Examining Sound Design’s Effect On A Player’s Wayfinding By Utilizing Musical Intervals.

En studie om ljuddesigns effekt på vägledningen av en spelare genom nyttjandet av musikaliska intervall.

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Abstract

As games get more complex, they can easily become overwhelming and difficult to navigate in. A way to make navigation and wayfinding in games easier is to add visual aids that help the player find the way, to progress to the next objective of the game. However, visual aids, such as arrows, or highlighted objects, can be distracting and break immersion. In this paper, the topic is how sound can be used to aid and guide a player in a game. More specifically, how using certain musically consonant or dissonant intervals can guide the player. A game prototype was created to examine how the use of musical intervals of varying degrees of consonance and dissonance would affect the participant’s choice of path. The results are analysed, and discussions are made on the results, what the conclusions made can be used for, and on future research in the area.

Keywords: Wayfinding, guiding, intervals, consonance, dissonance.
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1 Introduction

Sound design in games has evolved quickly in the past 30 years, from being simple monophonic electronic bleeps and blops to becoming Hollywood movie-like epic interactive soundscapes. The limitations of the (now) old hardware that was used for home computers and gaming consoles back in the days forced sound designers and musicians to adapt their sound design and musical visions, to the tools they had. Utilizing simple synthesizer circuits to produce all sound effects and music, a successful sound design could not be achieved by relying on realism. Sound design today is in many cases based on realism, by making use of recorded sounds of real objects instead of using basic synthesizer chips. Because of these limitations, sound effects in those earlier games had a very specific purpose, to accompany and/or confirm events happening in the game world. Most of the time the sound effects had a direct relationship to graphics and animations happening on the screen. They were, in other words, diegetic sounds, as described by Collins (2008:184). Sound effects needed to convey (or confirm) the right message to the player. Without the alternative to use real recorded sounds, the only way to do so with the basic sound palette available at that time, was by creating distinction between sound effects by being creative.

By analysing sound effects in games of that era, it is clear that there are games making use of “musical” sound effects. That is, sound effects that resemble melodies, chords and arpeggios. Some games use it to a greater extent than others. One example is Jack The Nipper (Gremlin Graphics, 1986) for the Commodore 64 (Commodore International, 1982) in which nearly every sound effect is a sequence of notes creating a melody. Melodies, chords and arpeggios (i.e. harmony) in music are dependent on determined note intervals. Some intervals are considered to be more or less musically consonant or dissonant, which in turn can be perceived as more or less pleasant.
As argued by Rick Molinari (2009), in his paper on guiding players wayfinding in video games with sound:

To this end, game developers have progressed greatly in creating new techniques to guide players through worlds in more engaging ways. Most of these new techniques have been visual in nature, as it is the easiest and most direct approach; utilizing methods such as lighting, color, landmarks, and visual patterns to aid in enhancing wayfinding. One resource that has gone relatively untapped though is sound.

Molinari, 2009, p. 5

In this project, it was examined how sound design based on musical intervals could have an effect on a players choice of path in a game environment; in order to expand on the idea of guiding a player with sound. The most common method to guide players is with the use of visual information. By adding sound, the ways of guiding players can be improved. Improving player wayfinding techniques and leading them through environments in a natural and effective manner helps to maximize player investment and immersion in a game (Molinari, 2009:6)
2 Background

2.1 Musical consonance and dissonance

Musical intervals are the foundation for how different musical notes, or pitches, are put together to create melodies, arpeggios and chords. Different intervals, the combination of two notes, can have varying degrees of consonance and dissonance. How consonance and dissonance is perceived can vary in different cultures. Therefore, this project focused on consonance and dissonance in the western music 12-tone equal temperament scale. It can also vary if examined from a musical or psychoacoustic perspective. As mentioned by Ernst Terhardt (1984), on the one hand, musical consonance somehow represents certain essential features of tonal music; on the other hand, it can be reduced to establish psychoacoustic phenomena such as pitch and roughness (Terhardt, 1984:278). In this project, musical intervals were used as a framework for sound design for computer games. This was done in order to see what effect sound design could have on a player's wayfinding, when using sounds based on musical intervals.

In music, multiple sounds with different pitches are combined to produce harmonies in the form of melodies and chords. At a minimum two pitches are required to be sounded together or within a short period for some degree of dissonance or consonance to be experienced (T.S. Amer, Jo-Mae B. Maris, Greg Neal, 2010:3). Certain combinations of pitches are combined to form harmonies, which have varying degrees of consonance.

“Dissonance (consonance) describes the degree of unpleasantness (pleasantness) or disagreeableness (agreeableness) to the human ear that exists when certain musical pitches are heard together or within a short period of time” (T.S. Amer, et.al., 2010:3).

The 12-tone equal temperament scale, or 12-tet for short, which most western music is based on is what determines the notes/pitches used in this study. Within the 12-tone scale certain intervals form harmonies that are either more or less consonant or dissonant.

“It is well accepted that in the “just intonation” tuning system (a system based on harmonic ratios, which are approximated by the 12-tone equal temperament scale) the following intervals are considered dissonant:

Minor second – one semi-tone apart
Major seventh – eleven semi-tones apart
Augmented fourth (tri-tone) – six semi-tones apart
and the following intervals are considered consonant:

Octave – twelve semi-tones apart
Perfect fifth – seven semi-tones apart
Perfect fourth – five semi-tones apart” (T.S. Amer, et.al., 2010:3)

The intervals mentioned above are so called perfect dissonant or consonant intervals.

Perfect consonances:

- Unisons and octaves
- Perfect fourths and fifths

Imperfect consonances:

- Major thirds and minor sixths
- Minor thirds and major sixths

Dissonances:

- Minor seconds and minor sevenths
- Major seconds and major sevenths
- Augmented fourth/diminished fifth

The remaining intervals in the 12-tet scale are thereby considered to be imperfect consonant intervals.

These intervals are:

- Major thirds and minor sixths
- Minor thirds and major sixths

It is worth noting, that the categorization of consonant and dissonant intervals has changed throughout history. The categorization used in this study is the most recent, and was therefore considered appropriate.

The unison is also a perfect consonance, although it might not be considered as an interval, as it physically is the same one note. In their research on sensory consonance, Daniele Schön, Pascaline Regnault, Sølvi Ystad and Mirielle Besson (2004) ranked the intervals as following: “...intervals were grouped into three categories: Perfect Consonances (PC: 1, 4, 5, 8), Imperfect
Consonances (IP: 3m, 3M, 6m, 6M), and Dissonances (D: 2m, 2M, 7m, 7M)” (D. Schön, P. Regnault, S. Ystad, M. Besson, 2004:107). The numbers and letters used in the citation above represent the different intervals, 3m being a minor third, 3M being a major third, etc.

2.2 Early sound design in games
The makers of arcade machines, consoles, computers and also the creators of games, acknowledged the importance of sound design in computer games early. During the increasing popularity of arcade game machines in the late 1970’s, pinball manufacturers realized that incorporating artificial electronic sounds into pinball machines made them more appealing. Before introducing electronic sounds into pinball games, many of them featured bells that made a sound when the pinball hit a target, as mentioned by Karen Collins (2008) in her book on game audio. One early example of pinball sound was found in the Pacific Amusement Company’s Contact (1934), which had an electric bell (Collins, 2008:7). The bell was a feature indicating that the player had scored points. Another common feature was what is called a ”knocker”. The knocker is a mechanical arm that produces a loud noise by hitting the inside of the wooden pinball cabinet, to indicate that the player has received an extra ball. Both sounds are trying to enhance the feeling of success. Collins (2008) compares this use of bell sounds to gambling machines, which make use of similar sounds. More important is that sound was a key factor in generating the feeling of success, as sound effects were often used for wins or near wins, to create the illusion of winning (Collins, 2008:8). In the mid-late 1970’s, electronically generated sound effects in pinball machines became popular. In 1977, Italian pinball maker Zaccaria introduced their first electronically generated sound effect in a pinball machine, in their game Combat. The sound was called a ”biri biri”, and played when a player had reached a high score. It was a distinct sound, reminiscent of a modern electronic fire alarm. In 1979, Williams Electronics released the first pinball machine featuring recorded speech, in their game called Gorgar. The game also featured an artificial heartbeat sound effect. It was a low frequency beating sound, which would speed up during the length of the game play, to put pressure on the player.

Arcade game makers, home computer- and game console makers, had already established the idea of using electronically generated sounds in games at this time. As described by Collins (2008) “the first mass-produced video arcade game, pinball company Nutting Associates’ Computer Space (1971), included a series of different “space battle” sounds” (Collins, 2008:8). By using the technology that was available and affordable at the time, which by today’s standards is relatively primitive, sound designers and music composers had little to work with,
compared with today. Having only basic synthesizer waveforms at their disposal, limited to a few number of simultaneous sound channels. One example is the Commodore 64 (Commodore International, 1982) also called C64. “The C64 sound chip (called the Sound Interface Device or SID) was a 3+1 chip, created by Robert Yannes in 1981...” (Collins, 2008:30). The SID supported four channels of simultaneous sound. The channels were split into three basic synthesizer waveform channels and one noise channel to create sound effects and music. It also utilized filters and envelopes to further shape sounds. These four sound channels were then shared between music and sound effects in games. A consequence of this is that interruptions can be heard in certain parts of the music sound track, when sound effects are played at the same time. The sound effects "steal" the music instruments sound channel. Using recorded sounds in games for home computers and game consoles was not an alternative at this time, because of hardware limitations. Sound designers had to use their creativity to try to replicate the sounds they needed, by using the basic tools they had to work with.

An example of this kind of early gaming console sound design is the sound that is produced when hitting a block and receiving a coin in Super Mario Bros. (Nintendo, 1985), which will be referred to as SMB from here on. SMB was produced for the Nintendo Entertainment System (Nintendo, 1983), which will be referred to as NES from here on. As Collins (2008:25) mentions, the NES makes use of a five channel sound chip, assigned to specific waveforms. To make the "coin sound" it uses one channel and plays a distinct sequence of two notes creating a major third, which according to western musical theory is an imperfect consonance. When you lose a life in SMB, the same sound channel is used but for this sound effect it plays a trembling, chaotic sound. The sound is both pitchbent a minor second up over the total time of the sound playing, while simultaneously being pitchbent down a minor second repeatedly three times. Both are intervals, which are considered to be dissonant. The game tells the player two different things using two sounds that are completely opposite from a perspective of musical consonance and dissonance. The “coin sound” lets the player know that points have been received, which is considered a successful event in SMB. “A stable tone combination is a consonance; consonances are points of arrival, rest, and resolution” (Roger, Kamien, 2008:41). The “death sound” lets the player know that a life was lost which is considered a negative event, a loss, or defeat. “An unstable tone combination is a dissonance; its tension demands an onward motion to a stable chord. Thus dissonant chords are "active"; traditionally they have been considered harsh and have expressed pain, grief, and conflict” (Kamien, 2008:41).


2.3 Audio Games

Audio games, is a genre of games “that originates from games for players with visual impairments as well as from mainstream music games” (Johnny Friberg, Dan Gärdefors, 2004:148). It is a genre of games that relies solely on audio, and as such, it features no graphics. One example of an audio game is Vanished (2013). In Vanished (2013), the player uses a smartphone together with headphones to play. The game consists of several levels. In each level the objective of the game is to navigate to a location, while avoiding monsters. The location, which the player is to navigate to, is “highlighted” with a looping sound. As the player tries to move towards the sound, monsters appear and try to find, and kill the player. By listening to the monsters sound effects, the player can avoid the monster. When a monster is heard, the player tries to move in another direction, going around the monster. Vanished (2013) uses the directionality of sound to guide the player in the game environment. It uses sounds directionality to lead the player towards the goal of each level, but also to help the player avoid the monsters. Directionality is a feature that is commonly used in audio games, since it is a natural way for people to locate things in the environment by hearing.
3 Problem

Games are constantly increasing in size, featuring vast worlds full of things to explore, with an increasing popularity of going towards non-linear game design (Molinari, 2009:3). This creates a lot of options for the player, which can make a game appealing. But it can also reach a point where it gets confusing and frustrating, when a game gets too complex and the player gets stuck. To aid the player, games incorporate different kinds of indicators to guide the player in the right direction. Such as arrows, pointing the player in the right direction, highlighted areas and hints for example. These are all visual elements, which clutter the screen and can make the game environment less immersive. To make guiding the player more efficient, and without breaking the immersion, games could benefit from adding an element of sound to the visual indicator, or using sound only, as an aid.

An example could be, to add a static repeating sound, located where an objective is in the game world, for example a burning fire. So the player clearly hears what direction to move, in order to reach the objective, instead of being pointed in the right direction by an arrow or other graphical aid.

A more subtle approach could be to highlight a certain part of the game world with audio, by triggering a distinct localized sound when the player gets close. For example, using the sound of a creaking door instead of highlighting the graphics of a door, to indirectly tell the player to move through the door, to progress through the game.

In order to make guiding with sound design effective, and without disrupting the player’s immersion, certain properties of a sound can be of use to get the player’s attention without interfering. What these properties are, and how we can use them, is what drives this project.

**Research question:** How can sound design based on musical intervals from the western music 12-tet scale, from a perspective of consonance and dissonance, affect a player’s wayfinding in a game environment?

3.1 Method

A first person game was created in which the player was put in a room with two doors. The game was made graphically plain and had no specific theme, to keep the player from relating the game to any specific contexts that could affect the experience. The player’s objective was to choose one of the doors and move through a corridor until reaching another room, just like the first one.
The process of choosing between two doors and moving through corridors was repeated through the test. Each room had a base note. The base note was a repeating sound that was constantly playing in the background in each room. When the player moved closer to each of the two doors, another note/sound attached to the door was increased in volume. The sound of each door was based on a musical interval related to the rooms base note. Each door used a different note. The intervals used were chosen with musical consonance, dissonance and imperfect consonance in mind. For example, in one room the person doing the test could be presented with the base note C. When the participant moved closer to one of the doors, a note/sound that was a minor second apart from the base note would play, a C#. The sound coming from the door, combined with the base note, created a perfect dissonance. The other door could then have had another note/sound, which for example used an interval that was an imperfect consonance or a consonance. To put focus on the musical intervals used, and not the character of the sounds, a piano sound was used. A piano sound was used, with the reason being that piano is considered to be a common instrument in many musical styles. It has a familiar sound to most people. There were no other background sounds or effects of any kind that could affect the player. The only sounds in the game environment were the piano sounds, associated with the rooms and doors, and footstep sounds to make navigating the game environment feel realistic. The game was constructed this way in order to see if the different musical intervals used would have an effect on the player’s choice of path (i.e. wayfinding). After the participant had gone through twelve doors and corridors the test would be over. In the end of the test, the game would save a scoreboard as a text file. The scoreboard specified which of the doors the player chose. This was done as a quantitative test, to be able to gather as many responses as possible. The scores from the text files were compiled to see if there are any similarities between the player’s choice of doors, and in turn the intervals associated with the doors. The target group was people above the age of 18, in order to avoid any legal issues. Both people who played and did not play games regularly, and did or did not have experience in sound design and/or music. These aspects were taken into account, by using questions that the person participating in the test would answer before the test was done, by filling out a survey that used a number of predetermined options to choose from. The survey was done in this way, using predetermined options, to make data collection and compilation efficient (Østbye, Knapskog, Helland & Larsen, 2010:158). Age was also recorded in the survey. Gender was not believed to have any significance on the results, and was therefore not taken into consideration in the survey. The game, and all content that was used to do the test, other than sound, was created in Unreal Engine 4 (Epic Games, 2012) since it was free to use for non-commercial purposes. The sounds used were created with the digital
audio workstation *Renoise 3.0.1* (Müller et. al., 2014) and *Kontakt 5* (Native Instruments, 2011). Completing the test and the survey was estimated to take approximately 20-30 minutes. The test and survey was available to download for anyone, to be able to gather as many individual responses as possible. The person doing the test needed to have speakers or headphones. This was made clear at the beginning of the test. Headphones were recommended, as they eliminate the need for properly set up speakers to achieve correct directionality. Both the test results and survey were supposed to be completed, for a response to be counted in the final results of the test. However, after the results from the pilot study were gathered and compiled, the conclusion was made, that age and musical experience made little or no difference in the choices made by participants. Therefore, the survey following the test was not included.

### 3.1.1 Pilot study: The general view on consonance and dissonance

In order to get a clearer perspective on what was generally considered as musical consonance and dissonance, a pilot study was performed. The pilot study consisted of sound samples that were compared. Each sample contained two different notes. The samples compared in the survey were created using the same sound source, with the only difference being the intervals used. Every interval within one octave was included and compared in the survey. The sound source chosen for the pilot study was also a piano. A piano sound was chosen by the same reason as in the main test, since it was considered to be an instrument widely common to people, compared to, for example, a bagpipe. The pilot study was performed as a quantitative survey, using *Google Forms* (2007), and took about 10-15 minutes to complete. Only people above the age of 18 were included in the survey, to avoid any legal issues. In the survey, prior musical knowledge was recorded, to see if musical consonance and dissonance was perceived differently by people with or without prior musical knowledge. No personal data was recorded, so the respondents were completely anonymous. That way there was no way to abuse the information collected, or to compromise the integrity of the persons that participated in the test (Østbye, et.al., 2010:126-127). In the pilot study it was clearly stated what the purpose of the study was. That it was to determine which intervals people generally perceived as being more or less consonant or dissonant. The level of the sounds consonance or dissonance was rated on a scale from 1(dissonant) to 5(consonant). At the end of the survey each person had the option to add a comment on anything related to the test. This way, aspects that were not accounted for in the survey could be corrected, before creating the main test of the study, to “strengthen the validity of the project” (Østbye, et.al., 2010:158)(my translation).
3.1.2 Discussion
The reason for doing both the main test and pilot survey as quantitative tests was to gather large quantities of data, to collect as many individual responses as possible. Quantitative data is easily gathered and compiled (Østbye, et.al., 2010:158), to get reliable results. The same reason was why the questions in the survey were closed-ended questions (Østbye, et.al., 2010:142). That was, to be able to compile large numbers of responses efficiently. Doing interviews with every person doing the test would not have been possible, due to time constraints. It would also have been impractical to gather that much data and try to evaluate and compile it. The reason for not doing the test on people under the age of 18 was to avoid legal issues. Neither the test nor surveys recorded any personal data. That way, any ethical issues that could otherwise have been relevant, were excluded (Østbye, et.al., 2010:153-154).

Because the tests were not done in a controlled environment, there was little control over how participants carried out the tests. This was especially of significance during the part of the test that took place in a game environment, the main part of the test. The conditions in which the participant performed the test were of importance. A participant might have had the volume turned down, speakers positioned wrong, surroundings that could disturb, for example. It was therefore advised to use headphones in a quiet room when doing the test, which was stated in the test itself. That way it was ensured that aspects such as volume and directionality were not compromised; neither would background noise disturb the participant. The advantage of letting anyone participate on their own was that more responses could be gathered. Doing the tests in a controlled environment would have taken longer time, to get the same amount of responses. It would however have ensured that every participant performed the test under the same conditions.
4 Implementation

4.1 Artefact
The artefact/product used to perform the test consisted of a small 3d game, which was played from a first person perspective. The game was created in *Unreal Engine 4* (Epic Games, 2012). This particular engine was chosen since it contained templates, which feature the basic game mechanics that can be found in most popular game genres, such as FPS (first person shooters). By using a first person shooter template together with the “blueprint” system in *Unreal Engine 4* (Epic Games, 2012), prototypes can be created quickly. It therefore suited the needs for creating the artefact for this test. The “blueprint” system is a type of visual scripting, which makes scripting possible without writing any code.

![Figure 1](image.png)

**Figure 1** The picture above is a sketch of the level created for the test. The red circle represents the point where the player character starts. The red rectangles represent the collider/trigger that teleports the player back to the starting point. The large blue oval represents the space in which the base note is heard. The brown and green circles represent the space in which the two separate intervals are heard, associated to each door on the left and right.
Figure 2  The picture above shows the script, or blueprint, which makes the player teleport upon entering a trigger, or collider in the game level. Screenshot from Unreal Engine 4.

4.2 Work process

4.2.1 Overview
The process of making the artefact was based on working in iterations. A basic room was created first, then a couple of placeholder sounds were created. The sounds were then placed within the room. By doing this, the size of the sound sources could be adapted to the room. This was to make sure that the sounds were separated, so that the player could hear a difference going from one side/door to the other. It was to make the directionality clearly distinguishable, like in Vanished (2013). The sounds also needed to be separated so that only two of the notes could be heard simultaneously. At a minimum two pitches are required to be sounded together or within a short period for some degree of dissonance or consonance to be experienced (T.S. Amer, Jo-Mae B. Maris, Greg Neal, 2010:3). Those sounds would be the base note and either one of the intervals, and never both intervals at the same time, which would otherwise produce a chord. During this phase of producing the artefact, modifications could also be made the other way
around, by changing the size of the room and moving the sound sources, had the room felt too small or big. After a level was completely built, going back and changing the size of one room could lead to problems that would have been time consuming to fix. In this project, three identical rooms were to be created. Because of that, finishing one room that could then be duplicated was considered to be the most convenient option. The goal was to have the room big enough, and the sound sources separated, so that the player could move to the middle of the room and only hear the base note. However, as the player would move towards either of the doors an interval would increase in volume. By working in iterations, these aspects were fine tuned and tested. The sounds initially placed in the room were basically static sounds, with attenuation, so that they faded in and out as the player moved closer to the sound sources. Static sounds could be placed throughout the level without any use of scripting. This made it possible to set up a prototype room first, to test how the sounds interacted with the player, before building the rest of the level. After finishing the first room and a corridor, the scripts needed for the project were created. Finally, the final sounds that were needed for the test were created.

4.2.2 Scripting with blueprints

The FPS template used for the project contained all functions for basic movement such as walking, turning and jumping, to begin with. So, there were a couple of functions that needed to be added. First of all, a main menu with instructions, a pause menu, and a menu that was revealed once the test was completed, were made. The main menu was supposed to make sure that headphones or speakers were used, and were set up properly. The participant also had to have the choice to end the test at any time, by clicking the quit button in either of the menus. During the test, pressing the escape button on the keyboard brought up the pause menu, as this is a common feature in games. Pressing escape would pause the entire game and muted sound.

After the menus were done, a script for the teleport was created. The script executed when the player entered a certain area of the level (i.e. upon entering another room), and sent the player back to the start of the level.
Figure 3  The picture above (left) shows the starting point in the artefact. The picture above (right) shows the trigger, or collider, that executes the teleport script upon entering a new room. Screenshot from Unreal Engine 4.

Last, a script was created, which took parameters that were saved throughout the test, and stored them as results in a text file. The text file specified which door was chosen in which of the rooms. A variable represented each room, and each time going into a new room this variable would be increased. This room variable, together with the door chosen (left/right) was then stored in its own slot, in an array. When all of the rooms were cleared, another script took all the room numbers and associated choice of door, which were stored in the array, and saved them to the text file. The text file was saved in the root folder of the game. The person participating in the test would then email the text file, to be compiled with the rest of the test results. By doing the test this way, many results could be easily gathered and compiled (Østbye, et.al., 2010:158).
Figure 4  The picture above shows the script/blueprint that saves all stored parameters into a text file. Screenshot from *Unreal Engine 4*.

4.2.3 Level design

The level used in the game was created entirely in the game engines editor. The level was built by using basic shapes, mainly cubes that were put together in various sizes, to form the level geometry. Stairs were made with a brush that lets the level designer specify certain parameters, such as steps and step size, and then generates the staircase automatically. The level was designed to be completely symmetrical and plain, to make sure that the level design would not affect the player's choice of path. As Christopher W. Totten mentions in his book on level design, “Visual communication can aid level design in other ways. The most important is guiding the players through environments” (Totten, 2014).
By using a basic environment, lacking detailed 3D objects and textures; more attention was put on the sounds and how player interaction affected the sound. After some iteration, the first room was finished. Second, the doors and corridors were built. The corridors were built the same way as the room, using cubes in different sizes for floors, ceilings and walls. Halfway through the corridor, an upward staircase was placed with the stair brush, mentioned above. When reaching the end of each of the corridors, the player would enter another room, which basically was a copy of the first room. Upon entering this room, the player was teleported to the start of the first room again. This was intended to make it look like the player seamlessly progressed to a new room each time going through a corridor, without having to actually copy and paste the same rooms and corridors over and over again.

Figure 5 The picture above shows the level viewed from the top. The first room is in the center. The left and right rooms can be seen on each side. Screenshot from Unreal Engine 4.
The staircase was intended to enhance the feeling of making progress. Without the staircase the player would have been walking in circles, while the goal was to give the player a sense of progression throughout the test. By using a teleporter this way, it was also easy to modify the number of rooms included in the test afterwards, by simply changing a parameter.

4.2.4 Sound
All sounds created for the artefact were produced in *Renoise 3.0.1* (Müller et. al., 2014), using a piano library for *Kontakt 5* (Native Instruments, 2011). The initial idea was to have piano notes playing repeatedly. However, to try to minimize any effect that tempo and rhythm might have
had on participants, a seamlessly looping piano sound was created. Each individual piano note was recorded through a reverb, using a long reverberation time, and a granular timestretcher. The result was a long, sustained piano note. The recorded samples were then edited. To make seamless looping tones, the initial transients (attack) of the piano sound was cut/removed, and the samples decay was also cut to loop smoothly. The finished sound still sounded like a piano, without the initial attack and decay in volume. It was still possible to hear the sound looping if listening closely, although it was not as obvious as playing repeating regular piano notes.

Within *Unreal Engine 4* (Epic Games, 2012), the sounds for each door are contained in two separate “sound cues”. Sound cues are objects inside *Unreal Engine* that contain sounds, and parameters to control the sounds. A parameter could then be set to choose which of these sounds were to be played, when the player had progressed to the next room.
5 Evaluation

Both the pilot study and artefact were shared on music and games forums, these forums were www.99musik.se and the group “Indie Game Developers” on www.facebook.com. The same instructions were given to every participant in order to ensure the test’s validity. The fact that the tests were taken in the participant’s own time, pace and place, ensured that stress and other factors that could have disturbed were reduced, and would not affect the outcome of the test. The interviews, following the main test, were held over Skype (2003) or in person. These interviews did not add data to the actual test results, but were only added as an extra source of information, in order to bring up any ideas that might have been overlooked when creating the test.

5.1 Results

5.1.1 Pilot study
The pilot study indicated, that the difference between responses from participants with or without a musical education was too small to have any significance. Participants with a musical education include those who have attended musical university, or a similar formal musical education. Self-taught musicians include those who have not received a formal musical education, and thus might not have learned proper musical theory and eartraining. The outcome was that participants who had a musical education had slightly more similar responses to the pilot study, than those without any musical background. The responses varied as much between participants with a musical education, and participants who were self taught musicians or music producers. The same was noted about responses from participants of different age, and musical taste. Because of this, these aspects were not accounted for in the main test of this project.

The numbers on the horizontal axis in the diagrams below represent the samples that were used in the survey. PC is short for perfect consonance, IP is short for imperfect consonance and D is short for dissonance. 1: octave (PC), 2: major seventh (D), 3: minor seventh (D), 4: major sixth (IP), 5: minor sixth (IP), 6: fifth (PC) 7: augmented fourth (D), 8: fourth (PC), 9: major third (IP), 10: minor third (IP), 11: major second (D), 12: minor second (D). The vertical axis represents the level of dissonance perceived, 1 being consonant and 5 being dissonant.
Figure 1  The figure above represents the consonance or dissonance perceived by participants who had a background in musical education.

Figure 2  The figure above represents the consonance or dissonance perceived by participants who had no musical education but were self-taught musicians and/or producers.
The figure above represents the consonance or dissonance perceived by participants who had no musical education or background as musicians/producers, labeled as “listeners”.

It is worth taking notice to the fact, that the participants without a musical background, the “listeners”, were a lot fewer than those who had a musical background. Out of 47 participants there were nine participants who had no musical background, 14 with a musical education and 24 who were self-taught.

5.1.2 Main test
Eight people participated in the main part of the test, which consisted of playing a game, and returned their results. The results gathered from the game, contained in text files, show which door the participant has chosen in each room. By looking at which intervals were used in the rooms, it is possible to see if there is a correlation between the intervals the participants have chosen. The text file created after taking the test contains a list. In this list, each row represents a room, and tells if the player went left or right in that specific room. These lists were then compiled using Excel (Microsoft, 2013) and examined. The figure below shows a compilation of the test results gathered from the artefact.
Figure 4  The figure above represents a compilation of the test results gathered from the artefact produced in this project. It shows a percentage of the doors chosen by the participants. Each of the numbers (1-12) on the vertical axis represent the rooms in the artefact, followed by the interval used for the left and right door in each room. For example, 1(5/2m) is room one, and uses a perfect fifth for the left door and a minor second for the right door.

When comparing the intervals used that were either consonant or dissonant (room 1, 2, 6 and 11), in a majority of the cases, except in room 2, the consonant interval was chosen over the dissonant interval. The difference was considerably smaller when comparing intervals used that were imperfect consonances and consonances, and also when comparing the choice between imperfect consonant and dissonant intervals (room 5 and 12). When combining the results from all rooms using imperfect and perfect consonances (room 3, 8 and 10), both intervals were chosen equally many times. The remaining rooms (4, 7 and 9) in the test used intervals that were equally consonant or dissonant, and thus were hypothesized to have an equal outcome of left and right choices. However, in room 9, a significant amount of participants chose the right door.
The distribution between imperfect consonant and dissonant intervals was relatively even, compared to the perfect consonant intervals, which were preferred by the majority of the participants.

**Figure 6**  The figure above shows a percentage of the individual intervals chosen by the test participants.
The figure above indicates that fourths (4P), octaves (8P), fifths (5P), and minor seconds (2m) were the most preferred intervals in this test. The least preferred intervals were the major seventh and major second, followed by the minor third, major third, minor seventh, minor sixth and major sixth.

5.1.3 Interviews
The unstructured interviews were added to gather additional information, which could help explain the choices made by the participants. The interviews were done verbally, to gain some insight into the participant’s thoughts about the test, and not to gather any additional data to add to the results.

Of the three participants that were interviewed, all three participants mentioned that they had felt confused as to how many rooms they had to go through, before the test was finished. When posting the test online, it was mentioned that the test would prompt the player when it was finished, although a visual counter could have been added to tell the participant how many rooms remained.

All three participants mentioned that, in some of the rooms they didn’t prefer any of the intervals, but rather just chose a door. When viewing the results, it appears the rooms using the same intervals, apart from room 9, had the most evenly distributed choices of left and right. The same could be found about the rooms using imperfect and perfect consonances. Had the counter been implemented, the participants would have been able to specify in which of the rooms they had not preferred one door over the other.

One of the participants stated, that since the lighting in the game is low, resulting in the game environment looking dark, he automatically compared it to horror games he had played. Because of that, he felt that he was drawn to the dissonant intervals, as they added a feeling of suspense to the game.
6 Concluding Remarks

6.1 Summary
The results from the test have shown that, when given the choice between consonant and dissonant intervals, a majority of the participants chose to move towards the consonant interval, with one room being an exception. The difference in the choice of doors when using imperfect consonant and perfect consonant intervals, and dissonant and imperfect consonant intervals was too small to show a preference for any of the intervals. When using the same interval for both doors there was also, with one exception, no difference in which door the participants chose.

The individual intervals which indicated to be the most effective in guiding players were the fourth, fifth, octave, and minor second. Apart from the minor second, which is dissonant, the effective intervals were consonant. Overall, consonant intervals were preferred.

Other than the fact that only eight responses were gathered from the main test, the project was successful. The participants took part of the test without any reported issues.

The conclusion was that, to only use musical intervals could be partially effective in guiding a player. However, since so few participated in the test, it’s not possible to make any real conclusions without further research.

6.2 Discussion
A greater number of participants would have given more reliable results. When submitting the test to the public, it should have been posted to more online forums and communities to reach more participants. An interesting result from the test was that, in two of the rooms, a majority of the participants chose intervals that contradicted their other choices. If the intervals used in the test had been randomized, the results might have looked different.

Although the goal was to make the test graphically plain, to ensure that the game would not be associated with any specific theme, at least one participant percieved the graphics as part of a horror themed game. The reason being that the lighting in the game environment was low.

Musical tonality can be of use when designing sound for user interfaces; an example is the sounds (earcons) that accompany the “exception messages” used within operating systems, such as Windows 7 (Microsoft, 2009). Using intervals of varying degrees of dissonance can help
signal the severity of the “exception message” that is present. “Using the concept of musical dissonance it is hypothesized that earcons comprised of musical intervals with high levels of dissonance will be perceived to communicate higher levels of severity of a computer problem associated with an exception message” (T.S. Amer, et.al., 2010:7). In a similar way, consonant and dissonant intervals could be used to a greater extent when designing sound for games. Using consonant or dissonant intervals in, for example, ambient/background sounds could enhance positive or negative events by using only the sounds by themselves, or by combining them with visual elements.

When using sound as an aid to guide players in a game, if using musical intervals as an aspect in the sound design, it could be useful to utilize intervals that correspond with the theme of the game. For example, a colorful and cartoony game might use consonant intervals as a part of the sound design, to draw a player’s attention. While a dark, horror themed game might use dissonant intervals to have a similar effect. It could also be of use to utilize both consonant and dissonant intervals in contrast to each other to achieve various responses, like in the test from this project, were the player is faced with the choice between a consonant and a dissonant sound. The fact that it is already common to use sound effects and, especially, music using certain musical intervals in conjunction with specific events in games and movies, would certainly have an effect on the outcome of the test too. For example, a violin playing a dissonant interval, such as a minor second, to create tension in a horror movie is common. This was the reason why one of the participants perceived the game prototype as a horror game, when hearing dissonant intervals in conjunction with seeing the low lighting visuals in the game.

Why the participants made these contradictory choices in two of the rooms could perhaps be due to curiosity, since the prototype is rather repetitive, further studies would be needed to properly answer that question. Having the rooms appear in a randomized order might have given different results.

The intervals that seemed to be effective in guiding players, in other words, fourths, fifths, octaves and minor seconds, could be used to draw a player’s attention to an area in a game. The least effective intervals could be used in contrast, to perhaps make another part of the game less interesting to the player. That way, it would be possible to lead, or guide the player using musical intervals.

Since the number of participants was so small, it’s difficult to draw a conclusion as to why these intervals were preferred. Perhaps it is because these intervals are commonly used in user
interfaces, movies, games and so forth. It could also be that the consonant intervals and dissonant interval stood out, and therefore got the attention of the participants. For example, the minor second sounds rough and unstable, while the consonant intervals, in comparison, sound stable and pure. These intervals could have been perceived to be in clear contrast to each other while the remaining intervals weren’t as easy to discern from each other.

All participants were made aware of what data was recorded in both the pilot study and main test. They were also told how the gathered data would be used. In combination with the anonymous nature of the tests, in that no personal information other than age was recorded in the pilot study, and the main test not recording any personal information at all, ethical issues were avoided that might have emerged if the test had been carried out in another way.

6.2.1 Social benefits
To guide/aid players with sound is an interesting topic when working with sound design for games. To be able to convey information, without the player having to direct attention to distracting visual parts of the game, could give opportunity to keep the player more immersed in the game. There are however more uses of conveying information through sound. Visually impaired could benefit from having more information conveyed through sound in busy/dangerous environments, like how some pedestrian crossings in urban environments feature sound. Sound based games could be of use in education, where consonance and dissonance are aspects that could be utilized within the games. It could be used in many situations where the eyes are already busy, whether in multimedia, IT, manufacturing, for example.

6.3 Future work
Utilizing musical consonance and dissonance in sound design is just a small part of the many aspects that could potentially be of use when trying to guide a player with sound. Aspects of sound such as, for example, volume intensity, frequency range, directionality and spatialization could also be of use when designing sound for aiding the player in a game environment. To follow up on this project, it would also be interesting to see how using consonance and dissonance would work in a fully developed game, featuring detailed graphics and sound design.

The idea for the artefact produced in this project could be further developed to create a game for learning musical theory, which could be an alternative to the ways we teach musical theory today.
References


Musical consonance and dissonance

An interval is the spacing between two musical notes. For instance, if you play two or more keys on a piano simultaneously, the notes come together to create a harmony, or chord. How the chord sounds depends on the interval between the notes, in other words, the space between the piano keys that are played.

Different intervals can sound more or less consonant (pleasant) or dissonant (unpleasant). Consonant intervals are usually described as pleasant and agreeable. Dissonant intervals are those that cause tension and desire to be resolved to consonant intervals.

This survey seeks to examine what the general view on consonance and dissonance is, by listening to and comparing a number of sound samples. It is recommended to listen to all sound samples first to hear the difference, then answer each question in the survey while listening to the related sample one at a time.

All sound samples can be found here (each individual sample is also linked in the survey itself):
https://soundcloud.com/tretiotre/sets/consonancedissonance-survey/s-njluC
1. Age
What is your age?
Mark only one oval.

- [ ] 18-20
- [ ] 20-25
- [ ] 25-30
- [ ] 30-35
- [ ] 35-40
- [ ] 40-45
- [ ] 45-50
- [ ] 50-55
- [ ] 55-60
- [ ] 60-65
- [ ] 65-70
- [ ] 70-75
- [ ] 75-80
- [ ] 80+

2. Musical background
What is your musical background?
Mark only one oval.

- [ ] Self taught musician/producer
- [ ] Educated musician/producer
- [ ] Neither

3. Musical preferences
What is/are your preferred genre/genres of music for listening and/or playing (rock/pop/electronic/orchestral/hiphop/etc for example)?

4. Sample 1: https://soundcloud.com/tretiotre/sound-example-01/s-KYpA
Would you rate the sound as being either consonant (pleasurable), dissonant (less pleasurable/unpleasurable) or somewhere in between?
Mark only one oval.

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5. **Sample 2:** [https://soundcloud.com/tretiotre/sound-example-02/s-OlvLb](https://soundcloud.com/tretiotre/sound-example-02/s-OlvLb)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?  
   *Mark only one oval.*
   
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6. **Sample 3:** [https://soundcloud.com/tretiotre/sound-example-03/s-RmZnO](https://soundcloud.com/tretiotre/sound-example-03/s-RmZnO)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?  
   *Mark only one oval.*
   
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7. **Sample 4:** [https://soundcloud.com/tretiotre/sound-example-04/s-L3yZj](https://soundcloud.com/tretiotre/sound-example-04/s-L3yZj)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?  
   *Mark only one oval.*
   
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8. **Sample 5:** [https://soundcloud.com/tretiotre/sound-example-05/s-h3bSI](https://soundcloud.com/tretiotre/sound-example-05/s-h3bSI)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?  
   *Mark only one oval.*
   
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9. **Sample 6:** [https://soundcloud.com/tretiotre/sound-example-06/s-cJkUh](https://soundcloud.com/tretiotre/sound-example-06/s-cJkUh)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?  
   *Mark only one oval.*
   
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10. **Sample 7:** [https://soundcloud.com/tretiotre/sound-example-07/s-D4alf](https://soundcloud.com/tretiotre/sound-example-07/s-D4alf)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?
   *Mark only one oval.*

   |   |   |   |   |   | Dissonant
   |---|---|---|---|---|
   1 | 2 | 3 | 4 | 5 |

11. **Sample 8:** [https://soundcloud.com/tretiotre/sound-example-08/s-QpTnk](https://soundcloud.com/tretiotre/sound-example-08/s-QpTnk)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?
   *Mark only one oval.*

   |   |   |   |   |   | Dissonant
   |---|---|---|---|---|
   1 | 2 | 3 | 4 | 5 |

12. **Sample 9:** [https://soundcloud.com/tretiotre/sound-example-09/s-EnCNv](https://soundcloud.com/tretiotre/sound-example-09/s-EnCNv)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?
   *Mark only one oval.*

   |   |   |   |   |   | Dissonant
   |---|---|---|---|---|
   1 | 2 | 3 | 4 | 5 |

13. **Sample 10:** [https://soundcloud.com/tretiotre/sound-example-10/s-Jwnq8](https://soundcloud.com/tretiotre/sound-example-10/s-Jwnq8)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?
   *Mark only one oval.*

   |   |   |   |   |   | Dissonant
   |---|---|---|---|---|
   1 | 2 | 3 | 4 | 5 |

14. **Sample 11:** [https://soundcloud.com/tretiotre/sound-example-11/s-um8ld](https://soundcloud.com/tretiotre/sound-example-11/s-um8ld)
   Would you rate the sound as being either consonant(pleasurable), dissonant(less pleasurable/unpleasurable) or somewhere in between?
   *Mark only one oval.*

   |   |   |   |   |   | Dissonant
   |---|---|---|---|---|
   1 | 2 | 3 | 4 | 5 |
15. **Sample 12:** [https://soundcloud.com/tretiotre/sound-example-12/s-KfwTF](https://soundcloud.com/tretiotre/sound-example-12/s-KfwTF)

Would you rate the sound as being either consonant (pleasurable), dissonant (less pleasurable/unpleasurable) or somewhere in between?

*Mark only one oval.*

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16. **Is there anything you would like to add (regarding the sounds, the survey, etc)?**

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