In a real game situation, is HRTF-enhanced game audio preferable over regular stereo game audio?

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C Essay

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Abstract

Game players’ audio preference during actual game play was tested for. The goal of the study was to investigate whether or not HRTF encoded audio is preferred over normal stereo sound in a real game situation. The test was done with two sound alternatives, the normal stereo sound output of an Xbox console and the modified surround output of the same Xbox console. The surround output modification consisted of playback over a surround system and then downmix via a KU100 Neumann microphone in order to obtain a HRTF-encoded stereo alternative.

The test was conducted with 20 test subjects playing a set of three games from different genres and for each game the subjects had to choose between the two sound alternatives and motivate their choice. For two out of three games the results were inconclusive and the whole groups’ choices of sound alternatives could not be considered statistically significant. The test result for the last game was statistically significant and pointed towards HRTF-encoded stereo sound being preferred. For the study as a whole it was not possible to either prove or reject the investigated thesis. This leads to the conclusion that further study, with an improved method, is needed to answer the original research question.
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1. Introduction

1.1. The game industry

The game industry has exploded during the last twenty years. Beginning with simple 2D-games like Tetris and Pac-man we now have sophisticated 3D-gaming, real time strategy games and online multiplayer games with over 11 million subscribers.\(^1\) With the development of computers the development of computer games have spiraled upwards steadily and that particular market is likely to expand further when computer prices continue to drop and the amount of potential gamers continues to increase. The expanding market and number of players in combination with hardware innovations will lead to game audio and graphics being improved further within the upcoming years. It is likely that the innovations yet to come will be just as significant as past improvements in the area have been.

Head related transfer functions (HRTFs) can improve a listening experience by giving the listener increased spatial localization of sound sources. Improving the gaming experience by using head related transfer functions might be one area of game audio improvement in the future. Enhancing stereo with HRTF encoding might be a way to bring a more surround like experience to the large amount of players using a normal stereo speaker or headphone setup when playing games. There are already ways of incorporating HRTFs in game development, but they are quite seldom used. A reason for this might be that it often relies on third party software to work.\(^2\)

1.2. Research question and aim

The topic for this essay is whether or not audio with HRTF-encoding is more preferable to players compared to regular stereo gaming audio, in a real game situation. This essay will study several modern video games and their different audio. The survey is designed to test for preference between the normal stereo sound and HRTF enhanced stereo sound derived from the games surround mix. This will be a way to investigate if there is any correlation between HRTFs and the game players’ preference of audio. Although there are several other aspects of game audio this might be one reason to why certain game audio is preferred. The aim is to investigate whether or not HRTFs is a part of creating successful game audio that the players prefers over other game audio. Hopefully the study will give more insight to how the average game player prefers to hear the game while playing.

The gaming environment is intense in many ways and offers visual, audio and tactile information to the player, which of course will take focus from the listening experience. This, in combination with an often intense plot in the game, raises the question of whether or not game players would even want a spatially improved audio experience. Do they at all consider HRTFs to be an improvement of the game sound? In a real game situation, is HRTF-enhanced game audio preferable over regular stereo game audio?

The purpose of trying to answer that question would be to set the stage for the future of game audio. If the average game player does not desire the effects of HRTFs while playing games this would mean that the gaming industry need not invest further time or money in developing more successful HRTF methods for their games. If the average player does indeed desire the HRTF effects

when playing it would mean that serious game developers should invest in further research within the area.

2. Background

2.1. Head related transfer functions

2.1.1. Spatial cues

When locating the direction of a sound there is a number of different cues the human hearing uses. Two such cues are inter-aural time differences and inter-aural intensity difference. The inter-aural time difference is dependent on the distance between the ears of the listener. This distance gives a sound a characteristic time difference and therefore also phase difference, depending on the direction from which the sound is coming. The inter-aural intensity difference works in much the same way, since it is also dependent on the distance between the ears. Due to the obstruction caused by the head and the inverse square law for sound travelling in air this will give all sounds travelling towards the listener a characteristic intensity at each ear, also depending on the direction from which the sound is coming. Together, these two cues are very important for the ability to locate sounds correctly. Other than this there is also some refraction on the listeners head, torso and external ear which also effects the directional impression of a sound.

These are the major cues that head related transfer functions consist of. Measurements of phase, intensity and time difference is gathered and compiled to transfer functions, which can be used together with normal stereo sound or single mono sounds to give an enhanced impression of directionality. Depending on the way the transfer functions are gathered they will consist of different components. A computer simulation generally consists of inter-aural time differences and inter-aural intensity differences. It normally does not have the ability to calculate external ear and torso reflections. As opposed to this it is not possible to measure HRTFs with a physical model without gathering these reflections, if the model in fact has a torso and external ears.

2.1.2. Implementation of HRTFs

There are many different ways of implementing head related transfer functions. It is possible to use both speakers and headphones when listening to synthesized 3D audio. The HRTF data used does not vary notably depending on the sounds source, but the source defines a few other boundaries of the system. In other words, depending on which kind of sound source is used to reproduce the recorded sound there are a few things to consider.

Headphones will, due to their construction, be less prone to system problems. In comparison to using speakers the listening room will not affect the spatial impression with its own acoustics when using headphones. Using a traditional speaker system will mean problems with interference between the two speakers which might affect the spatial impression of the reproduced sound.

The actual implementation of the head related transfer functions on the audio is done a bit differently depending on what kind of output is desired. One such way is by means of binaural synthesis, which through convolving implements inter-aural intensity differences and inter-aural time

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4 Ibid. p 15
5 Youngtae Kim, Sunmin Kim, Jungho Kim, Joonhyun Lee, Sang-il Park (2005). New HRTFs (Head Related Transfer Functions) for 3D audio applications. p 7 f
6 Ibid. p 8
differences to make it possible to place a sound in the listeners’ spatial dimension. When wanting to enhance the listening experience more generally head related transfer functions can be used to give the illusion of a wider stereo image or even be used to reproduce surround sound through a normal stereo setup. In the latter two of these three examples the head related transfer functions are implemented on a group of sounds and not just on a single sound as is done when wanting binaural synthesis. Binaural synthesis can be applied both when listening through speakers and headphones, whereas both widening of the stereo image and surround sound reproduction through stereo is used primarily for a stereo speaker setup. 7

2.1.3. Difficulties in implementing HRTFs
Implementing head related transfer functions usually involves several problems of different severity. Using HRTFs to widen stereo audio or mix down surround sound to stereo doesn’t always perfectly give the desired result. Experiments have been done with enhancing specific parts of the transfer functions in order to more accurately reproduce the desired spatial impression.8 Other than that there is research showing that the desired distance to the perceived sound source demand high quality and high resolution transfer functions in order to work properly. Expanding the perceived distance horizontally requires less detail in HRTF measurements compared to when expanding the perceived distance vertically9 and moving sound sources will require less detailed transfer functions than stationary sounds in order to assure successful localization.10

2.1.4. HRTF flaws
Regardless of the measurement method and the planned application there will always be imperfections and flaws in the theories behind the HRTFs. Both empirical studies and the theories themselves prove problems with spatial localization. This can largely be considered due to the fact that there are several points around the listeners head with much the same inter-aural time difference and inter-aural intensity difference.11 When that is the case the listener will have to rely on reflections from the external ear and torso in order to successfully place the sound in the spatial dimension. Since the head related transfer functions are not measured for every single listener this will mean that there might be some confusion as to the direction of the reproduced sound.12

Other than this there are reported cases of front versus back confusion and problems locating the sounds “outside” of the head.13 Moreover the transfer function theories and measurements assume that the listener will have symmetrical external ears, even though this might not always be the case.14 Some research has been done with the aim to improve the listening experience when using head related transfer functions, which might also prove to be a solution to the problem of non-individual transfer functions and front versus back localization problems. For example by

7 Youngtae, Sunmin, Jungho, Joonhyun (2005). pp 7-9
8 Zhang Ming, Tan Kah-Chye, Er M.H (1998). Three-Dimensional Sound Synthesis Based on Head-Related Transfer Functions. pp 1-4
9 Minnaar Pauli, Plogsties Jan, Christensen Flemming (2005). Directional Resolution of Head-Related Transfer Functions Required in Binaural Synthesis. pp 9-10
10 Ibid. pp 5-7
11 Cheng, Wakefield (2001) pp 3-7
12 Ibid. p 6
13 Ibid. p 6
emphasizing torso and external ear reflections it is possible to create an even better listening experience.\textsuperscript{15}

\textbf{2.2. Game audio}

Game audio today is dominated by listening through a normal stereo setup, either through headphones or loudspeakers.\textsuperscript{16} Surround setups is fairly common and 31\% of the computer players listen in surround and approximately 35\% of the console players listen in surround.\textsuperscript{17} The ratio of headphone users varies greatly depending on whether or not the player plays on a console or a computer. The headphone users are roughly three times as many amongst the computer players as among the console players.\textsuperscript{18}

The most frequent way of using audio within games is to create a library of sounds that the game engine then relies on in order to create dynamic game audio. The different sounds are fetched from the audio library and then modified with for example reverb and panning depending on the virtual location of the sound in the game.\textsuperscript{19}

Many of the modern consoles make use of Dolby Digital or DTS encoding for 5.1 in game sound, real time Dolby Digital encoding of game audio is offered with the PS3 console from Sony and the Xbox and Xbox360 from Microsoft. The Wii console from Nintendo still only outputs analogue stereo sound.\textsuperscript{20} Up to date the only way of incorporating HRTFs in the game audio is by incorporating it in the recording process or by using third party software or middleware software when programming and processing the gaming material.\textsuperscript{21}

\textbf{2.3. HRTFs in game audio}

Despite the many headphone and stereo speaker users not all consoles or computer games make use of head related transfer functions in order to enhance the stereo experience. One very large type of arena for gaming with headphones is local area network parties. When attending such events it is regularly not allowed to bring surround systems or even subwoofers, it is common for only small computer speakers or headphones to be allowed.\textsuperscript{22} The fact that headphones are used by quite a large percentage of the players shows that it is still an interesting topic of research and that HRTFs possibly could be used to improve the gaming experience for many game players.

In a game audio context using HRTFs would mean enhancing the overall gaming audio experience by transforming the output of the normal audio engine in the game.\textsuperscript{23} Even though this technique has been available for some time game audio has not yet reached its full potential. Most games still use regular stereo sound for their own audio and the focus for gaming audio has historically been obtaining and using nonlinear sound in order to make the audio interesting.\textsuperscript{24} The full potential of the audio as a game experience enhancer is therefore not yet realized.

\textsuperscript{15} Zhang, Tan, Er (1998). p 5
\textsuperscript{16} Goodwin Simon N. (2009). 3D sound for 3D games – Beyond 5.1. p 3
\textsuperscript{17} Ibid. pp 3-5
\textsuperscript{18} Ibid. pp 3-5
\textsuperscript{19} Schmidt, Brian (2002). Playing with sound: Audio hardware and software on Xbox. pp 2-3
\textsuperscript{20} Goodwin (2009). p 4
\textsuperscript{21} Huiberts, Van Tol, Went (2009). p 1
\textsuperscript{22} DreamHack Winter 2010. Event rules and conditions for participation. §5.4
\textsuperscript{23} Youngtae, Sunmin, Jungho, Joohyun (2005). pp 7-9
\textsuperscript{24} Vachon Jean-Frederic (2009). Avoiding tedium: Fighting repetition in game audio. p 1
Due to several facts there is, to date, no extensive use of HRTF encoded sound for use within the actual game. For a computer to successfully handle the many different sounds that would be needed to use HRTF encoded sound throughout a game it would mean handling a great amount of data within very short amounts of time.\textsuperscript{25} Since reading and using that amount of data from a disc (BLU-RAY/DVD/CD-ROM) is practically impossible this would mean transferring large amounts of audio data to the players own computer or to the hard drive of a console and relying on that it can process it fast enough. A suitable compromise between using HRTF encoded audio for all audio within the game and not using any HRTF encoded audio at all might be to only use it for specific sound effects.

The process of introducing recorded HRTF audio for use within games would mean introducing a few new steps in the audio development process of a game. The recording process would need to be altered in order to make room for more extensive HRTF recording. With harsh economic restrains for a game title this alone might make it impossible to use HRTF encoded audio within the game. On the other hand prices for digital storage space has been spiraling downwards during the last few years and thus providing many different audio files with the game should at least not be hindered by storage space any longer. Recording the game audio with HRTFs would also mean that an improved gaming experience with increased spatial localization can be achieved without relying on third party software or middleware.

3. Method

When testing for the preferred game audio experience there is a lot of things to consider. There is always a risk of the result varying greatly depending on, for example, the test subjects earlier experience of gaming, whether or not the tests are done with actual game play or not. The test performed is a qualitative test for whether or not players prefer HRTF encoded game audio over regular stereo game audio in a real gaming situation.

The tests were done with the subjects actually playing the games, in order to obtain as realistic game circumstances as possible. This meant that the test subjects had quite a bit of control over the sound environment of the game. As in any regular gaming situation the sound output of the game depended on exactly what they chose to do when playing. They could generate the sounds and at the same time see the game and to some extent also feel it through the consoles controller. The amount of sounds generated varied with each game and what the players chose to do while playing. This might of course have affected the results of each test subject, but was essential in order to achieve the authentic game situation without which an answer to the thesis would become quite invalid on account of lacking ecological validity.

3.1. Audio Setup

A game console (Microsoft Xbox) was used to output surround sound from a real game, which was re-recorded as HRTF encoded stereo. The same console also outputted the normal stereo sound of the game.\textsuperscript{26} The test subjects played a short sequence in a predetermined section of each game and did this with two audio options, the normal stereo sound and the HRTF encoded stereo. The tests were done in this manner in order to minimize the influence of time between the two audio setups. As opposed to letting the subjects play the whole course with the first sound alternative and then changing before letting them play again this setup allowed them to change between the sound

\textsuperscript{25} Cheng, Wakefield (2001). p 6
\textsuperscript{26} Schmidt (2002). pp 5-6
alternatives while playing, thus giving the subjects the option to test the same sounds several times at the same place in the game and more closely comparing the two sound alternatives. Letting the subjects change between the two audio setups during the actual game sequence also gave them an increased opportunity to focus on the differences between audio alternatives.

Since the aim for the study was to compare normal stereo sound from a game with HRTF encoded surround sound from the same game the stereo sound could not have the entirely same signal path as the HRTF encoded stereo sound. The alternative would have been to output the stereo sound in the same venue as the HRTF downmix was done and then re-record that sound alternative too. This would have lead to the study being a comparison between the HRTF encoded surround sound and the re-recorded stereo sound, which was not the aim of the study.

3.1.1. The two sound alternatives
The surround sound was taken from the consoles output as Dolby Digital surround sound and then decoded through a Yamaha receiver (HTR 5760) into six separate channels. These channels were then A/D- and D/A-converted by a Yamaha receiver (HTR 5760) into six separate channels. These channels were then A/D- and D/A-converted once more by the Studer Route 6000 core before being played back over a surround setup consisting of Yamaha MSP5 speakers in a standard ITU\textsuperscript{27} surround setup. This surround output was then re-recorded with a KU100 Neumann microphone. The distance between the speakers and the microphone was two meters. This was done on location at the LTU department of Media and Music in Piteå. The room used for the conversion was K4, a sound control room mainly used for mixing broadcast audio.

This HRTF-encoded stereo sound was then A/D- and D/A-converted once more by the Studer Route 6000 and then outputted through the headphone amplifier of a Studer Vista 8 console. The normal stereo sound from the console was sent directly into the Studer Route 6000 for A/D- and D/A-conversion and then outputted through the headphone amplifier of the same Studer Vista 8 console.

By controlling these two stereo channels with separate VCA faders it was possible for the subjects to instantly change between the two sound alternatives by pressing two “Mute” buttons at the same time, thus un-muting one of the stereo channels and muting the other stereo channel. The actual listening was done with a pair of Sennheiser HD201 headphones. Figures of the sound setup can be seen below.

\textsuperscript{27} International Telecommunication Union, Geneva, 1992 \textit{ITU Recommendation ITU-R BS.775-1 “Multichannel Stereophonic System With and Without Accompanying Picture”}
3.2. Game types and games
In order to ensure results applicable to several game types the tests were conducted with three
different kinds of games. The games were chosen based on their game types and were of three
different genres since the goal for the study didn’t involve testing for preference based on one game
type only. The only requirement that was not compromised was that all three games had to be able to output surround sound in order for the experiment to work. The three games were:

- Turok: Evolution (Acclaim Entertainment, 2002)
- F1 Challenge ‘99–’02 (EA Sports, 1999)
- Prince of Persia: Warrior Within (Ubisoft, 2004)

One game was a first person shooter (Turok: Evolution), one game was a racing game (F1 Challenge ‘99–’02) and one game was a third person adventure game (Prince of Persia: Warrior Within). This meant that the subjects were able to play games with many different kinds of audio. The range of games covered many different kinds of sounds, both sound effects and environment sounds. Sound effects included sounds from guns, swords, bows, engines etc. The environment sounds consisted of foliage, waterfalls, birds, cheering crowds and such. The variation in sounds was important to ensure that a possible preference was not the result of doing the test with only one setup of sounds.

The actual sequences played were chosen based upon their complexity in order to not present the subjects with far too complex game situations. Before starting with each game all test subjects had to play the game for a short moment to test it, with game audio in speakers and at low volume in order to familiarize themselves with the controls of the game. This was done in order to even out some of the differences between the inexperienced and experienced players. It also effectively made it easier for the test subjects to play the game and focus on the audio instead of the game play during the test.

3.3. Subjects

The test subjects were all gathered from Piteå and most of them were students at the Department of Music and Media at Luleå University of Technology and only two of them did not attend the school. Twelve of them were studying to become sound engineers. It can be argued the sound engineers’ education would give them an advantage in judging the different aspects of the sound and that therefore only sound engineers should be used in the test. Since the aim for the study is not to test for a perceived difference between the two sound alternatives but is instead to test for preference the ability to evaluate the sound alternatives compared to each other is of lesser importance. In order to ensure enough test subjects the author had to find a few participants that were not sound engineers.

The subjects’ ages ranged from 17 to 26 years and they all claimed to have normal hearing without any known hearing impairments. All of the test subjects had played console games at previous occasions although their experience varied to some extent. Most of them had started playing console and computer games at younger ages and had experience of different kinds of games and different kinds of platforms. Eight of them played computer or console games actively, spending more than ten hours on it each month. Twelve of the test subjects only played more seldom, spending between one and four hours each month.

3.4. Test sessions

The actual tests were done in sessions of approximately one hour, with approximately 15 minutes of play for each of the three games and five minutes to answer questions after each game. The time spent on game play varied a bit from person to person and the only requirement given to the subjects was that they simply had to play until they could choose on sound alternative over the other and motivate the choice. After each game they were asked to choose and write down which of the two sound alternatives they preferred. They also had to motivate their choice of sound alternative
either by using a set of attributes predetermined by the author or by writing own attributes as a part of their motivation. The predetermined attributes were “more intense”, “clearer spatial impression”, “better tonal balance”, “more enveloping” and “less latency”. The attributes were chosen since they begin to describe the many differences that can be found between HRTF-encoded stereo and normal stereo. Each attribute was accompanied with a reinforcing word in order to further clarify what aspect of the attribute that was intended. At the end of each test session the subjects were interviewed shortly in order to confirm that their motivations were understood properly.

In order to not contaminate the subjects before the tests they were not given any exact information about what the aim of the tests was until after they had done their individual test. For the order of the games to not affect the test results the order in which the games were played and what audio setup was used first was randomized for all tests.

4. Results

The following figure and table show the results of the test session with the 20 subjects. The figure shows which sound alternative the test subjects preferred, shown as percentage divided between the three games and a total for all test answers. The table shows the same values numerically.

![Figure no 3. Percentage results](image)

<table>
<thead>
<tr>
<th></th>
<th>Stereo</th>
<th>HRTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turok</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>F1 Racer</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Prince of Persia</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>34</td>
</tr>
</tbody>
</table>

*Table no 1. Numerical results*
The use of the predetermined attributes can be seen in table no 2. It shows how many times each predetermined attribute was chosen with each sound alternative.

<table>
<thead>
<tr>
<th></th>
<th>Stereo</th>
<th>HRTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>More intense</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Clearer spatial impression</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Better tonal balance</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>More enveloping</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Less latency</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table no 2. Use of predetermined attributes

5. Analysis
As can be seen above, the mode results for both one of the games and the whole game series points towards the HRTF alternative being preferred over the regular stereo alternative. The mode of the two remaining games points towards the regular stereo alternative being preferred. With this in mind it is apparent that more analysis is needed in order to understand the results.

A chi-square test was used to investigate the significance of the test results. The chi-square test gave the following chi-square values:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Turok</td>
<td>0</td>
</tr>
<tr>
<td>F1 Racer</td>
<td>7.2</td>
</tr>
<tr>
<td>Prince of Persia</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>1.0667</td>
</tr>
</tbody>
</table>

Table no 3. Chi-square values

Using a chi-square table for a test with one degree of freedom and a p-value of 0.05 means that each game needs a chi-square value of at least 3.84 in order to be significant. The only game with a chi-square value that high is the F1 Racer. The chi-square value for a total of all games is 1.0667 and that means that neither that result is significant even though the mode for all three games pointes towards the HRTF alternative. The very much significant result from the F1 Racer can in other words not be used to grant the whole test series significance.

Despite this it is still interesting to analyze possible reasons for why the F1 racer displayed significant results whereas the other two games did not. It is most likely that the different results are related to the fact that the three games have a very different soundscapes and very different game mechanics. As an example both Prince of Persia and Turok:Evolution contains quite a large amount of turning back and forth, thus demanding the soundscape to move around the player. The same kind of movements can be found in the F1 racer but is in that case not as intense and the game does not demand the same amount of turns in order to be played. Other than that it is also quite possible that the relation between SFX and environment sounds varied greatly between the different games. In the F1 racer the environment is quite static in comparison with the other two games where the player is allowed to more or less freely explore the environment that the game is set in. This of course sets a major framework for what kinds of sounds are used and when the different sounds are played.
The results from the predetermined attributes are harder to analyze since the test subjects were not forced to use the attributes. A few of them used the attributes alone, but most of them used the attributes in combination with a motivation they wrote themselves. Quite a few of the test subjects did not use the predetermined attributes at all. One could argue that there is a pattern in the attributes chosen, but it is not possible to statistically justify this from such a small group of test subjects whose use of the attributes varied greatly.

6. Discussion
The results were not as conclusive as was the intention of the study. Despite the test results for one of the games being statistically significant it is not possible to say that the study as a whole confirms that game players in a real game situation would prefer HRTF encoded stereo over normal stereo audio. Although the study did not prove the thesis to be true it was not conclusive in either way, in other words the study did not prove that game players clearly prefers normal stereo audio over HRTF encoded stereo audio. In extension this gives ground for the claim that further study within the area in order to determine if, and in that case how, HRTFs should be used in game audio situations.

The reasons for the inconclusive results can be many and it is most likely that the method needs to be improved. It was not possible to do this test by actually modifying an existing game audio engine, thus resulting in the fact that the surround sound of the tested games had to be used as opposed to having the game output HRTF-encoded sound directly. One of the major problems would be the phase problems being introduced by using several speakers in the same venue to create the HRTF alternative. There are several consistencies among the different test subjects’ answers and motivations that also point in that direction and lead to the conclusion that the method needs to be improved. Several of them did choose the regular stereo alternative with motivations such as “better tonal balance” and “less comb filtering”, probably due to the fact that the HRTF-encoded sound alternative had the serious phase problems that the regular stereo alternative lacked.

Although the method needs to be improved to rule out all other possibilities of interference besides the HRTFs the actual study still has some validity. The method used insured that HRTFs were introduced to one of the sound alternatives via a KU100 microphone, thus making that alternative differ from the other audio alternative. Unfortunately it also introduced other artifacts as mentioned above, making it impossible to claim that the results are due to the HRTFs and the HRTFs alone. This means that the study meets the requirements written in the aim, but with a method not detailed enough to ensure exhaustive results.

There were several indications of the subjects choosing the HRTF-encoded alternative due to its superior envelopment compared to the regular stereo sound, which gives good ground for the claim that further study is needed although the results in this case were not statistically significant. The fact that one of the games gave a significant result in this study means that it would also be interesting to further investigate why and how this affects the differences between an HRTF encoded stereo alternative and a normal stereo alternative. Doing the same type of test with a more accurate setup, more games and more test subjects would be a natural extension of this study. Also studying the actual games to a greater extent might prove the research tests’ validity. In order to insure even more ecological validity it would also be interesting to research how using HRTFs for players with headphones would affect the stereo output if listened to from a regular speaker. Even though quite a large portion of the game community listens in headphones an even larger portion of it listens in some form of speaker setup, be it stereo or surround.
7. References

7.1. Written


Youngtae Kim, Sunmin Kim, Jungho Kim, Joonhyun Lee, Sang-il Park - New HRTFs (Head Related Transfer Functions) for 3D audio applications. Audio Engineering Society Convention Paper 6495, May 2005.


7.2. Webb

Visited: 2010-04-04
Appendix 1 – Enkät lyssningstest

Namn: _____________________________________________

Har du några hörselproblem? __________________________________________________

Hur ofta spelar du TV- eller datorspel varje vecka? ______________________________

Hur många timmar spelar du TV- eller datorspel varje vecka? _______________________

När du spelar, vilken plattform använder du oftast? □ PC □ Konsol

När du spelar, hur lyssnar du oftast? □ Högtalare (Stereo) □ Högtalare (Surround)
□ Hörlurar

Hur skulle du beskriva bra TV-/datorspelsljud?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
Spel 1

Vilket av de båda ljudalternativen föredrog du? □ Alternativ 1 □ Alternativ 2

Motivera:________________________________________________________________________
________________________________________________________________________________

<table>
<thead>
<tr>
<th>1. Mer intensivt</th>
<th>2. Tydligare riktningsintryck</th>
<th>3. Bättre tonal balans</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Mer omslutande</td>
<td>5. Mindre fördröjning</td>
<td>Egen motivering</td>
</tr>
</tbody>
</table>

Spel 2

Vilket av de båda ljudalternativen föredrog du? □ Alternativ 1 □ Alternativ 2

Motivera:________________________________________________________________________
________________________________________________________________________________

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Spel 3

Vilket av de båda ljudalternativen föredrog du? □ Alternativ 1 □ Alternativ 2

Motivera:________________________________________________________________________
________________________________________________________________________________

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