adaptations of visual games and do not use the full potential of audio-only gaming. This section is to motivate for the development and design of *new* audiogames that utilize more of the immanent possibilities. The most interesting features are the strong fitness for narrative environments, as well as a perfect qualification for mobile (not necessary cellphone only) gaming. The only technology needed is a computer with a 3D sound system, headphones and eventually a head-tracking device. All these components are affordable and lightweight. This mobility also smoothes the way for the development of augmented audiogames, which are played in a real environment using an artificial auditory world [32]. Another benefit is the increased level of immersion. As everyone envisions a different world (stimulated through the players own phantasy), this world appears much more realistic than a photorealistic rendition of the same environment.

The quality of sound, speech and music is of the highest importance, as flaws are easily noticed and hamper the immersion. The exaggeration of sound effects (Doppler) and a non-realistic sound modelling can greatly aid in the perception of the auditory environment and the interaction with it. Sound textures and interaction groups can be used to integrate additional information in the environment for player interaction.

The next directions in the evolvement of audiogames are portable and augmented sound systems. Such techniques are not only useful for playing games, but can be used in a number of applications, ranging from navigation and education to the design of assistive devices for the visually impaired.

5. CONCLUSIONS AND FUTURE WORK

In this work we have examined audiogames regarding their structure, aim, storytelling and their methods for sonification and interaction. Therefore, we carefully looked at and played several audiogames that are publicly available. From this analysis we have derived some basic rules which are important for the design and development of audio based computer games. We further motivated for the integration of additional techniques, which were used in the development of four simple audiogames. These games were developed within our audio framework and evaluated in a short user study.

With this work we have shown that audiogames possess a large potential for varying game scenarios and are not bound to the classic screen based computer games. Real 3D games with a true 360° field of interaction are easily possible. Care has to be taken in designing the auditory environment and the games story. If too many information is presented, the navigation and orientation can get more difficult due to a cluttered auditory display.

Various directions for future improvements exist. As the current results are encouraging, we will further proceed in this direction and extend our framework by new possibilities for sonification and interaction. With the advantages of sound in the development of transportable, mobile applications, we will focus on the exploration of augmented audio scenarios. Thus it is possible to create *real world* computer games with an artificial or enhanced auditory environment.

Another direction for future research is the combination of interactive audiogames with narrative audiobooks. We would like to extend the initial approaches of auditory adventures by combining them with a non-linear game play and a non-linear storytelling.

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