The musical aspects of sound (pitch, dynamics, timbre) as the core element for interaction in sound based computer games.

This dissertation is submitted in partial fulfilment of the requirements for the Degree of Master of Arts in Interactive Multimedia

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Abstract

The use of sound in the context of computer games is presented. The result analysis of a user testing of a computer game prototype showed at what extent the musical aspects of sound (pitch, dynamics, loudness) can be used as the fundamental element in computer games. The concept of this work and its application in specifically designed computer games could be suitable primarily for blind people and useful in music teaching. It could also be used in any commercial computer game as it enhances the environment of multimedia offering a unique experience to the users.

Keywords: audio, blind people, computer games, dynamics, loudness, music, pitch, psychoacoustic characteristics, sound, timbre
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Chapter 1. Introduction

1.1 Overview

"We begin to hear before we are born, four and a half months after conception" writes Walter Murch in the foreword of Chion’s (1994) book "Audio-vision: sound on screen". In the beginning of human history, communication was based primarily on sound and hearing until the invention of writing. However in two cases the visual communication preceded and was dominant to sound communication: films and computer games. Movies were voiceless for 35 years since the birth of cinema and the first ever commercially available home video game had no sound (Robertson 1979).

The core innovative idea behind computers is that they are devices that can execute mathematical operations fast and accurately. Unlike cinema and television they were not necessarily meant to use a screen as a way of communication with the users/audience. In fact computers use several other output devices like speakers, printers and Braille embossers. In that sense a screen and all the visual data that a computer communicates to the user should not be the exclusive context for computer games.

Nowadays it is beyond imagination to produce a soundless movie. Even the voiceless movies were accompanied by music. Regarding the games industry, the last couple of years, sound design has become an important part of it. "Developers and publishers alike are starting to take audio seriously, and allocate better budgets" (Jordan 2003).

However a genre of computer games using sound as their core element for the interaction between the user and the system is something relatively new and known mostly to the blind gamers. The developers of sound based games vary from amateur hobbyists to small companies dedicated to the visually impaired community. Some of them claim that their games are also entertaining for sighted people.

It is arguable though if a sighted gamer in the contemporary game industry would be interested in sound based games. The majority of these games offer a Text-To-Speech facility that reads out loud for the blind user. This facility is redundant for a

1 "AllinPlay Poker": a card game for blind and sighted alike that can be accessed at http://www.allinplay.com/
sighted gamer. In contrast the sighted person has a vast variety of high-quality computer games with exceptional visual elements to choose from.

Some other game designers have developed games that are based on the ability of the acoustic characteristics of sound to convey spatial characteristics such as position of the player in the game environment and the opponents’ positions. In these games the user has to adjust her/his position in the game according to a number of sound stimuli (usually sound effects - SFX) that the system provides her/him with.

There is a distinction between the acoustic (physical) and the psychoacoustic characteristics of sound. The acoustic characteristics are related to the physical parameters of sound such as intensity, frequency and waveform that can be objectively measured. The psychoacoustic characteristics approach the concept of sound in terms of how it is perceived by the human ear and brain, i.e., loudness, pitch and timbre respectively (Truax 1984, Mackenzie 1964). In this work the words "musical aspects" are used instead of "psychoacoustic characteristics" as the researcher’s approach examines sound in a more musical context.

As the meaning of the musical aspects of sound is concerned it could be stated that they are the basic elements that are applied in Western music to create musical pieces. The musical aspects of sound that are considered in this work are the pitch, the loudness (dynamics) and the timbre.

Pitch is the way the human ear perceives the tone of a note. There is a range that starts from a low tone (bass sounds like these produced by a double bass) to high tone made by instruments like the violin. Pitch is closely related to the frequency of a sound.

Loudness is the way the strength of note or a sound is perceived. If a sound is very easy to listen to then its loudness is high. If it needs much attention to listen to, then its loudness is low.

Timbre is the way the human ear can distinguish two sounds of the same pitch and loudness. It is the identifiable colour with which a sound that a violin produces is different from that of a trumpet.

2 "Pong": a sound based computer game for blind people by Jim Kitchen that can be accessed at http://www.kitchensinc.net
1.2 Aim and Motivation

To the knowledge of the author there is no a sound based computer game that uses the pitch, dynamics and timbre (musical aspects of sound) as the core elements of interaction between the system and the user. On the other hand, there are ear training software applications based on methods used by music schools that can be described as educational titles. These educational titles are far away from being considered as computer games.

The aim of this dissertation is to explore, probably for the first time, the extent and how the aforementioned musical aspects of sound can be used in computer games. As a result, another aim of this work is the proposal of a different use of sound in computer games that will build the interaction between the user and the system on the musical aspects of audio rather than its acoustic characteristics. Access for blind people to games and a theoretical background to enable game designers to enhance the total multimedia experience of fully sighted people are considered as well.

From a marketing point of view computer games as an industry and blind people as a target audience, are very important. Computer games industry "is a multi-billion dollar business bigger than the film industry and more popular than television. In 2002 over 221 million computer and video games were sold in the USA - two games for every household" (Collins 2003). Regarding blindness two million UK citizens (RNIB 2003) are blind and severely visually impaired people. In the United States, this number reaches the ten million.

Until recently, the regular approach for designing products targeted to people with disabilities dictated that an already successful piece made for the rest of the community should be adjusted to the needs of the disabled people. The new media industry has now been forced\(^3\) (Slatin and Rush 2002) to adopt a more advanced approach: the product itself has to be as inclusive as possible. Thus, designers have started designing products such as a new web site, having accessibility in mind.

This work challenges both these approaches by proposing a new concept. It is stated that disabled and especially blind people would like to feel included in community by having access to the same products and services that are made for the sighted. They do not wish to be treated differently (Howell 2003). What a better

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\(^3\) US Section 508 and related laws in Europe, Australia, Japan and other countries.
challenge then than producing a theory, a product, made for blind people that will be desired by the sighted?

On the other hand the theory and the conclusions of this work could be applied in a sound computer game that will enhance the ear training experience and the acoustic skills of music students, musicians and wannabe musicians.

1.3 Structure and Methodology

To accomplish its aim this dissertation starts with a literature review and a theoretical analysis on issues related to the musical aspects of sound. Pitch, dynamics and timbre are examined from a psychoacoustic and a musical point of view. This background theory is vital for understanding the potentialities and the limitations that these characteristics have. Moreover it is very helpful for evaluating the use of the musical aspects of sound in films and computer games.

The next chapter (Chapter 3) investigates the use of sound and especially the musical aspects of sound in the film context. Film sound being almost 50 years older than sound in computer games has to show a series of achievements. Despite the fact that linearity in films is the rule whereas in computer games non-linearity is dominant, these two environments have many similarities. Many films have inspired game developers (Star Wars, Die Hard, Alien, Indiana Jones). Lately the commercial success of some computer games has forced the film industry to take advantage of the popularity of their characters and stories and use them in films (Super Mario Bros, Streetfighter, Mortal Kombat, Lara Croft Tomb Rider, Wing Commander). It is very useful for the researcher to have a clear idea of how a mature competitor, in terms of popularity and context, of the computer games has used the sound. The drawn conclusions from this literature survey can be used directly or with necessary modifications in computer games.

A literature review and a critical analysis of the use of sound in computer games follows (Chapter 4). The purpose of this review is to identify the ways that sound has been used so far and more specifically when and how the musical aspects of sound have been used in computer games. This will provide a background theory for exploring ways of enhancing the use of these aspects. It is also important to investigate if the use of these aspects has already made conventions known by the
game developers and gamers alike so that any experiment can take advantage of these conventions.

Generally speaking, the knowledge of a technique and its manner of application and the experience gained from its use, assists the researcher to by-pass the existing disadvantages and to avoid mistaken actions in his effort to create a faultless object. Moreover this knowledge inspires the researcher / innovator to apply and at the same time to justify the originality of her/his new ideas.

In chapter 5, a user testing of a Prototype is presented. The user testing was conducted in order to form the primary data of this research. The aim of the user testing was to explore how the musical characteristics of sound can be incorporated in a computer game context and how the users interact with them.

In order to achieve this goal, three different Prototypes were tested for each of the musical aspects of sound. Each Prototype was in the form of a computer game. The user had to adjust the musical aspects of the sound (pitch, loudness and timbre respectively) that s/he was listening from the left channel of a headphones set ("user's sound") to the musical aspects of the sound in the right channel ("system's sound"). Pressing certain keys from the keyboard could do this, e.g. by pressing the arrow up key the user was making the pitch of "user's sound" a semitone higher.

The scope of the test was to investigate if the users could understand the difference between the two sounds and how easy it was for them to adjust the "user's sound". Moreover, the engagement of the users and the degree of their excitement about the prototype of the game were also examined.

In the last chapter (Chapter 6) the conclusions of this work are presented and possible future work is discussed. Through this procedure is supported that no matter the music background a person has, the musical aspects of sound, under certain conditions, can structure and communicate a game that could be competitive, engaging and fun to play with.
Chapter 2. Theory of musical aspects of sound

In this chapter, the musical aspects of sound, pitch, loudness and timbre are investigated from a theoretical and a psychoacoustic point of view. Issues of hearing perception are considered in an effort to explore the possibilities and limitations of using the aforementioned characteristics as the main stimuli in computer games.

2.1 Pitch

"Pitch is defined as that subjective quality of a note which enables one to place it on the musical scale" (Mackenzie 1964). The formal definition by the American National Standards Institute reads: "pitch is that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high" (Howard and Angus 2001).

The concept of the pitch is the first to be introduced to music students (Danes 1996). The ability of the human ear to distinguish different pitches is relatively high: about 1500 separate pitches can be identified. "The normal human ear can detect the difference between 440 Hz and 441 Hz" (Nave 1997). It is internationally stated that 440 Hz is how an A4 (A or La above the middle C note) sounds. The next note on the piano (A#4) has a frequency of (466.2 Hz). It can be concluded that roughly, the human ear can detect twenty five (25) different pitches between two semitones.

Moreover most of the people do have this ability. «It is more likely for a person to be colour blind than to be tone deaf» Manoras (2003) stated. At the very first year of an ear training class the students are taught to distinguish at least seven (7) pitches in an octave.

In terms of physics, the concept of pitch is related to the physical characteristic of sound called frequency. Theoretically, the human ear can hear sounds with frequency ranging from 20 Hz to 20,000 Hz (Truax 1984). Actually this is valid for a young and healthy child. As a person gets older, this ability is reduced specially for the higher tones. Thus at the age of twenty years the upper limit goes down to 16,000 Hz. At the retirement age a person can listen sounds in a frequency range between 20 Hz to 8,000 Hz (Howard and Angus 2001).
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**Subsonic Sound**

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**Stevens's Rule**

- From this note and upwards the pitch will be perceived to be getting higher if its loudness is increased.
- From this note and downwards the pitch will be perceived to be getting lower with increased loudness.

**Graph showing the analogy between Frequency and Pitch and the range of sounds:**

- A. that are heardable and unheardable (ultrasonic, subsonic)
- B. accessible by a piano instrument
- C. accessible by human voice
- D. that Stevens's Rule has and has not an effect
- E. the human ear is highly sensitive in terms of loudness
It is mentioned in various sources that the pitch perception of a sound is also related to its volume. Thus, «a high pitch (> 2,000 Hz) will be perceived to be getting higher if its loudness is increased, whereas a low pitch (< 2,000 Hz) will be perceived to be going lower with increased loudness» (Nave 1997). This effect is known as "the Stevens’s rule". If a sound has a frequency less than 1000 Hz or higher than 2,000 Hz this effect is more obvious. Between 1000 Hz and 2000 Hz the effect is hardly ever noticed. Practically for volumes less than 40 dB the pitch perception is not affected and generally speaking this effect is rarely encountered in music (Howard and Angus 2001).

Another interesting phenomenon with pitch is the Doppler effect. If the distance between the source of the sound and the subject (the listener) changes so does her/his perception of the pitch of this sound e.g. a listener has the impression that the pitch of a sound of a train that goes away becomes lower. The Doppler effect states that if the distance between the source and the listener increases, the pitch becomes lower in the ear of the subject (Mackenzie 1964), (Holman 2002).

2.2 Dynamics (Loudness)

"Loudness is defined as the magnitude of the auditory sensation which a sound produces" (Mackenzie 1964). In a more musical context, every kind of instructions that convey information on the degree of loudness and softness of sounds are called dynamics (Palmer 1992).

The concept of dynamics is taught to music schools at a higher level. When a student practises a musical piece, firstly s/he will study the notes and her/his purpose will be to play or sing in tone. This concept is related to the pitch of the sound. At the same time s/he will try to play in rhythm and play each note for the right duration (rhythm and duration). At the stage where s/he refines her/his performance s/he will take into account the dynamics: how loud or how softly each note of the piece should be played.

In comparison with pitch, dynamics have a much less detailed range. An average singer can sing a range of more than two (2) octaves. In other words the singer can produce more than 24 different pitches. There are only eight (8) grades of loudness (pppp - pp - p - mp - mf - f - ff - fff) in Western music and regularly two or three are used in a musical piece. Thus singers or players are required to produce three levels
of loudness when at the same time they are required to produce twelve or even more different pitches in a single piece.

From an acoustics point of view loudness is related primarily to intensity (volume). Moreover loudness depends on frequency as well as the threshold-of-hearing intensity varies over the frequency range eg. the most sensitive range is between 2 - 4 KHz. As a rule of thumb an average person can understand the difference in volume between one (1) dB. Regarding the fact that no (0) dB stands for an absolutely non audible soundscape and 130 dB is the threshold of pain it can be concluded that the average human ear can recognise about 130 different levels of loudness. Trained sound mixers though can recognise almost the double number of levels (Holman 2002, Howard and Angus 2001).

Even in the latter case it is obvious that loudness is significantly more limited in comparison with pitches as the average human ear can recognise about 1500 different pitches in total.

2.3 Timbre

While pitch and loudness are quantitative characteristics, timbre is a qualitative musical aspect. Timbre or tone quality is the "tone colour which enables a listener to recognise the difference between two sounds having the same loudness and pitch" (Mackenzie 1964).

Lessons of timbre recognition are occurred in a quite advanced level for music students. Good knowledge of the musical instruments used by the western symphonic orchestras is a requirement for these lessons and generally speaking familiarity with sounds and their source is an advantage for someone who wants to develop her/his timbre recognition skill.

Thus from the three musical aspects examined in this dissertation timbre is the one that not only is enhanced by a natural charisma but it is evolved in a constant learning process.

Many studies and research have been done on timbre recognition. Results from the research show that in most cases the subjects who were musicians scored better results than non musicians. Also research showed that there is usually a problem in recognising two different instruments from the same family (Martin 1999).
The most important families in the western musical instruments are three (3). Strings (violin, viola, cello and double bass) are the most difficult to identify between each other considering that a subject compares single tones that have the same pitch and loudness. Otherwise it is much more easier to recognise if a certain part of a piece is played by a specific instrument according to the range of pitches it uses: violin plays the higher pitches, viola and cello the middle ones and double bass plays the lower pitches. The same concept applies to the brass family that includes the cornet, trumpet, fluegel horn, trombone, French horn, baritone, euphonium, and tuba.

The third family of the western orchestra, the woodwind instruments, includes three subcategories: the double reeds (oboe, English horn, bassoon, and contrabassoon), the single-reed clarinets (tenor and bass clarinets), the flutes (piccolo, flute, alto flute, and bass flute) and the saxophones (soprano, alto, tenor, and baritone). It is very difficult to distinguish the musical instruments of the same subcategory.

2.4 Summary

Pitch and loudness are quantitative musical aspects of sound while timbre is a qualitative one. In the process of designing a game based on these characteristics the researcher has to comply with the following:

• Regarding the fact that the average age of a gamer is 28 years (Collins 2003) use pitches that have a frequency between 20 Hz and 8,000 Hz.
• A difference of a quarter of a semitone in pitch is safe enough in order to be understood by the average human ear.
• The use of Doppler effect can add realism to a computer based sound environment.
• Use of different levels of loudness as the core element of interaction in a computer game could confuse the gamer and it should be avoided.
• If the purpose of the gamer will be to distinguish various timbres, using timbres of musical instruments of the same family could make this purpose extremely difficult.
Chapter 3. The use of musical aspects of sound in films

Computer games and films were launched in our lives soundless and monochromatic. Both of them have a scenario, a story, heroes and villains. They use images, animation and sound in order to create emotions. Apart from this, nowadays they are fierce competitors in the show business and entertainment arena.

Sound in films is almost 50 years older than sound in computer games. Regarding all the aforementioned similarities this work examines the use of the musical aspects of sound in films in order to take advantage of the theory and the practises used in a much more mature industry than computer games.

In the process of film production the sound track is created separately from the images and can be manipulated independently and flexibly. Basically sound in films takes three forms: speech, music and sound effects. Sound can dictate how people understand the images and where people focus within an image (Bordwell and Thompson 1985). This chapter examines how sound designers have used pitch, loudness and timbre in order to contribute to a more enhancing experience of the film for the audiospectators.

3.1 Pitch in films

Although the idea of pitch is related to music and musical notes it can be applied in voices and other sounds as well. By raising his pitch someone can attempt to talk like a woman (Holman 2002). Another example in films is a young boy who tries to deepen his voice so that he could sound like a man. The joke that comes as he fails is based primarily on pitch (Bordwell and Thompson 1985).

A very rare example of using pitch in a very musical context in a film is the song “Do-Re-Mi” that Julie Andrews sings in The Sound of Music. Not only as a way to amuse the children in the story of the film but also as a learning experience this song develops, perhaps unconsciously, the musical skills of the audience in a very relaxed way.

The Doppler effect is also frequently used in movies and sometimes it is

* Listen to the DoReMi.mp3 audio file of the accompanying CD
overemphasised. "In the Philip Kaufman version of Invasion of the Body Snatchers (1978), when two characters are riding in a car" ... "we hear cars pass us on a busy San Francisco street. The exaggeration is in the amount of pitch shift used: those cars would have to be travelling in excess of 90 m.p.h. to produce that effect!" (Holman 2002).

3.2 Loudness in films

Film sound constantly manipulates volume. Radical changes in volume can convey very intensive moments. After a fussy and intensive scene that is accompanied by very loud sounds, peace and quite (low volume) follows. The other way round, from peace to extreme loudness, mostly will try to convey a shocking feeling to the audiospectators. Further more, a loud sound or voice conveys strength and power while a quiet one shows weakness and humility.

Except from the emotions that the use of volume can contribute in a movie, spatial characteristics of sound can also be conveyed. Volume can show the distance between the camera (the spectator or the subject of the movie) and the source of the sound. The louder the sound, the closer the image is to its source. This is exactly what happens in real life so it adds to the reality of the film. In the same way, the fussier the sound, the more out of focus the image is or the longer shot we see.

3.3 Timbre

The use of timbre from the film makers has been also widely explored. By mixing Vietnamese musical instruments with conventional Western orchestra, the Danna brothers accomplished to convey the local colour of Vietnam in the movie "Green Dragon".

Moreover, conventions and clichés used by film composers help to build up a vocabulary of timbres. For instance usually behind of scenes of seduction we listen to slick saxophone tones. "More subtly, in the opening sequence of Rouben Mamoulian’s Love Me Tonight people pass a musical rhythm from object to object - a broom, a carpet beater - and the humour of the number springs in part from the very different timbres of the objects" (Bordwell and Thompson 1985).
3.4 Summary

In its 75 years' history sound in films has developed a vocabulary that is built on the musical aspects of sound. Manipulation and creative use of pitch has been applied in films in order to entertain the audience and make them laugh. It has also been used in order to increase realism (Doppler effect).

Loudness control affects more the emotional mood of the audiospectators. Spatial characteristics and the distance from objects and people can be conveyed as well, via dynamics enhancing the realism of a film. Timbre on the other hand has been used informatively to convey local colour. A vocabulary of timbres has been built where timbres of specific and recognisable by the audience musical instruments accomplish to convey a responding feeling or mood to the image they are created on.
Chapter 4. The use of sound in computer games: a brief history

The exploration of the relevant historical context is essential for the development of any kind of research. The use of sound in computer games is examined in order to identify successful practices used in the past, popular conventions and particularly the use of musical aspects of sound in computer games environments. A brief analysis of the technical specifications of the platforms of computer games reassures that at least technically, the industry is ready to accommodate the use of musical aspects of sound in its products.

4.1 Television and Arcade Games: 1972 - 1984

In May 1972, Magnavox, an American television set manufacturing company (Baer 1999), launched the first ever commercially available home video game, called Odyssey. It was accessed via a television set and to cut production costs it was in black and white with no sound at all (Robertson 1979), (Winter 2003).

Unlike the history of cinema where it took 35 years after its birth to introduce sound in film, a few months after Odyssey, the second computer game commercially available came with sound (November 1972). Atari’s Pong was a coin-operated arcade game. Every time a player started a game s/he would listen to a beep. "When her/his paddle made contact with the ball there was a beautifully resonant "pong" sound, and the ball bounced back to the other side of the screen." … "the constant pong noise was attracting the curiosity of others at the bar. Before closing, everybody in the bar had played the game" (Cohen 1987). "The sonar-blip sound that’s generated as a digital ball is batted back and forth proves to be oddly compelling and kind of hypnotic" (McDonald 2001).

As it can be seen three were the aims served by sound in the first ever computer game that used it. The first was functional: by listening to the sound the user was confirmed that s/he had successfully hit the ball. Thus her/his most important sense for the video computer game, vision, could concentrate on other elements of the game like the position of the opponent’s paddle or the direction of the motion of the ball.

The use of two different pitches in the game, one for the left player and another for
The right player was also important. According to the pitch the players, as well as the people who were close to them could identify on which side the ball was.

The second was aesthetical. The "beautifully resonant" "pong" sound was a way to amuse and let the user interact with a more enhanced game environment.

Finally it was a marketing tool. In the pub environment where normally the vision is distance limited by the crowd the distinct "pong" sound proved to be a stimulus for the curiosity of the customers.

These 3 roles of sound, functional, aesthetical and promoting are still what characterise the use of sound in contemporary computer games.

In 1974 "Simon says" was launched. This handheld game was the first to use sound as a game element. The gamer was listening among four (4) different tones in a certain order and s/he could see at the same time, coloured buttons related to the tones, to light. Then s/he had to repeat the sequence by pressing the colour buttons (Robertson 1979).

Four years later, in 1978, there was another milestone game in the history of computer games: Space Invaders. "Even early games like Space Invaders earned much of their addictive appeal by getting into your head with thumping, repetitive sound schemes. As the aliens got faster and closer, the music got faster and louder. Properly designed, sound and visual cues work together to produce an experience greater than the sum of their parts" (McDonald 2001).

The convention already used in films where the closer the subject is to the source of the sound the louder the sound is heard, is used in computer games in this case. As this convention is consistent with real life it enhances the realism of the game.

<table>
<thead>
<tr>
<th>Game</th>
<th>Form of Sound</th>
<th>Use of Musical Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pong (1972)</td>
<td>SFX</td>
<td>Pitch works as a functional element. Two different pitches convey two different positions (on the horizontal axis) of the ball.</td>
</tr>
<tr>
<td>Simon Says (1974)</td>
<td>SFX 4 different tones</td>
<td>Pitch is used as an element the player has to identify.</td>
</tr>
<tr>
<td>Space Invaders (1978)</td>
<td>SFX</td>
<td>Loudness conveys distance between player and opponent.</td>
</tr>
</tbody>
</table>

Table 1: The use of the musical aspects of sound in the early days of computer games

In 1980, Pac-man is released and becomes the most popular computer game ever. The sound the game plays when the user dies in the game became a sound symbol
of defeat universally accepted (McDonald 2001). A year later, the arcade game Tempest is launched by Atari. For the first time in the video game industry a stand-alone sound track was released for the game.

For an objective study of the use of sound in computer games it is essential to be aware of the technical specifications of the platforms used by the games. Thus, as the first video game, Odyssey, was targeting homes and families it was fair enough to omit sound in order to reduce the cost per unit. It is no surprising that the next game that was released, incorporated sound. The manufacturers of Pong which was an arcade game, did not have to consider primarily for the cost of the machine, as the gamer had only to insert a coin to play the game.

This was not the case though with the home computers industry that exploded in the early eighties. The games produced for home computers targeted to an audience that had to own the computer and it was important that its cost should be low. As a result one of the first very popular home computers in the United Kingdom, Sinclair ZX81, did not have sound at all.

Although computers invaded homes as educational tools the truth is that they were used more like game consoles rather than their original purpose. Their spread influenced significantly the games industry. Due to the demand for low cost though they initially did not accommodate innovative game concepts but actually they were following behind the video games designed for arcades and consoles.

In that sense it is important to mention that in 1982, Atari’s 5200 game console came with a sound chip that allowed four music channels to be played. Still the sound was monophonic. A year later, Dragon’s Lair was one of the first arcade games to use stereo sound.

Eventually the evolution of home computers was so radical that made the console game industry to crash in 1984 (Herman et al 2003), (Mazurowski 1996). The previously intense penetration of new comers in the industry who did not care about innovation and quality also proved to be fatal.

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7 "Listen to the pacman_dies.mp3 audio file of the accompanying CD
4.2 Consoles, computers and handhelds: 1985 - 2003

In 1985 there was another milestone for the use of sound in the computer games' industry: the launch of the Nintendo console and the rebirth of computer games'madness with the Super Mario Bros\textsuperscript{8}. The game set new standards for sound design. In the game, the constantly shifting tone accomplishes to match the action on screen. The sound in this game, gave valuable information to the player without which s/he was unlikely to play successfully. "Try playing the game with the sound off, and you'll quickly miss those music and sound cues-for example, the exact timing of your immunity power-up wearing off" McDonald (2001) writes.

For the years to come the most interesting issue for sound in computer games was the technical evolution of the sound hardware used. Sound designers took advantage of the advanced technology creating sophisticated soundtracks for the games. They also designed more impressive sound effects and continuous commentary in sports games was introduced in 1991.

However the intension of the present work is not to make an exhaustive description of the technical specifications of sound in computer game platforms but rather to identify and evaluate the creative use of it in the games' context.

In this sense, it is relevant to say that in 1998 Nintendo launched a computer game called "Legend of Zelda: Ocarina of Time". Ocarina is a flute-like wind musical instrument and one of the most important items the hero of the game uses. During the game, Link, the hero of the game, learns a variety of tunes in ocarina. By playing a specific song, Link accomplishes specific "magic" tasks. It was the first time that a contemporary non-dance title featured music-making as part of its gameplay. "There's also a musical puzzle in which you must follow the bass line of a song to make it through the Lost Woods" (McDonald 2001). Also the location of the player is taken into account: in canyons and dungeons the echo is quite realistic and when Link is underwater the sound effects are very convincing (Gerstmann 1998).

Finally the evolution of the soundtracks made for games was so important that "in 2000, the National Academy of Recording Arts and Sciences (NARAS) decided to let interactive games compete in the annual Grammy awards)" (McDonald 2001).

\textsuperscript{8} Listen to the Super\_Mario\_Original.mp3 audio file of the accompanying CD
<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Platform</th>
<th>Processor for sound</th>
<th>Mono/ Stereo</th>
<th>Channels</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>Odyssey</td>
<td>Console</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No sound</td>
</tr>
<tr>
<td>1972</td>
<td>Pong</td>
<td>Arcade</td>
<td>-</td>
<td>Mono</td>
<td>1</td>
<td>Beeps and &quot;pong&quot;</td>
</tr>
<tr>
<td>1975</td>
<td>Gunfight</td>
<td>Arcade</td>
<td>YES</td>
<td>Mono</td>
<td>1</td>
<td>Pitch, volume, distortion can be controlled individually</td>
</tr>
<tr>
<td>1981</td>
<td>Tempest</td>
<td>Arcade</td>
<td>2 &quot;POKEY&quot; chips</td>
<td>Mono</td>
<td>4 each</td>
<td>Pitch, volume, distortion can be controlled individually</td>
</tr>
<tr>
<td>1981</td>
<td>ZX81</td>
<td>Home computer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No sound</td>
</tr>
<tr>
<td>1982</td>
<td>ZX Spectrum</td>
<td>Home computer</td>
<td>Mono</td>
<td>1</td>
<td>5 octaves</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>Atari 5200</td>
<td>Console</td>
<td>&quot;POKEY&quot; chip</td>
<td>Mono</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>Dragon's Lair</td>
<td>Arcade</td>
<td>Stereo</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>Nintendo Entertainment System (NES)</td>
<td>Console</td>
<td>Mono</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>Sega Master System</td>
<td>Console</td>
<td>Texas Instruments SN-76596 PCM</td>
<td>Mono</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>Nintendo's Game Boy</td>
<td>Handheld</td>
<td>Stereo</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>Sega Genesis</td>
<td>Console</td>
<td>Texas Instruments TI 76489 PSG chip, Yamaha YM 2612 FM chip</td>
<td>Stereo</td>
<td>6</td>
<td>Audio RAM: 8 Kbytes</td>
</tr>
<tr>
<td>1991</td>
<td>Nintendo Super Entertainment System (SNES)</td>
<td>Console</td>
<td>8 bit Sony SPC700</td>
<td>Stereo</td>
<td>8</td>
<td>Audio RAM: 512 Kbit</td>
</tr>
<tr>
<td>1992</td>
<td>Sega (Mega) CD</td>
<td>Console</td>
<td>Stock Genesis audio (16-bit)</td>
<td>Stereo</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>Sega Saturn</td>
<td>Console</td>
<td>32-Channel PCM</td>
<td>Stereo</td>
<td>8-Channel FM Stereo</td>
<td>44.1 kHz sampling rate (CD Quality)</td>
</tr>
<tr>
<td>1995</td>
<td>Sony Playstation</td>
<td>Console</td>
<td>Stereo</td>
<td>24</td>
<td>44.1 kHz sampling rate (CD Quality) 4 Mbit RAM</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Sony Playstation 2</td>
<td>Console</td>
<td>Stereo</td>
<td>48</td>
<td>2MB sound memory 48 KHz sampling rate (DAT Quality)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: The Evolution of the technical specifications of sound in computer games

* Programmable Sound Generator
4.3 Computer games based on sound: two examples

In the following two examples of computer games the use of sound and its importance for the player and for the fulfilment of her/his purpose in the game are examined. Bemani games have been described as music games and currently they are very popular in the UK. “Drive” is a unique example of a sound based computer game designed by MA students.

4.3.1 Bemani games

In 1998, the Japan based Konami company, introduced a new genre of computer games called Bemani. Although these games are called by some writers as "music" games (Gerstmann 2000), (McDonald 2001), it is more sensible to call them "rhythm-action" games (Pratchett 2003). Pratchett supports that Bemani games are "accessible to anyone regardless of age, gender or experience, because they tap into our musicality rather than our actual ability to play the instruments or create unique dances for real".

In "Dance Dance Revolution", probably the most popular of these games, the gamer stands on a metal or plastic platform that has four sensors. Each sensor has the sign of an arrow indicating one of the four directions, i.e., up, down, left and right. At the same time s/he can see at the top of a screen these four arrows. As a song starts playing, the player can see on the bottom of the screen a pattern of arrows that scroll up to the top. At the moment one of these arrows matches the corresponding arrow at the top of the screen, the player has to step on this particular arrow that is on the platform.

Thus, the dominant stimulus for playing this genre of games is related to vision. The gamer has to see on a screen a specific arrow on which s/he has to step on in order to proceed in the game. Familiarity with the song and its rhythm can certainly help the gamer to step on that specific arrow at the right moment.

This kind of music games include other titles like "Guitar Freaks", where the user has to play a guitar according to music and "DrumMania", a drum kit simulation game. As all these games are based on the same concept i.e., the reaction of the user to visual stimuli that convey music, it is inevitable that eye to hand coordination is the
skill that they have as the main purpose. The musical aspects of sound investigated in this dissertation are not explored at all in this genre.

On the other hand, the contribution of these games in assisting the user to develop a sense of rhythm can not be ignored. "Konami’s Bemani games challenge your rhythm, timing, and dexterity", Gerstmann (2000) writes.

4.3.2 Drive

In 2001, three MA students of Music Technology from the Utrecht School of Arts designed and produced a game called "Drive". Their primary target audience were blind children aged between 10 and 14 (Calvert 2002). Rather than translating once more a computer card game or adventure game into a version that would be suitable for blind people they designed from scratch a computer game that would use only sound. The game did not have any visuals at all. In that sense they did not treat blind people as handicaps.

"Drive" is a racing game in which the aim of the player is to test the maximum speed of a racing car. Driving along a fixed track the player will reach a certain top speed. If s/he wants to overpass this limit s/he has to collect some "boosters". Boosters can be identified during the game by a specific sound effect that they produce. The player then has to press as soon as possible a certain key in order to catch the booster. After a successful attempt the player will be confirmed by another special sound effect.

At the same time the player listens to several sounds that build up the soundscape in which the game takes place as well a particular background music. This make her/his mission more difficult. The human hearing system has a property called "the cocktail party effect" with which a person can focus on a certain conversation among several ones (Tol et al 2003). That is exactly the skill the game challenges. By inserting new sounds into the existing sounds in the game the system tries to trick the player. The game's design team also incorporated the Doppler effect in their game in order to achieve a higher level of realism.

"Drive" is a successful example of creating a computer game that conveys all the information to the player using only sound. To achieve this, the game treats sound

[10] The game can be downloaded from <http://drive.soundsupport.net>
mostly as an effect. Additionally, the system adjusts the loudness and the pitch of specific sounds enhancing the realistic feeling of the game. It could be supported that in this case the player unconsciously develops an ear to hand coordination.

However, even in this game the musical aspects of sound are applied at a subdominant level: they add realism to effects produced by the system (Doppler effect). It can not be supported that it is crucial for the player to have an awareness of the pitch or of the loudness of certain sounds in order to proceed on during the game.

4.4 Summary

Thirty years of creative use of sound in computer games has enriched their culture in various ways. Sound in computer games is used in the form of sound effects (SFX), Music, Environmental - Atmospheric sound and Narration.

Its purpose is functional and informative. In the form of SFX mostly sound conveys useful hints to the player about her/his position, opponent’s position, presence and location of useful or harmful items. It also informs the gamer for the type of her/his actions and their outcome successful or not. With atmospheric and environmental sounds the player also gets useful information and is properly introduced in the mood of the game. Games especially designed for blind people use narration to provide the player with most of the aforementioned information and also to give them the instructions of the game.

The purpose of sound in a game can be aesthetical. In the beginning, music for games had very low standards because of poor technical specifications. Today, games' soundtracks are considered as a respective genre of music. Their presence in the computer games enhances the interest and the joy of the gamers. This leads to the promotional and marketing purpose of sound in computer games.

As it was mentioned in the beginning of this literature survey the first arcade game attracted the audience by its "pong" sound. Today in arcades the competition among the games is much harder and a well composed sound track accompanied by a sophisticated SFX design can certainly help the popularity and the sales of the game. The computer industry counts on the soundtracks of the games for another
reason as well: they can be sold separately as audio CDs increasing the return of the investment.

Regarding the musical aspects of sound from the very first game ever that appeared with sound, pitch was used to inform the players of the position of a game’s element. Loudness has also been used to convey the distance between the player (in the game) and her/his opponents or other elements in the game. The synchronised use of pitch and loudness (Doppler effect) is also used in order to enhance the realism of the computer games. Timbre in a broader meaning characterises sound effects that are used in games and sometimes are very important for the actions of the player.

On the other hand in no computer game so far the musical aspects of sound were the dominant elements for the gameplay. The users could achieve the same level of progress by paying attention to the visual elements of the games or to non-musical aspects of some sound effects. In fact if the users were not aware of the visual elements of a game in most of the cases they would easily loose.

Finally in the early days of computer games, the poor technical specifications platforms used for sound would not allow sound designers use fluently all the musical aspects of sound. Pitch could not be adjusted precisely, loudness could not be programmed and the reproduction or imitation of timbre was of a poor fidelity.

The technical characteristics of all the platforms used by computer games reassures that today a sound designer for games has limitless options in using the musical aspects of sound. The Compact Disc (CD) and the Digital Audio Tape (DAT) quality most consoles in use have, offer to sound designers and composers the same environment for creative work that the music industry does. Designers can manipulate the pitch, the loudness and the timbre of sounds in such detail that musicians of the past would not be able to dream of.
Chapter 5. The Prototype User Testing of musical aspects of sound

In this chapter, the musical aspects of sound, pitch, loudness and timbre are investigated from a practical point of view. A series of prototypes were constructed based on the theoretical findings of the previous chapters. User testing of these prototypes was conducted in order to identify the practical implementation of the theoretical findings on computer games.

5.1 The Prototype and the Methodology of the User Testing

A series of prototypes were developed in order to identify in what way the musical elements of sound should be applied in a sound based game in order to make it interesting and engaging.

All the prototypes were made in Macromedia's Director 8.5 and they were simple sound based computer games where the user was listening to two different sounds: one was representing the system ("system's sound") and the other the user ("user's sound"). The aim of the user was to adjust her/his sound ("user's sound"), (that was coming from the left channel of a headphones set) to the "system's sound" (right channel). Each examined musical aspect of the "system's sound" was kept unalterable.

For example, the first prototype was focusing on the pitch. Thus, in every round the system was choosing randomly a pitch among the 12 pitches that one octave has (from G3 (first G below the middle C (C4)) to F#4 (first F above the middle C (C4)) excluding C4 that was the initial pitch of the user's sound.

By pressing the Arrow Up and the Arrow Down keys of the keyboard the user was changing her/his pitch making it a semitone higher or lower respectively. The time the user had was limited so after some seconds the system was detecting if the user had guessed correctly or not, offering him/her the appropriate feedback. The user was the winner by guessing correctly first, the pitch, ten times in a game.

Another prototype was developed to examine loudness (dynamics) of the sound. In this case the pitch was the same for the system and the user. The user had to adjust the volume of her/his sound to the volume of the sound of the system.
A third prototype was developed in order to examine the interaction between the system and the user using primarily the timbre.

By user testing these prototypes to a number of users the writer collected information that formed the primary data of this research.

### 5.2 Pitch

In chapters 3 and 4, it was mentioned that the pitch has been used in computer games as an informative element for the gamer ("Pong" game). Its creative use can also enhance the realism of sound effects conveying spatial characteristics (Doppler effect). By applying the theory in the construction of a prototype of a computer game based on pitch, the researcher investigated the possibilities of using the ability of the gamer to recognise the pitch of a sound fast and accurately as her/his main purpose in a computer game.

The sample for the user testing (7 subjects) and the "Asking user" test (11 subjects) was consisted of eighteen (18) people. Two persons were blind and six persons had a musical background of various levels. The rest ten persons were sighted people without a musical background.

For the most of the users a game based exclusively on sound was an exciting experience. The satisfaction of the users could be measured with their expressed desire to play more than it was scheduled for the structured interview of the prototype user testing (Buaud et al 2003). Thus in many cases although the scheduled time for the test was about 30' minutes it finally lasted for one hour as the subjects (no matter that before playing they mentioned that they were not available for more than 30 minutes).

Another factor that indicated the satisfaction of the user with the pitch version of the prototype is that five out of seven subjects at the interview of the user testing, answered warmly that they were interested in getting a copy of the final artefact.

Considering the adjustment of the pitch of the sound itself there were various reactions depending on:

1) the musical background of the subject and
2) the level of concentration and engagement of the subject.
All the subjects with musical background considered the game easy or too easy to play. Those who answered that the game was too easy to play felt at the same time that the game was rather boring and suggested ways of improvement to make it more challenging.

This was also the case with one of the blind subjects who was actually born blind. This was not very surprising as according to a research (Ockelford 1996) one out of three blind born people have the ability of the perfect pitch, a very rare phenomenon in the rest of the population.

Another interesting point is that there was a significant improvement in the subjects’ performance when they played the game for the second time. This is a fact that shows that simple pitch recognition is a skill that gamers can get in a relatively short time.

### 5.3 Loudness

The purpose of this prototype was to test at what extent the subjects could identify in a computer game’s environment different levels of loudness. The theoretical findings of chapter 2 suggested that the human ear’s loudness resolution is significantly weaker than its pitch resolution and also that the human ear can identify more than 130 different levels of loudness from absolute piece to the threshold of pain.

In the Prototype for the loudness a sound of a percussion musical instrument called "mute cucia" was used. According to the previous prototype for the pitch where there were twelve (12) different pitches, twelve (12) different levels of loudness were applied. The lowest level was equal to absence of sound where the highest was the loudest sound the system could produce. The subjects had to adjust the loudness of their sound ("user’s sound"), (that was coming from the left channel of a headphones set) to the "system's sound" (right channel). The pitch of both sounds was kept unalterable.

By pressing the Arrow Up and the Arrow Down keys of the keyboard the subjects were changing their loudness making it one level higher or lower respectively. The time the players had was limited so after some seconds the system was detecting if they had guessed correctly or not, offering them the appropriate feedback.
players were the winners by guessing correctly first, the loudness ten times in a game.

The results of the user testing showed that the average of subjects was interacting better with loudness than with pitch. However, that was the case in the first game they played, and in most of the rounds it seemed to the researcher that the subjects were not absolutely sure of what they were doing. There was no improvement in the subjects' performance in the second game.

A very interesting point was that in most cases successful rounds in the game were achieved when the randomly selected level of system's sound was low. In other words, it was easier for the subjects to realise the difference between absolute peace and a low level of sound than to distinguish the level of loudness between two strong sounds.

The reason that this issue was raised was a fundamental difference between the "pitch" prototype experiment and the "loudness" prototype experiment. In the first case, the succession of the pitches followed an arithmetic order when the success of the levels of loudness followed a logarithmic one.

Moreover, the hearing conditions of the environment proved to be crucial for the results of the experiment. The first levels of loudness were not heard at all by the subjects in rooms that there was no absolute absence of environmental sounds.

Another issue that should be mentioned is that the maximum sound a regular computer system can produce with a pair of headphones without any additional amplifier can hardly ever reach the threshold of pain. Thus, the experiment used a limited loudness range that made the process of identifying different levels of loudness more difficult for the subjects.

5.4 Timbre

The last prototype that was designed for this work had as its purpose to identify ways that timbre could be incorporated in computer games.

Following the previous prototypes, it was decided to include twelve different timbres following this particular order: Banjo, acoustic nylon guitar, violin, pizzicato
strings, harpsichord, **acoustic grand piano**, church organ, accordion, pun flute, trumpet, muted trumpet and oboe. These sounds were produced from the internal MIDI instruments of a Macintosh system. A key factor for selecting them was their fidelity to the original sounds that they represented.

As it can be seen the list starts with some string instruments: violin, pizzicato strings, acoustic guitar and banjo. No matter that these instruments belong to the same family and this could raise the difficulty level according to the theoretical findings for the timbre (see page 13), they have very distinguishable timbres. The timbre of a violin played with a bow is significantly different from the pizzicato way of playing strings where the performers pluck the chords with their fingers. On the other hand the acoustic guitar is not one of the "official" instruments of the western symphonic orchestra and banjo is an ethnic musical instrument with a very characteristic timbre.

The harpsichord is the next instrument on the list. This musical instrument has a keyboard like a piano. When the performer presses its keys, plectrums are actuated and excite strings (Mackenzie 1964). Most of the people are familiar with the sound of piano which is produced with a similar way to the sound of the harpsichord: instead of plectrums the piano uses wooden hammers.

The rest of the musical instruments belong to the greater wind instruments family (brass and woodwind). The church organ has also a keyboard that interacts with a series of pipes. Accordion, a portable instrument not involved in the symphonic orchestra works with a similar way. Pun flute is an ethnic organ with a unique timbre. Usually in jazz orchestras a trumpet is played with an extra device called a mute (muted trumpet). This produces a very distinguishable sound from the sound of the trumpet which belongs to the brass family. And finally oboe is a woodwind musical instrument with a very characteristic sound.

Similarly to the previous prototypes the users were pressing the Arrow Up and the Arrow Down keys to browse through the musical instruments of their sound. Their aim was to adjust the timbre of their sound to the sound of the system. Loudness and pitch (C4 - middle C) did not change during the prototype.

Users were not informed from the beginning of the test about the order of the instruments. That caused several problems. Some of them were browsing the instruments rather randomly and they were just looking to find a timbre similar to
the one they were listening from the right channel. When the researcher gave them
the hint that they start from piano and by pressing the arrow up key they scan
through "wind" instruments and by pressing the arrow down key they scan through
"strings" instruments their performance improved significantly. Given on paper the
order of the musical instruments their performance was almost perfect.

It is not at all surprising that people with a musical background scored much more
better in this prototype and generally they found this part to be easier than the two
previous prototypes (pitch and loudness).

5.5 Summary

The design, the process and the results of a prototype and its user testing were
presented in this chapter. The prototypes' design and structure was very simple. The
users had to adjust musical aspects of a sound that they were listening from the left
channel of a pair of headphones, to the sound of the right channel. They could
adjust the sound by pressing certain keys on the keyboard.

The subjects with musical background found the Pitch version rather too easy and
boring while those without musical background found it from just right to rather
difficult. Concentration proved to be a very important and positive factor for the
performance of the subjects. In most of the cases the subjects scored better results
when they played the prototype for a second time. That is a proof that the game
introduces a skill that can be improved in a relatively short period of time that is
very important in the games environment.

On the other hand there were severe problems with the Loudness version of the
prototype. Most of the users no matter their music education had problems on
adjusting the two sounds and most of the times they were confused. The
environment requirements for this prototype were more severe. Even a low amount
of environmental noise could make the game impossible to play. There was no
improvement of the subjects' performance during the process and it was proved
that they adjusted the sounds easier when their loudness was low.

The Timbre Prototype version of the game worked quite well with most of the
subjects. As timbre is the only qualitative musical aspect of sound examined in this
work it proved to be the most knowledge demanding. Subjects with a musical background scored higher than the non-music educated. The selection of the musical instruments and the order they were placed seems to be quite successful and easy to understand.

Generally most of the users found the process interesting, engaging and even exciting. This shows that the idea of using the musical aspects of sound and especially pitch and timbre in a proper way as the core elements of a computer game can be quite successful. Tedious analysis of the process of designing a new computer game based on them could even lead to a successful commercial product.
Chapter 6. Conclusions - Further development

This work began with a theoretical study of the musical aspects of sound: pitch, loudness and timbre. Limitations and potentialities of their use in a computer game context were examined for each of them. Pitch was proved to be the most applicable aspect of sound in a computer game and the one that users could interact with to a high level of detail.

After that, a literature survey of the use of musical aspect of sound in films was conducted in order to identify ways of creative treatment of the musical aspects of sound in a quite similar with the computer games environment. A well-established vocabulary was explored that enhances realism, communication of emotions and cultural clues that films convey.

A brief journey in the history of use of sound in computer games showed that its purpose is functional, informative and aesthetical. Pitch, loudness and timbre have been used in various ways but no computer game so far used these aspects as its dominant element for its gameplay.

In chapter five a series of prototypes of a game were described and the results of their user testing were analysed. The analysis showed that the use of pitch and timbre as the core elements could build a game that would be engaging and exciting to play with.

On the other hand the study of the use of loudness as a core element in a computer game did not have positive results. Instability of sound conditions in various environments and the limitations different computer configurations have, make usage of loudness a rather problematic task. Discussions with people at Macromedia about the use of loudness / volume in Director MX and a more thorough study of issues related to loudness should be considered for a further development of this work.

As far as the pitch is concerned the prototype was actually based in minor 2nd intervals (one semitone). Further studies should investigate the reaction of the users in less than one semitone intervals (eg. quartertones and so on). In the pitch prototype the range of the pitches used belong to one octave. The interaction of the users with a range wider than one octave should also be examined.
Moreover in these prototypes the three musical aspects of sound were studied being isolated. When the pitch was changeable, loudness and timbre were stable. It would be very interesting to investigate how gamers can cope in an environment where more than one of the musical aspects change.

Further development of this work should also focus on a thorough justification of a taxonomy of the timbres of musical instruments. This could contribute to a more effective use of timbre in a game where even users without advanced music education could enjoy and learn from.

In the experiments of this work only the keyboard was used as a way of feedback and communication from the user to the system. Further more different ways of interaction between the users and the system could be applied. Alternative ways like joysticks, touch pads, or even singing (pitch recognition) could be tested.

This might bring us in a game and an educational environment where the hardcore gamers will take advantage of the richness in terms of knowledge and sound experience that music students and musicians have access to. On the other hand the same environment could be applied to music students in order to let them approach music via the magical world of computer games and thus making the music teaching a more enjoyable experience. Blind people could also benefit and become more included from a game where visuals are not important for its gameplay.
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