Enhanced music therapy

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Abstract

In the Netherlands thirty thousand people suffer from Parkinson's disease. These people suffer from various physical and cognitive problems. Regular physical exercise can alleviate these problems and can slow down the physical and cognitive decline of these patients. One method for physical exercise is music therapy. An example of this is TIMP, in which physical exercise is combined with the playing of music instruments.

In this research, ways to enhance this therapy through the addition of visual cueing were explored in order to make it more fun and engaging. These ideas were eventually developed into a system resembling a xylophone, that allowed its users to play along to a song. Along these visual cues, the effect of other features such as sound effects that played when a user was performing well were researched.

User tests proved that the system showed promise. Firstly, visual cues proved to be usable by most people, as long as these are used in moderation. Secondly, most users responded positively to using this system. Thirdly, the sound effects seemed to motivate users from the target population. However, the current prototype is not as sensitive as it should be and playing it does not feel enough like playing an actual xylophone. Also, further testing should be done with a larger subject group.

Acknowledgments

First, some people have to be thanked for the part they played in this project.

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1. Introduction

1.1 Situation and Questions

Neurological music therapy has proven to be an effective way of treating symptoms caused by Parkinson's disease. Parkinson's disease is a non-reversible neurodegenerative disease that commonly affects older people. The disease affects patients' motor systems, causing problems with all types of movement, as well as speech, behaviour, cognitive skills and mental health. In the Netherlands there are 32000 people who suffer from Parkinson's disease and related disorders, furthermore Bloem et al. estimate 62000 patients to remain undiagnosed [17][1]. Music therapy can be used to diminish these symptoms and increase the quality of life of patients.

Music therapists at Artez Enschede commonly treat patients with therapeutic instrumental music performance or TIMP. TIMP is a type of music therapy which combines physical movement with rhythmic auditory cues and real musical instruments. These cues allow patients to perform these physical exercises for much longer than they usually would.

Although these exercises are successful in decreasing patient's symptoms, patients often need guidance from their therapist, especially if they are having trouble performing the exercises as well as they need to. There are, however, always more patients present at the therapy session than there are therapists, which causes the attention of the therapist to have to be divided. This causes two big problems. Firstly, patients don't always have the guidance and support they might need as the therapist is occupied with helping others. Secondly, therapists are not able to make every observation they could make in order to determine the progress of a patient.

1.2 Challenges

Goal of this research is to develop a technological system that can expand TIMP exercises. For this, the addition of visual cues, given by an ambient environment, to the audible cues already present in TIMP exercises will be researched. If these cues prove feasible, this will be developed into a functioning installation.

This installation should perform two main tasks. Firstly, the system must guide Parkinson's patients in performing TIMP exercises during the music therapy session. Secondly, the system should collect data from the patients' exercises and store this data so the patients' therapist can study this later.

The main question of this research is "How can technology be used to enhance conventional therapeutic instrumental music performance for Parkinson's patients?." This question will be answered by researching first which exercises of the TIMP sessions are most feasible to be adopted into such a system. And second, which technologies can be best used to enhance the therapy exercises. After this a system will be developed and finally evaluated using real patients.

1.3 Structure

First an introduction to Parkinson's disease and music therapy will be given. After this, the state of the art on music technology, music therapy technology and other interesting technologies, such as video games, will be discussed. Then the ideation process for the system described in this document will be described. After this, the realization of this system will be described. Following this, the system will be tested. Finally, some conclusions based on these test results and some recommendations for further research will be given.

2. State of the art

2.1 Background research and Problem analysis

This section will provide some background information on subjects that are important for this project. First a short definition of Parkinson's disease will be given. After that, the two most important types of neurologic music therapy for Parkinson's disease, RAS and TIMP, will be discussed. And finally some research will be done on the feasibility of visual cues during physical exercise. This background information is important to gain a better understanding of the target user group for this project, as well as what exercises can help this target group and how to enhance these exercises.

2.1.1 Parkinson's Disease

Parkinson's disease, or PD, is a progressive neurodegenerative disorder, most commonly found in older people. It is caused by the death of dopaminergic neurons in a central part of the diseased persons brain [5][7][8][9]. The decrease in dopamine producing cells in this part of the midbrain, named the substantia nigra after its heavily pigmented cells, causes a variety of movement related problems. The disease is irreversible and causes deterioration of the patient's ability to move and slowly progresses until the patient is unable to move at all and eventually dies [8][9].

According to Lim et al. Parkinson's disease is most prevalent in older people, with preponderance increasing with age. In Europe, two in one hundred people aged over 65 suffer from Parkinson's disease [7][8]. In the Netherlands there are 32000 people who suffer from Parkinson's disease and related disorders, furthermore Bloem et al. estimate 62000 patients to remain undiagnosed [17][18].

Parkinson's disease causes various characteristic symptoms, most of them influencing the patient's ability to move. The six symptoms typical to Parkinson's disease are; a tremor in the patient's extremities, slowness of movement called bradykinesia, rigidity in the patient's body, instability causing falling, loss of movement called Hypokinesia and a slow stride characterized by patients taking short, quick and irregular steps [5][7][9]. Next to these physical symptoms, Raglio claims that Parkinson's disease is the cause of many psychological problems in patients such as anxiety and depression. These problems sometimes occur even before motor problems [5].

2.1.2 Neurologic Music Therapy

Neurologic music therapy can be used for treating various symptoms of Parkinson's disease. This therapy mainly targets the redevelopment of motor skills and the improvement of sensory and cognitive functions and can be divided into two types; active therapy, also called music based movement therapy, and passive therapy. Passive therapy is defined by de Dreu et al. as therapy during which the patients mainly sit and listen to music. During active therapy patients actively participate in making music or perform physical exercises to the rhythm of music [2][3][5].

Three types of active therapy are identified by Bukowska et al, namely rhythmic auditory stimulation, or RAS, patterned sensory enhancement, or PSE, and therapeutic instrumental music performance or TIMP [10]. TIMP is the type of therapy targeted in this project and will therefore be discussed more in depth later in this chapter. Because of its popularity and effectiveness, a short description of RAS will also be given.

2.1.2.1 Rhythmic Auditory Stimulation (RAS)

Rhythmic Auditory Stimulation or RAS is a type of music based movement therapy focused on patients performing simple gait exercises to metronome beats [5][6][7]. Thaut et al. explain the focus of RAS to be the rehabilitation of movements such as walking, which are rhythmic in nature. This claim is supported by others such as [2] who claim RAS can improve walking skills, posture, step length and mobility of patients, as well as sensory and cognitive functions [2][5][6][7]. Furthermore, de Dreu et al. explain that RAS can increase walking speed and step length of Parkinson's patients as well as their walking cadence..

Thaut et al. explain two uses of RAS. The first as a stimulus used while performing movement. The second being as a stimulus used to achieve a more functional gait pattern [11]. De Dreu et al. explain this first use by giving an example of patients performing walking exercises to either a simple beat or more complex music, as well as visual cues. An example of such visual clues are transverse stripes on a treadmill [11]. Nombela et al. support the use of a simple metronome beat and explain the importance of this beat being tailored to a patients' baseline gait tempo. This tailoring and the simplicity of the beat especially important for Parkinson's patients because when rhythms become too intricate and when the tempo differs too much from a patients' comfortable walking speed, it becomes too cognitively demanding and loses its value [6]. The same need for simplicity of rhythm was reported by one of the music therapists at Artez.

2.1.2.2 Therapeutic Instrumental Music Performance (TIMP)

Thaut et al. Define therapeutic instrumental music performance as the playing of music instruments for the stimulation of movement patters and exercise [11]. Mertel, as well as Miller et al. and Bukowska et al., describes TIMP as a therapy method which uses musical instruments to help patients perform physical exercises targeting motor functions [4][10][12]. The addition of musical instruments to physical exercises adds auditory feedback, as well as a visual target for patients to hit during exercises [4].

The goal of TIMP is to train functional everyday movements, which are often problematic for Parkinson's patients. The auditory feedback patients receive from the musical instruments they play acts as a feedback system. This feedback enables patients to anticipate auditory cues and helps them plan their movements accordingly [4][12]. TIMP is claimed by various sources to be very effective in improving range of motion as well as motor functions and motor planning in Parkinson's patients [4][10]. Thaut et al. also claim TIMP to help improve endurance, strength, finger dexterity and limb coordination [11]. This claim is supported by both Mertel as well as explanations about TIMP by music therapists at Artez [12].

During TIMP various musical instruments are played in such a way that they facilitate the required physical exercise [NMT definitions]. The most commonly used type of instruments used during TIMP are percussion instruments, which are played in various ways, some examples of such exercises will be given later [4][10]. Percussion instruments are often used, because interaction with them is simple and they give clear auditory feedback.

2.1.2.2.1 examples of TIMP exercises

In Handbook For Neurologic Music Therapy a couple of TIMP exercises are describes. One example of a TIMP exercises has patients holding two mallets with which they have to hit two drums located an arm's length above their head while alternating between their two arms. This same exercise was observed during a music therapy session at Artez [12].

Another example has patients again holding two mallets while a drum is standing in front of them. The patient then has to bend their knees in order to make hit the drums with the held mallets [12].

A third exercise was observed during a music therapy session at Artez. During this exercise a patient was seated behind a drum kit. This patient had to alternate between hitting the bass drum using a pedal with their right foot and closing a hi-hat with their left foot. This had to be done to the rhythm of a piece of music played by the music therapist.

A fourth exercise was also observed during a therapy session. For this exercise a patient had to stand in between two drums and had to hit these drums on the rhythm of the music. In order to do so, patients had to twist their torso to alternate between hitting the drum on the left of them with their right hand and vice versa. More mobile patients would ‘hit’ an imaginary drum halfway through each rotation.

A final exercise observed during the therapy session had patients standing between two drums and shift their weight in order to hit them. The patient had to reach out and shift their weight onto one foot in order to be able to hit the drums on their right and left side. Drums had again to be hit on the rhythm of the music played by the therapist. For this exercise it was important that the distance between drums was adjusted per patient, in order for them not to fall.

2.1.2.2.2 TIMP music

The Music played by the music therapists during the TIMP sessions had certain characteristics. Most of the music were older, but popular, mainly Dutch songs. These songs were often recognized by patients who were encouraged to sing along if they recognized the song and sometimes would enthusiastically do so. The music therapists explained that commonly a tempo of approximately 100bpm would be used, but that this tempo had to be adjusted to accommodate the slowest patient of the group.

During some earlier performed stretching exercises the therapist noted the importance of the music reflecting the actions performed by patients. For example, if a patient had to raise their hands, the music therapist would play ascending arpeggios on the piano. Descending arpeggios were then played when the patient had to lower their hands again.

2.1.2.3 Psychological effects of music therapy

Music therapy can also have positive effects on the mental wellbeing of Parkinson’s patients. De Dreu et al and Miller et al describe the music as distracting patients from the fact that they were performing heavy exercise. This decreased fatigue and allowed patients to perform the exercises for longer, which improved the results of the exercises [3][4]. de Dreu et al claim the added music also improves the mood of the patients, making the exercise more fun [3]. Furthermore, playing an instruments at the same time as other patients can be beneficial for patients’ mental wellbeing. This sense of collaboration can provide patients with a sense of accomplishment and fun, increasing their motivation to continue to perform the exercises [12]. Therefore the addition of music to physical exercise it not only good for their physical, but also for their mental wellbeing.

2.1.2.4 The effect of rhythmic visual cues

As mentioned earlier, rhythmic visual cues can also be used as a means of stimulation for physical therapy. A study performed by Sidway et al. has shown that use of exercises combined with visual cues helped increase step length of Parkinson’s patients more than the same exercise without visual cues. This claim was supported by Suteerawattananon et al., who also noted an increase of walking speed and stride length. Furthermore, Sidway et al. and Rochester et al. both noted an increase in range of motion of hip and knee movement in Parkinson’s patients after exercises combined with visual cues [13][15][16].

A study on the effect of transversely drawn lines on a treadmill showed similar results. During this study, Parkinson’s patients had to walk on a treadmill with randomly varying speeds. Transverse lines with a distance of 25 or 50cm were drawn on this treadmill as a guide for these patients. From this, Leussie et al. concluded that the patients walking on the treadmills with lines showed a greater increase of gait speed and step length, as well as a greater decrease in step frequency and variation in step length, than patients walking on the conventional treadmill used by the control group [14].

However, some studies also reported less positively about visual cues. Rochester et al., for example reported that auditory cues were far more effective in increasing step length and the performance in dual-motor tasks (performing two or more cognitive and motor activities while maintaining postural control). Test subjects also reported that they found visual cues hard to use [15]. Furthermore, Suteerawattananon et al. noted a decrease in gait cadence after patients performed physical exercise with visual cues [13].

2.2 Technological state of the art

This chapter gives an overview of the state of the art of technologies connected to this project. First an overview of some active video games will be given. Then there will be an overview of music technology. And finally some interactive light installations will be discussed. All these technologies help give a better understanding of possible interactions for the installation designed during this project and how they are already used.

2.2.1 Active video games

This section discussed various active video games. These video games are particularly interesting as TIMP focusses on active physical therapy. These games show applications of physical movement use as input for technological system and therefore could function as inspiration for input for the installation developed during this project.

Nintendo Wii

Nintendo Wii is a video game controller using a motion sensitive remote rather than a conventional game controller. Games on the Wii system are played by pointing this remote at the screen where a sensor bar senses this. Various addons can be added to this remote, for example a vitality sensor and a balance board [18].

1 Nintendo Wii

Nintendo Wii balance board

The Nintendo Wii balance board is an add on peripheral device for the Nintendo Wii video game console. The Nintendo Wii balance board resembles a household scale. By standing on this board, which houses four pressure sensitive pads, players can control games by shifting their weight and leaning to a side. The balance board detects this weight shift and translates this to game input [19].

2 Nintendo Wii balance board

Playmotion playbox Core

The Playmotion Playbox is a system that can be used to project an interactive video game on any wall. People passing by the wall can interact with the game by standing and moving in front of it. For example by tossing balls in a digital volleyball game. There are 12 games available ranging from sports games to interactive psychedelic images [20].

3 Playbox Core

Microsoft Kinect

The Microsoft Kinect is a motion sensitive game controller developed by Microsoft. The Kinect's main purpose is to function as an input device for Microsoft Xbox line of video game consoles. Kinect is based around a camera and is able to track the movements of people standing in front of it. This movement can be translated to input for video games [21].

4 Kinect

Ingress and Pokémon Go

Ingress and Pokémon Go are location-based, augmented-reality games developed by Niantic. Both Pokémon Go and Ingress are played on the smartphones of players. These players need to walk around in the real world in order to reach certain in game places of interest. This type of play is very successful in moving video games from computer screens to the streets and encouraging people to be more active.

In Ingress players the goal of the game is to conquer in game bases of the opposing team of the players by physically moving to a spot on the real world map where the in game base is located and defeating some enemies there [22].

The goal of Pokémon Go is for players to walk around and use their phones to collect cartoon creatures called Pokémon. Eventually players will have to find similar bases as in Ingress and conquer these for their own teams [23].

6 Ingress

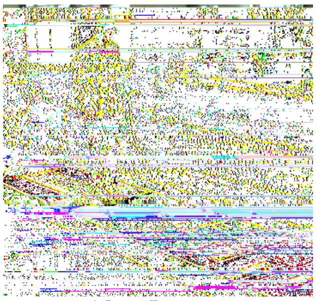
5 Pokémon Go

Tag 2.0

Tag 2.0 is an interactive installation developed by the HMI group of the University of Twente. Tag 2.0 uses beamers and Kinect devices fixed to the ceiling of the room in which it is installed to project an environment on the floor and detect the positions of players. The game itself functions as a conventional tag game wherein one player has to tag another by touching them, but expands this by giving certain players powerups as well as steering the movement of players [24].

7 Tag 2.0

UT video floor



8 LED video floor

The video floor is another installation developed by the HMI department of the University Of Twente. It uses a pressure sensitive LED floor which detects the positions of players. The game environments are shown on the screens in the floor. The goal of the game is for players through progress through game levels by stepping on things like leaves, bricks, rocks etc. [25].

2.2.1.1 Active video games for patients of Parkinson’s disease

This section discusses some video games designed for people with Parkinson´s disease. This gives an idea of to which extent technology has already been attempted to be used for stimulating Parkinson´s patients.

WuppDi!

9 WuppDi!

WuppDi! is an active video game for Parkinson’s patients developed by the Serious Games Master study of the university of Bremen. The goal of WuppDi! is to help Parkinson’s patients perform active exercises, while adding the fun of playing a video game. WuppDi! is controlled using a webcam and brightly colored markers held in the player’s hands. Software on the game computer tracks the movement of the markers and translates this to in-game movement.

WuppDi! has four different games; The first in which players have to mirror dance moves performed by an in game character. In the second game player have to collect items by moving through levels by making swimming movements. The third game has players catching bubbles with a net. In the fourth game, the player has to guide a character through different levels by moving an on screen marker which the character follows. In the final game mode the player has to remember a sequence of on screen buttons that have to be pressed and press on screen buttons on the right sequence. All games have fairy-tale theme [26].

Phone app: Parkinson home exercises

Parkinson home is a phone app made specifically for Parkinson’s patients. The app is available for both Android and IOS. Goal of the app is to show Parkinson’s patients 50 physical exercises they can perform at home. These exercises are meant to enlighten symptoms of patients [27].

2.2.1.2 Music video games

This section discusses some music video games. Goal of this section is to understand how musical instruments are used as video game input and how musical instruments can be used for input to a technological system. Furthermore, this section broadens the understanding of how music can be made digitally in a playful way.

Rock band/Guitar Hero/Rocksmith

Rockband, Guitar Hero, and Rocksmith are music video games played with guitar-like controllers. Rock band an guitar hero both use plastic guitar-shaped controllers whereas Rocksmith uses a real electric guitar as the input device. The goal of both games is to play notes or press buttons on time as shown on screen [28][29][30].

10 Guitar hero

Wii music

Wii music is a music game with a focus on arranging and composing. Using the Wii remote and its nunchuck controller, players control various on screen instruments. This allows players to create and arrange music and songs on the fly. In contrast to games that tell players what music to play such as guitar hero, the aim of Wii Music is to give players more creative freedom, focusing on composing and improvisation [31].

11 Wii Music

Donkey Konga

Donkey Konga is a rhythm based music game designed for the Nintendo GameCube console that is played using a bongo-like device rather than a conventional GameCube controller. Players have to rhythmically hit the controller in order to progress through levels [32].

12 Donkey Konga controller

Dance dance revolution

13 Dance dance revolution pad

Dance dance revolution is a dance game for various video game consoles. Dance dance revolution is controlled using a board on which the player stands. This board has 4 arrows drawn on it. These four arrows reflect arrows shown on screen. Players have to imitate patterns of arrows on time as shown in the game, similar to the notes in Guitar hero. Goal of the game is to jump on as many arrows in time as possible, resulting in a high amount of points [33].

2.2.2 Music Technology

This section gives an overview of music technologies that might be interesting for this project. These technologies will be divided into four subgroups; Electronic music instruments, MIDI controllers, Novel music instruments and Music instruments for therapeutic use.

2.2.2.1 Electronic musical instruments

The following section gives an overview of some electronic musical instruments. These instruments are often modelled after traditional musical instruments and are meant for imitating one specific instrument, rather than the MIDI controllers discussed later.

Theremin and Terpsitone

14 Theremin

The theremin is an electronic instrument that can be played without making physical contact with the instrument. Two antennes determine the position of the player´s hands. One antenna controls the pitch of the note produced, while the other determines the intensity. Players can move their hands to control these [34].

The Terpsitone is a larger version of the theremin, which can be played by a person by moving their whole body. The user takes place on a platform in which an antenna is built and moves their arms and body to control the produced sound [35].

Aerodrums

Aerodrums is a system that enables the user to play virtual drums by moving their hands in the air. The system detects movement by sensing the users arms while the user hold two drum sticks with white balls at their tips. This detection system enables users to play high speed drum music without having to use an actual drum kit [36].

15 Aerodrums

Kurv guitar

The Kurv guitar is a digital guitar that uses a button pad held in one hand of the user and a plectrum-like object in the other hand of the user to play songs one would usually play on a conventional guitar. The buttoned pad allows the user to determine which notes or chords they want to play when moving the plectrum [37].

16 Kurv guitar

2.2.2.2 Midi Controllers

This section gives an overview of various MIDI controllers. A MIDI controller is a device that is able to send messages using the MIDI protocol, a protocol designed to control various electric and software based instruments [49]. These instruments often resemble traditional instruments, but the adaptability of MIDI makes this a different class of instruments than electronic instruments designed for one purpose.

Laserharp

Laserharp is a system that allow its users to control virtual instruments by disrupting beams of light. The played note is often determined by which beam is disrupted, while the intensity of the note and other dynamics are influenced by the distance of the user's hand to the base of the laserharp [38].

17 Laserharp

Novation Launchpad

The Novation Launchpad is a controller for digital music instruments with a grid of touch sensitive pads. Users can assign a variety of things to pads, like musical notes, sound effects etc. The intensity with which the user hits pads can be used to influence certain variables such as note volume and vibrato [39].

Haken Continuum

The Haken Continuum is a touch sensitive controller for digital music instruments. The continuum uses a keyboard like surface that can be controlled by the user by touching it. Usually the position of the users touch along the length of the touch surface determines the pitch of the note played. The width position of the user hand as well as pressure intensity can be used to control a variety of variables [40].

19 Continuum

MIDIcreator

MIDIcreator is a device that can turn any object into a musical instrument. MIDIcreator uses various sensors to transform vibrations into MIDI signals, which can be used to control various electronic and software based musical instruments. [11]

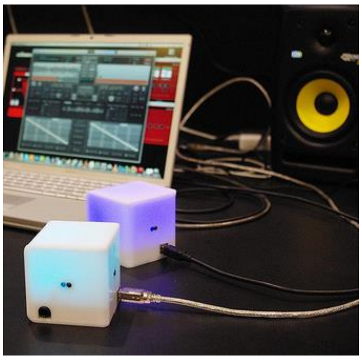
20 MIDIcreator

2.2.2.3 Novel Musical instruments

This section gives an overview of some novel musical instruments. These instruments are often MIDI controllers, but the interaction players have with them in order to play them is very different than the interaction with conventional MIDI controllers.

Audiocubes

Audiocubes is a novel controller for software based musical instruments shaped like small cubes. These cubes can be moved around a room by users and base pitch etc. of the played note on either the distance to objects in their vicinity or their distance to a preassigned receiver block. The objects measured by the audiocubes can be everyday objects like apples or a cat etc. [41].



21 Audiocubes

Dodecaudion

Dodecaudion is a controller for virtual music instruments that uses a dodecahedron shaped box which measures the distance of a user's hands around it and translates this to sound. The Dodecaudion uses infrared sensors in each one of its walls that detects the presence of a user's hands and their closeness to the Dodecaudion.

Dodecaudion is Arduino powered and open scource. This means the dodecaudion can be used to control other things than just musical instruments, for example visual installations powered by processing [42].

22 Dodecaudion

Skoog

Skoog is a cube shaped electronic musical instruments. Users can interact with Skoog by touching the rounded surfaces on its faces. Skoog is designed for use in special needs education and music therapy because its interaction is more easily accessible than conventional music instruments [43].

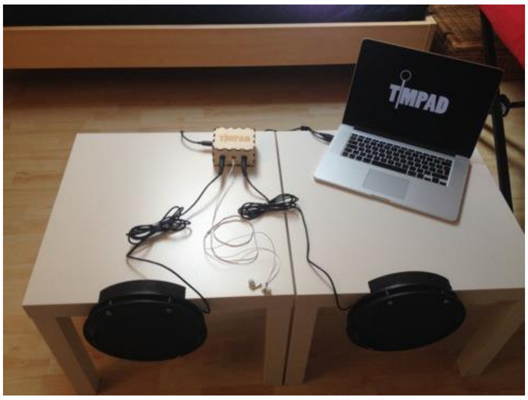
23 Skoog

2.2.2.4 Therapeutic musical instruments

This section gives an overview of some musical instruments designed for therapeutic uses. These instruments are commonly designed to support or achieve one or multiple therapeutic exercises and often offer interaction different than that of conventional musical instruments.

Timpad

Timpad is a music therapy device constisting of two impact sensitive drumpads. Timpad is designed by Daniel van Pel for his Creative Technology graduation project. Timpad is designed to replace and improve various exercises from conventional TIMP therapy. The timpad uses of two electronic pads that can be attached to different pieces of furniture as desired by the person using it to fit the exercise that is going to be performed. Patients can hit these pads using either their hands or sticks in the same manner that they would hit drums during normal TIMP sessions [44].



24 Timpad

Sound Beam

Soundbeam is an electronic musical instrument specifically designed to be used by less mobile people. Soundbeam consists of two devices that emit beams of ultrasound. These beams can be interrupted by users, using their hands or even their whole body, after which the Soundbeam device will translate these interruptions into sound. This handsfree interactions makes the Soundbeam perfect for use by people who are unable to move and make music in conventional ways, like wheelchair users [45].

25 Soundbeam

2.2.3 Interactive light installations

This section gives an overview of interactive light installations. Goal of this section is to get an overview of possible ways to implement responsive visual cues. Such interactive visual cues could possibly be also implemented in an installation for TIMP exercises.

Great Street Games

Great Street Games is an interactive light installation. The installation is designed to make public spaces more inviting. Similarly to the Tag 2.0 playground, Great Street Games tracks the position of users and draws various light patterns around people interacting with the installation. However, the difference between Great Street Games and Tag 2.0 is that this installation uses heat sensors to track the position of users and is able to cover a much bigger area [46].

26 Great Street Games

NunoErin Sparkle Table

NunoErin is a company that makes interactive furniture. The Sparke Table is an example of such a piece of furniture. Sparkle Table and similar items have a touch sensitive surface with lights embedded in it. When users touch or sit on these lights, their colors will change and respond to the presence of users [47].

27 NunoErin Spark Table

Mood Light Motion

Mood Light Motion is an interactive installation that uses panels of LEDs wherein motion sensors are embedded. The LEDs will respond to users moving their hands near the surface of the panels without actually having to touch the panels [48].

28 Mood light motion

2.3 Conclusion, further proceedings and design rationale.

Concluding; which therapeutic instrumental music performance exercises are the best candidates to be adopted by an interactive installation? A variety of exercises are performed during TIMP sessions. It doesn't really matter which are chosen, as long as there is a variation between which muscle groups are stimulated. All these exercises should be performed to simple (metronome) or more complex music, as long as it doesn't become too cognitively demanding. For certain exercises the use of arpeggio's or scales can be used as a guiding help.

Conventional music therapy is effective in increasing gait speed and step length etc. in Parkinson's patients. As an extension to this, research has been done on the effect of visual cues on therapies for Parkinson's patients. Most of these studies shown that visual cues can help increase step length, gait speed and range of motion in Parkinson's disease, with only some studies claiming a decline in walking speed. Studies agreed, however, that some patients found visual cues challenging to use, therefore they should be kept simple. Most studies are positive about the use of visual cues and therefore it is feasible to improve TIMP exercises by adding visual cues.

The most simple types of instruments to use are percussion instruments. Therefore these should preferably be used. An summary of possible technologies that can be used with percussion instruments will be given now.

For impact on the percussion instrument, a similar system as the TIMPad could be used as a trigger for audible cues, similarly to how a conventional drum works. The same result could be achieved by fitting a sensor for the MIDIcreator device into everyday objects and having patients touch or hit these.

Motion based exercises which don't require patients to hit a percussion instrument can be supported by systems such as the Soundbeam and the Nintendo Wii controller. These can function as input for technological devices and trigger sound and visual without the patients having to hit anything. A simpler version could be made using infrared sensors rather than ultrasound, similar to the Dodecaudion.

Visual feedback could be given on screen, using a system similar to the Mood light motion, or through an installation using beamers on the floor or other surfaces such as used in the Great Street Games and Tag 2.0 installations. These systems could be used to have light reflect the motion of patients through following this motion, changing color or other means of feedback.

It is important that these visual cues remain simple and don't attract too much attention as the music should remain the most important cues, with an emphasis on the metronome beat and the helpful arpeggio's. The music used also should not be too cognitively demanding and should align with the likes of the patients.

3. Ideation

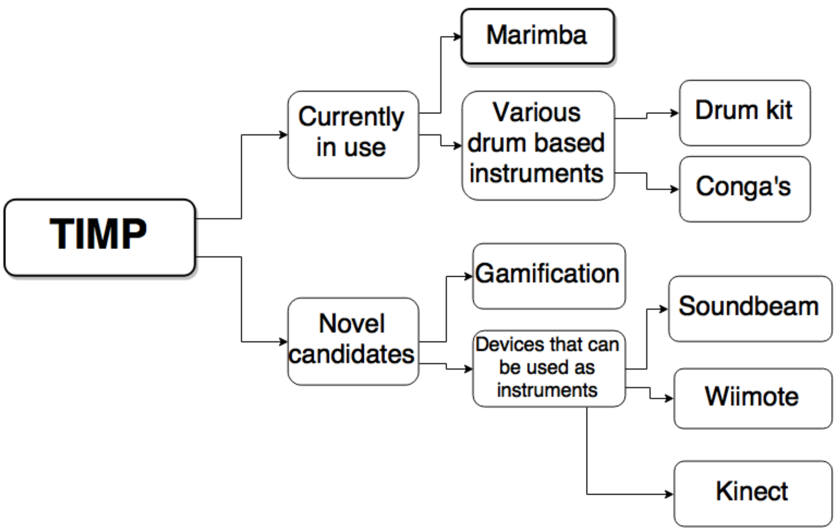
This chapter will describe the ideation process of this project. First a divergence phase will be described wherein a lot of different ideas were given. After that a convergence phase was done, wherein the best ideas were selected and developed further. Finally a best idea will be selected and requirements will be given.

Note: in this chapter mind maps will be added as illustrations for the brainstorming process. These mind maps have colours that denote whether an idea would be a form of visual cueing or visual feedback. Blue colour indicates that the idea is a form of visual cueing, while orange means visual feedback.

3.1 Divergence phase

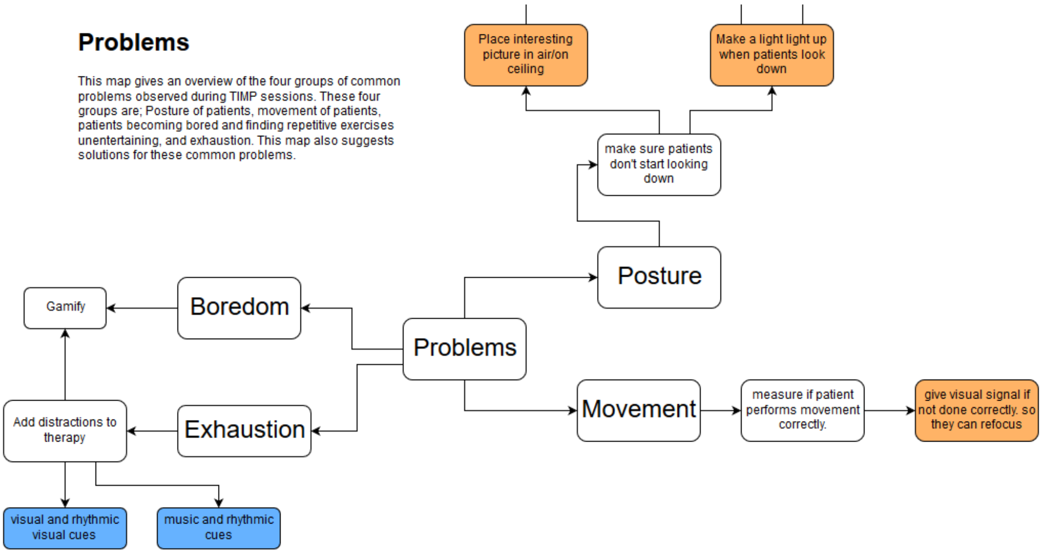
In this section, the initial ideation phase of this project will be described. Goal of this section is to come up with as many ideas possible. These ideas will later be evaluated and further refined in the convergence phase. During this initial ideation process, three main themes were looked at. The first two concerning the conventional instruments currently used during TIMP and novel technologies that could replace or expand these conventional instruments. The third theme was the problems that often occur during TIMP.

The first two themes were instruments used during TIMP and technologies that could replace or complement them. Currently used instruments are mainly percussion instruments, such as a drum kit and a tambourine. Novel candidates for instruments are often technological devices or video game controllers, such as the Nintendo Wii controller and the Microsoft Kinect. These devices could very well be used as input for digital music instruments or other systems.



29 Instruments used in TIMP

The third theme for ideation was the problems that often occur during TIMP. From observations during TIMP sessions and literature, four main problem areas were found. Firstly, patients will often become exhausted from the physical exercise performed during TIMP. This exhaustion is already to an extent remedied by adding a distraction in the form of music to physical exercise, but perhaps it could be decreased further by further improving the distraction element of the music therapy. The same counts for the second problem area, boredom. Exercises performed during TIMP are often very monotonous, which can easily lead to boredom. This could be solved by making the exercises more engaging and interesting, for example by adding a game element to them. Another problem is the posture of patients during exercises. Often patients would not pay attention to their posture, because they were too busy focussing on their movement. It would be beneficial for them to be corrected if they had a wrong posture. Finally, it is important for patients to perform the movements of the exercises correctly. However, often patients did not do so, because they either did not feel like doing the exercises correctly, or they were convinced that other, easier movements have the same effect of the desired movements. It could be beneficial if a system would guide them in correctly performing movements.



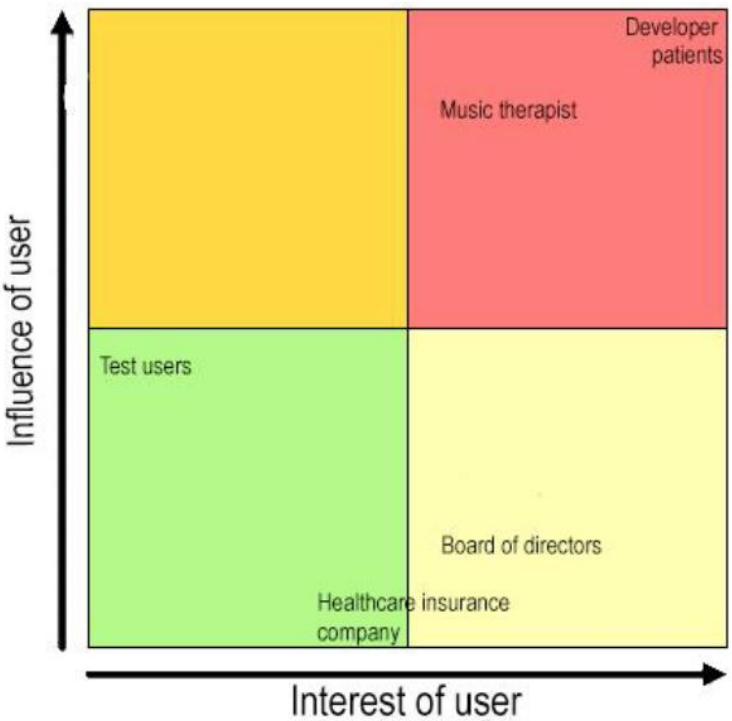
30 problems noticed during TIMP

3.1.1 Stakeholders

To get a clearer picture about the people that will be affected by this system, it is useful to identify the systems stakeholders and how they will be affected by the system. A stakeholder can be defined as everybody that uses or comes in touch with a system. Sharp et al. [56] define three stakeholder types. The first type of stakeholder is the primary user, who are people that are likely to often use the system. These people often belong to the target group. The second type of stakeholder is the secondary user, who will indirectly use the system. And finally the tertiary users, wo do not actively use the system, but will still be affected by and will influence the purchase of the system.

For this system, six stakeholders were identified. Primary users of this system are; The patients as well as their music therapist. If this system were to be actually used, tertiary users of this system would be the board of directors of the institute that will use the system and healthcare insurance companies that will have to compensate the cost of this system. Other users are test users, who are people that will use the system while testing it, and the developer of this system.

These stakeholders have varying degrees of influence and interest in the development of the system. These degrees of influence are visualized in figure 31 which ca be found below. The developer of this system and the patients have the highest influence and interest in this system. The developer obviously has a high influence because they actually make the system. They also have a high interest, because developing a bad product can harm their reputation and career, whereas developing a good system can be beneficial for both. Patients have a high interest because they will be using the system and the system can possibly help them in their treatment. They also have a high influence because the opinions and needs of the patients will be taken into high account while developing the system. The music therapist also has a high interest and influence, albeit lower than that of the patients and the developer, because they will actually be using the system. Usage of this system could benefit their therapy and allow them to treat patients more efficiently and effectively. Furthermore, their expertise will be an important influence for certain design choices. Test users have a moderate influence, because their test results can tell certain things about the usability of the system. They, however, have a very low interest, because they will probably not use the system after these test sessions. The board of directors of the institute that will use the system and the healthcare insurance companies have moderate interest and low influence. Their moderate interest springs from the fact that these stakeholders will have to agree with the purchase of the system and will only do so if the system proves to be worth the investment. However, because they will not directly use the system, they have a low influence on the development of the system.

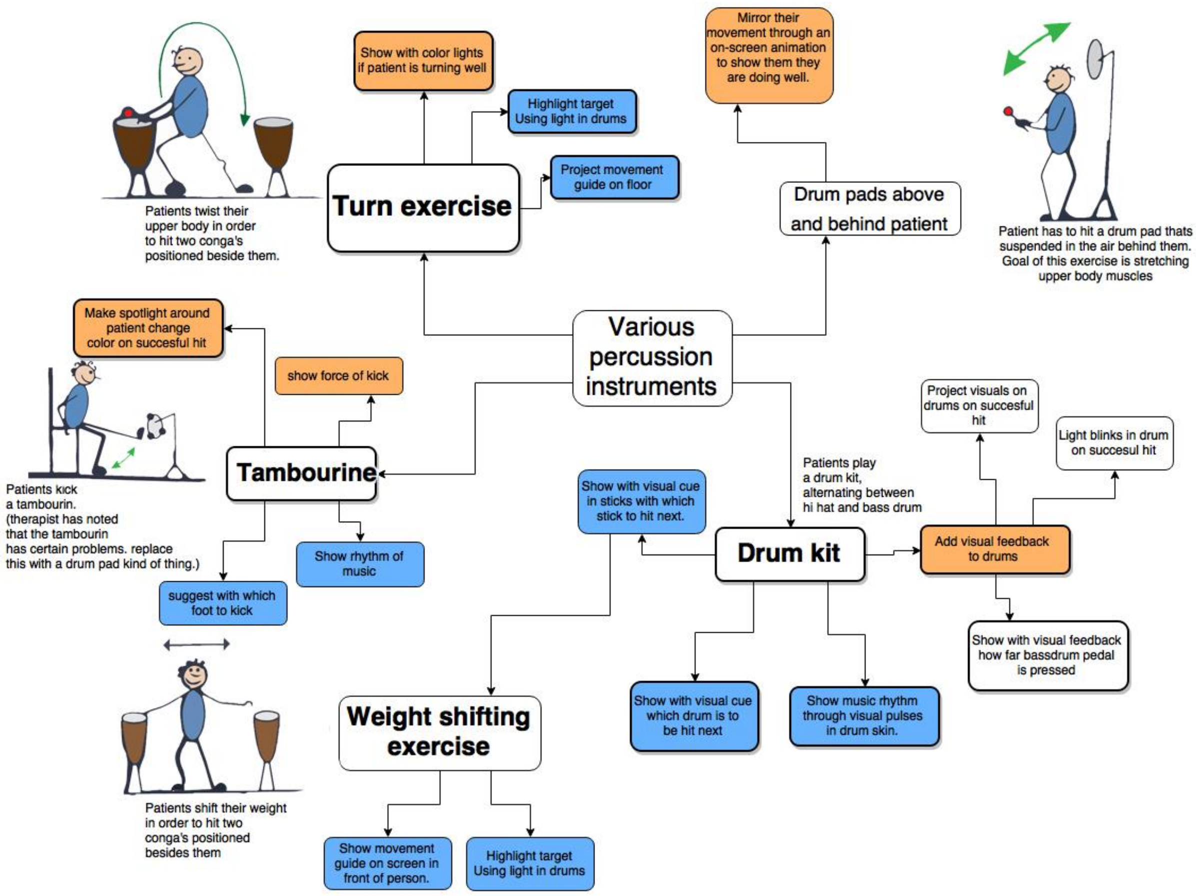


31 Stakeholders

3.1.1 Initial ideas

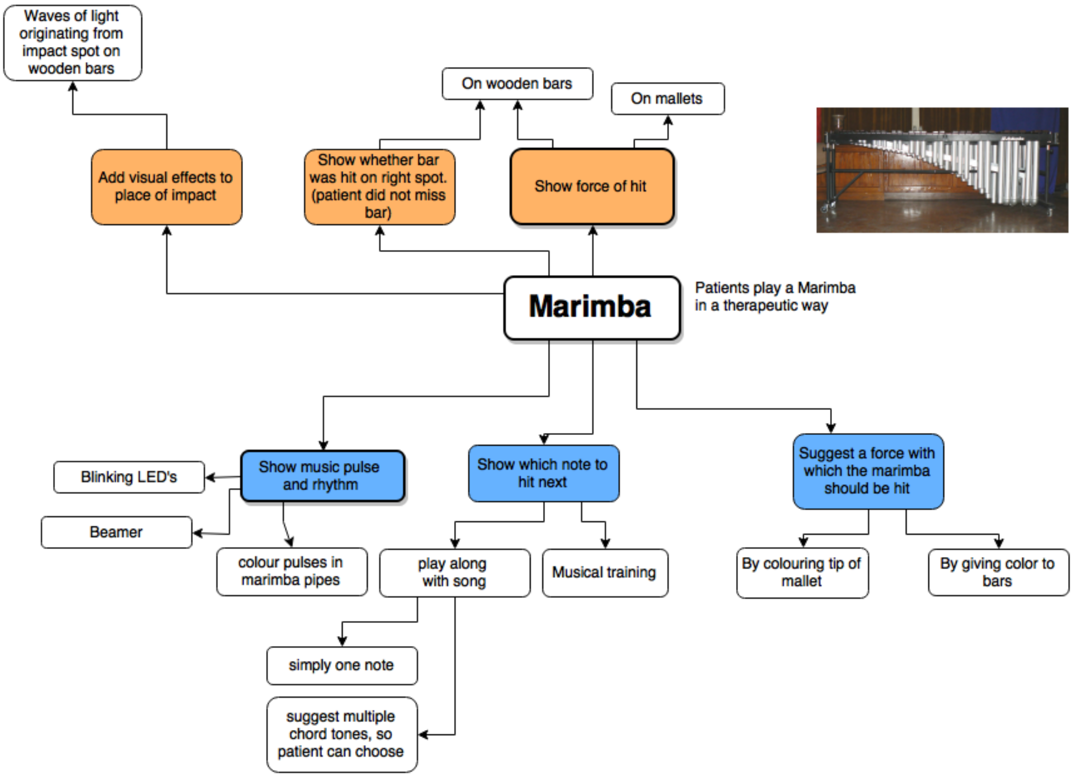
With these problems and these instruments in mind, some initial ideas were formed. These ideas are written down in the mind maps in figures 32 through 34. These mind maps were later expanded after the first test session with a lo-fi prototype, which will be described later. The themes of these three mind maps are various percussion instruments, a marimba, and gamification.

The first mind map, in figure 32 deals with various percussion instruments. These are all percussion instruments currently used during TIMP. These instruments are; Congas, which are used during both the turn exercise and the weight shifting exercise, a drum kit, a tambourine and drum pads. Examples of ideas for enhancing these instruments are to make them control the environment in which user's play these instruments, or to show the rhythm of the music through the use of visual pulses in the instrument.



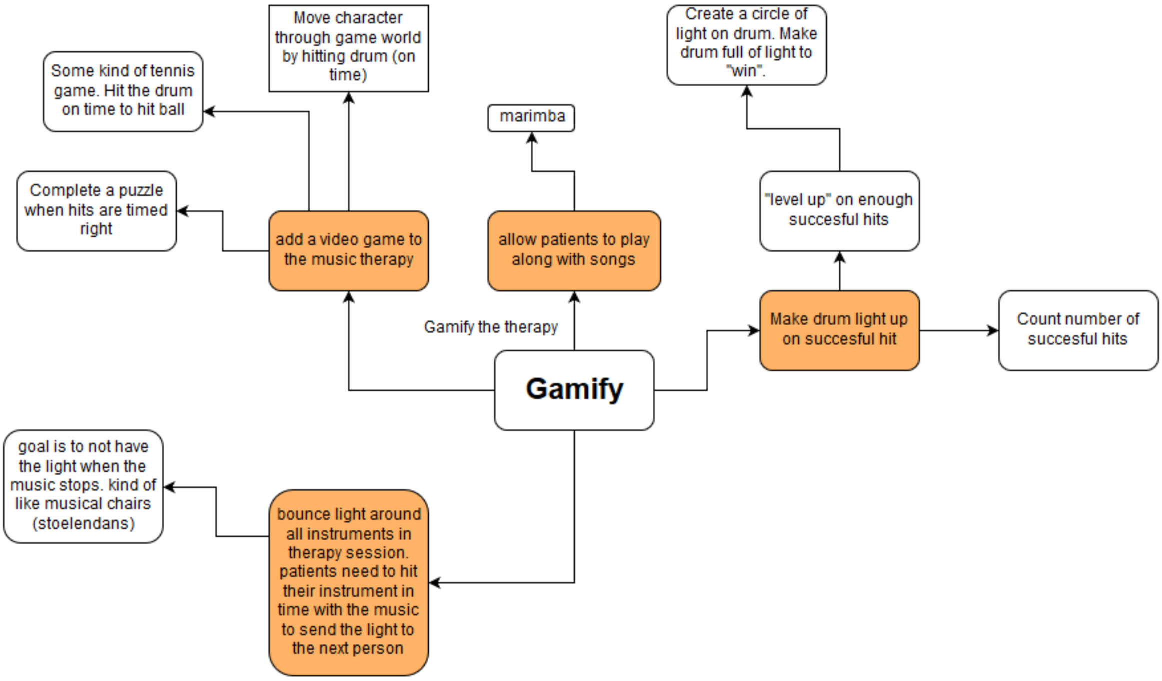
32 percussion mind map

The second mind map, found in figure 33 deals with a specific percussion instrument; the Marimba, or xylophone. A xylophone is currently sometimes used during TIMP. Patients generally enjoy playing the xylophone, as it offers a change from the other drum based percussion instruments. A downside to a tuned instrument such as the xylophone, however, is that, when playing along to the song played by the music therapist, patients will play out of key, resulting in bad sounding music. Therefore, it could be interesting to develop a system that allows patients to play along to the music played by the therapist while playing a xylophone. Furthermore, the system could also show the force with which people hit the xylophone bars and encourage them to try harder.



33 marimba mind map

The third mind map, found in figure 34 deals with gamification. Gamification in this context means the addition of gameplay elements to parts of the therapy, for example patients could control a character in a video game by hitting a drum, or play a musical chairs-like game with other patients by passing a light to the next player on a successful hit.



34 gamification mind map

3.1.2 Lo-fi prototype one and first test

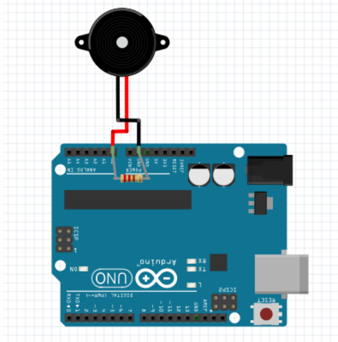
After these first ideas were formed, a lo-fi prototype was developed. This prototype was used to test how users responded to visual feedback (on a computer screen,) as well as whether or not they liked such feedback and whether they deemed it distracting. Furthermore, this test helped understand the efficacy of rhythmic visual cues and their potential for later prototypes.

Finally, feedback from this test session was used to expand the mind maps mentioned earlier and to determine requirements for the final prototype. Because most ideas that seemed feasible concerned percussion instruments, and the patients were also already familiar with percussion instruments, this lo-fi prototype would also be a percussion instrument.

3.1.2.1 Lo-fi prototype


35 Lo-Fi prototype

The Lo-fi prototype used during this test can be found in figure 35. This prototype was made of a shoebox in which an Arduino connected to a piezo transducer was placed. On this Arduino the knock sensor Arduino sketch example, which is a simple Arduino program that detects when a piezo transducer is hit, was installed on this Arduino. When users hit the shoebox, this triggered a response in a processing sketch. The processing sketches used will be discussed later.


36 Knock sensor

The piezo transducer was connected like in 36. One wire from the piezo transducer was connected to the A0 pin of the Arduino Uno, the other to the ground. A 1MOhm resistor was connected in parallel to this, to make it behave more reliably. The code used on the Arduino can be found in appendix B1, as well as on the processing website [55].

The first processing sketch used for this lo-fi prototype tested showed a picture of a snare drum on a computer screen. When a test subject would hit the shoebox, the processing sketch would respond to this by showing a brightly coloured green ring at the edge of the snare drum, this green colour would then fade to black after which the ring would disappear again.


37 Lo-Fi sketch

The second processing sketch combined the interaction of the first sketch with visual rhythmic cues. The green ring would now automatically start at the edge of the drum and shrink towards the centre of the drum, starting over at the outer edge after reaching the centre of the drum. When a test subject would hit the drum, a circle would appear at its centre. This circle was either green when the green ring would also be in or near the centre of the drum, or red when the green ring was not near the centre. This circle thus provides visual feedback about whether or not the test subjects timed their hits correctly. The tempo with which the ring would reach the centre could be set to either 25 or 50 beats per minute. A screenshot of this program can be found in figure 37.

First Test

This test session was performed during a TIMP session at Artez. The test subjects were two Parkinson’s patients from the therapy group of Laurien Hakvoort. Both subjects were asked to interact with the lo-fi prototype and the two processing sketches controlled by this prototype. During this interaction, observations were made. After the interaction, subjects were asked to reflect on the interaction and provide feedback on this type of interaction. The main focus of this feedback was to determine whether these users enjoyed interacting with such a system and whether the interaction was not too hard and not too distracting.

Results

From this first test, some results can be derived. Firstly, the results about the interaction will be discussed. both test subjects understood the goal of this prototype and how to interact with it fairly quickly with minimal instruction. Timing the hits using visual cues was not a problem for both subjects, with subject one never missing a hit and subject two missing a maximum of 15% of hits. These missed hits, however could mainly be blamed on the sensitivity of the drum, rather than the subject's ability to time hits, subject two was simply not hitting the shoe box drum hard enough.

Secondly, something can be said about the feedback. Both patients understood the feedback the system provided, but noted that they would prefer to receive only positive feedback from the system. This because they felt that otherwise they would feel demotivated to continue, whereas positive feedback would make them feel better about themselves and motivate them to try harder.

Thirdly, about the visual rhythmic cues. Both subject were able to time hits using only rhythmic visual cues really well, rarely missing a hit due to timing issues. However, both test subjects mentioned that they missed an audible cue next to the visual cue provided by the prototype. In addition to this, subject two specifically mentioned that they would prefer to hear only music instead of only seeing visual cues. Finally, subjects mentioned that the pulsating visuals of the sketch were somewhat obnoxious and they thought they would give them a headache.

Finally, subjects gave input regarding improvements they deemed necessary. Subject one proclaimed that they would find the addition of a more playful type of interaction to the therapy fun. An example they gave was completing a puzzle when timing hits correctly. Also, adding different instruments than the basic drums usually used during TIMP was noted as interesting by them. For example, allowing them to play along to the songs played on the piano.

Further observations and feedback

The therapist also noted during this session that it might be a good idea to track movements of patients, check if these are performed well and giving feedback to the patient on how to improve these movements. But the only issue that showed during the therapy session was one of the patients standing hunched over.

Furthermore, it was noticed that one of the patients had trouble with fully pressing the bass drum of the drum kit, as well as the exercise performed behind the drum kit being fairly monotonous. This could be made more interesting, for example by adding visual cues to the drums of the kit as well as visual feedback to performed movements.

3.1.3 Conclusion

From these results, observations, and feedback, some conclusions were made that should be taken into account for the final prototype. Firstly, patients sometimes had trouble getting the system to respond, whereas it was pretty easy for other patients. Therefore the sensitivity of the system should be adjustable to fit the needs of the person using it. Secondly, patients expected that when the system would tell them they were performing badly, they would feel demotivated. Therefore, an emphasis on negative feedback should be avoided. Thirdly, patients explained that they felt that the music was more important than the visuals in the system. The music should remain the key element of the therapy. And finally, patients explained that they would enjoy the addition of play elements to the therapy, such as a video game or something that allows them to play along to music.

3.2 Convergence phase

3.2.1 Four ideas

From this final mind map, four ideas with most potential can be derived. First, all ideas were reviewed using the table found below. From this table could be concluded that the four most interesting ideas were the light bounce, the marimba play-along, the enhanced drum kit and the Wiimote stretch exercise. These ideas have the most check boxes filled, namely 5.

The colour codes used in the table mean; Idea name, goal of system, type of visual cue, type of instrument, Solve a problem, increase group interaction.

Idea	modification of existing instrument	new instrument	provides visual guidance	Provides visual feedack	Increase fun of exercise. (gamify)	Increase exercise performance	Solves a problem	Increase group interaction
Use Wiimote as egg shaker that causes visual effects in spotlight around user.								
Use Wii remote to encourage stretching exercise. By lifting it in the air, acts as "magic wand" to control light effect around users.								
Use wiimote to hit non physical drums								
Bounce light around all instruments in therapy session. Users need to hit their instrument in time with music to send the light to the next person. Tick Tock Boom.								
make drums fill with light on succesful consecutive hits. Allow user to level up								
Count number of succesful hits and show this to users afterwards.								
Suggest a force with which users should hit marimba by varying color on marimba bars.								

Idea	modification of existing instrument	new instrument	provides visual guidance	Provides visual feedack	Increase fun of exercise. (gamify)	Increase exercise performance	Solves a problem	Increase group interaction
Make drum liight up on succesful hit								
Make random things light up/make sound in surrounding of drum on succesful hit								
show visual rhythmic pulse in drum								
Make spotlight around patient change colour on succesful hit								
Show force of kick against tambourin								
suggest with which foot to kick tambourin								
Guide person through weight shifting exercise through visual cues on a screen in front of them.								
Make sure person does not stand hunched over during exercises by measuring their movements and correcting them.								
Use hits on drums as video game controller								
project visual effects on succesful drum hit								
Show how far bassdrum pedal is pressed through light on drums								
suggest which drum on the drum kit is to be hit next								
suggest with which drum stick to hit next								
suggest which marimba bar to hit next								
show force of hit on marimba sticks or bars								
Use hits on drums as video game controller								
Allow users to play along with songs by making marimba light up on certain notes								

3.2.1.1 Light bounce

The first idea is the light bounce is a game in which all instruments in the therapy session play a part. During this game, a light will move between all instruments involved. The light will leave the instrument of one player when they hit their instrument on time. The goal of the game is somewhat like a game of musical chairs, or Tick Tock boom. The player who has the light when the music ends loses the game.

This game does not target the therapeutic benefits of the exercises performed. However, it increases fun and connects patients with the rest of their therapy group. This should increase distraction and as a consequence decrease exhaustion.

3.2.1.2 Marimba play along

The second idea is the marimba play along. During TIMP sessions, patients sometimes play the marimba. Patients generally enjoy this, as it is a nice change from the drums they use in most exercises. However, the big downside to playing the Marimba, is that patients often play out of key with the song the music therapist is playing. This makes it sound unenjoyable and discourages patients.

The marimba play along solves this. By showing through visual cues which note from a chord a user should play next, people can play along to songs, without knowing them. This allows patients to play along with the songs played by the music therapists. This system can be made simple, by only showing one note from every chord and when to play them to users, but can be made more expressive by showing every note from an arpeggio - a chord broken into its individual chords, which are usually played one by one - or scale that fits in the chord the therapist is playing. Visual feedback can be used to let users know whether they played the correct note, as well as the force of their hit. Visual cues can be also used to show the rhythm. Furthermore, this system can be simply attached to a pre-existing marimba, without having to alter the instrument.

This system also does not target the therapeutic benefits of the performed exercises. But, like the light bounce game, it distracts the patient, causing them to feel less tired, as well as creating a connection between them and the rest of their group.

3.2.1.3 Wiimote stretch exercise

The third idea is the Wiimote stretch exercise. One of the most important exercises performed during TIMP are exercises of stretching the upper body. The only exercise targeting that that is currently being done at Artez TIMP sessions, is the one during which two drums are suspended in the air above and behind the heads of patients. Patients then have to hit these drums using mallets. This exercise, however, is very impractical, as a second person is needed to hold the drums. This is often a second music therapist or an intern, but doing this exercise means one less person is present for guiding patients and the exercise cannot be performed when no second therapist is present.

This can be solved by introducing a Wiimote to this exercise. When patients hold this Wiimote and stretch it above their heads, the sensors inside the remote can tell when a patient stretched enough and give visual feedback to this person. Instead of a Wiimote another system, such as a Microsoft Kinect, could also be used.

Goal of this system is to improve the therapy exercises currently performed, rather than make them more fun or more interesting.

3.2.1.3 Enhanced drum kit

The fourth idea is the enhanced drum kit. Another exercise done during TIMP sessions, is one using a drum kit. Patients are seated behind the drum kit and alternate between pressing the pedals of the bass drum and the hi-hat. When a patients desires to perform a more interesting or challenging exercise, they can use drum sticks to hit the other drums in the drum kits and the cymbals, however, not many patients elect to do so. The main problem with this exercises is that it is a very monotonous movement, and pressing the drum pedals can prove very challenging for patients whose disease is at a further state.

This system solves these problems, by making a conventional drum kit more interesting. Visual feedback from LEDs in the respective drums reflects how far the bass drum and hi-hat pedals are pressed. Furthermore, LEDs in all other drums, such as the snare drum and the toms, function as visual cues and suggest which drums are to be hit next by the user. Visual cues in the drums will also reflect the rhythm of the music and show if and how hard a user has hit the drum. Furthermore, visual cues can be alternated between drums, encouraging users to change the order with which foot they press the bass drum and hi-hat pedals.

In this way, the system enhances various aspects of the therapy. It helps patients perform movements correctly, by showing them if the drums are correctly hit. It also gives users direct feedback on how hard they are hitting the drums, possibly pushing users to perform even better. Furthermore, it makes using the drum kit less monotonous by allowing and encouraging users to hit multiple drums in multiple different orders.

3.2.2 Final idea

From the four ideas previously described, one was chosen to be developed for the final prototype. The Marimba play along system was deemed most interesting for this setting, as it is an enhancement of a currently used system, so the intended users should be familiar with it already and not have too much trouble using it. If such a system works well, it could improve the fun users feel while doing the exercise and improve their motivation and results. Furthermore, such a system can be easily extended with visual cues, which can prove their effectiveness.

3.2.3 Requirements

For this system some requirements were made. These requirements are used during the realisation phase to make the system function optimally. These requirements are ordered using a MOSCOW (must, should, could, won't) system.

User requirements	System requirements
Must	
Users must be able to play the xylophone in a way similar to how they would play a conventional xylophone.	The system must sense when one of its bars is hit. And play a xylophone sound according to this bar.
Users must receive feedback when their mallet hits the wrong xylophone bar.	The system must give visual feedback on the bar hit by the user.
Users must be able to play along with songs.	System must suggest notes to play by giving (visual) cues at these notes.
The system shows the user at least one note of the chord that's played every bar.	The system highlights the to-be played note using visual cues at the right bar of the marimba.
The rhythm of the system should reflect the rhythm of the music.	To-be played notes should change to the rhythm of the music.
User must see which notes to hit next after they hit the current ones.	The system senses when the user hit a marimba bar and switches the visual cues.
The music tempo must be adjustable to the user's needs.	The system should have a way of setting the rhythm of the cues.
The playable area of the marimba should span at least 12 notes.	The system must house at least 12 sensors and sources of visual cues.
Should	
User's therapist should be able to view results of using the system.	System should store results connected to a user.
The system should offer a selection of different songs.	There should be a way to change the song suggested by the system.

When a user gets three or more successful hits, a special sound effect should play as a reward.	The system should count successful hits. On the third hit, a special sound should play.
Could	
The system could show every note of the chord that is played, allowing them to pick which to play.	The system shows visual cues at various bars of the marimba corresponding to the notes in the chord.
The system could show the rhythm of the music using visual cues.	The system should have a light or visual that blinks rhythmically to the music.
The songs that the user plays along with could be the same as the songs played during therapy.	Songs suggested by the system could be the same songs as played by the music therapist
Won't	
The system teaches users musical scales or theory.	
The system teaches users how to play songs.	

4 Realisation

In this chapter the construction of a final prototype is documented. Using the ideas from the previous chapter, combined with the requirements and the feedback from the first test sessions, one of the four most feasible ideas could be chosen. It was decided that the most interesting idea was the Marimba that allows patients to play along with music, therefore this will be developed further.

This chapter describes how the prototype for this system was developed in multiple parts. First, an overview of the system will be given. After that, the electronics within the system will be described. Then, the construction of the frame of the system will be described. Finally, an outline the software that controls the system will be given.

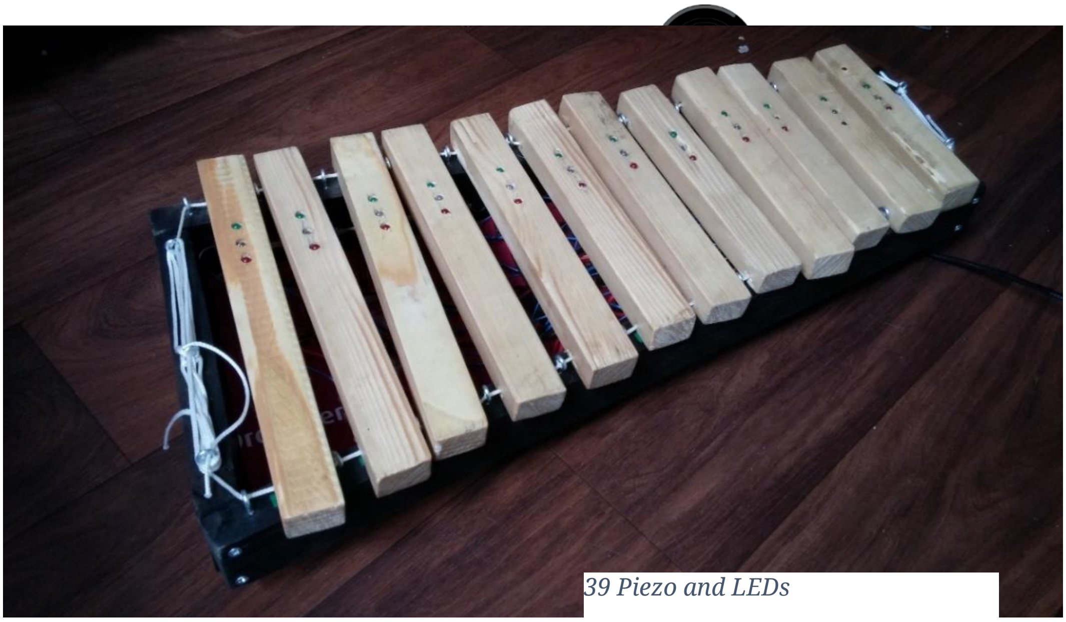
4.1 Overview

The final prototype visually resembles a xylophone. It has twelve bars, which users can hit using mallets. The system can be connected to a computer using the USB cable that extends from it. Its dimensions are approximately 0.50x0.25x0.1m. A picture of this system can be found in figure 38.

Feedback is given to users through the three LEDs in every bar. The white LEDs will show which notes are to be hit next by users. The green LEDs show which notes can currently be hit in order to play along to the song. The red LEDs either show which notes to avoid or whether the user has hit a wrong note. Furthermore, every bar a piezo transducer glued to its bottom. These electronics are connected to an Arduino and will be described in further detail later.

The system is controlled by a computer. This computer has to run a processing sketch in order to set up and start the system. The processing sketch allows users to pick which song they want to play along to, as well as the bpm. On pressing start, the computer starts playing the song and the system's LEDs will start working. When a user hits one of the bars of the system, a xylophone sound will play in the processing sketch.

4.2 Electronics



39 Piezo and LEDs

38 System

Like previously stated, every xylophone bar houses three LEDs and a Piezo transducer. These are all connected to their own Arduino pin and to the Arduino ground. An overview of such a one-bar circuit can be seen in figure 39.

Some resistors are used in this circuit. Between the anode of every LED and its respective Arduino pin, a 270Ω resistor is placed. This resistor is present to limit the current through every LED to prevent the LED from burning out. A 1MΩ resistor is placed in parallel to the piezo transducer to make it behave more reliably.

4.3 Music and Sounds

This section describes the music and sounds that play while using the system.

4.3.1 Sounds

The sounds played by the system are sampled marimba sounds. These have been downloaded at patcharena.com [50]. From the 63 samples in the pack, 12 have been selected ranging from notes C3 to B4. These notes have been trimmed down using Reaper – A digital audio workstation software which can be used to edit audio - in order to make the response when hitting the system's bars as natural as possible, without any delay occurring between the user hitting the system and the note playing.

4.3.2 Music

The music played by the system is a MIDI based version of "Let It Be" by The Beatles. The MIDI file was downloaded at midiworld.com [61]. These files were then edited using Reaper in order to make some instruments, like the piano sound better by using higher quality MIDI instruments than the standard MIDI synthesizer in windows, as well as changing the tempo.

This song will be played by three instruments. The most important instrument of the music is a piano, for which the Sound Magic Piano One plugin was used [52]. The focus on piano was done to reflect the setting of conventional TIMP. Two other layers, an organ and a brass section will provide an extra layer to the music to add some dynamics without becoming too distracting. These are played by the AM Music VL-122 and the DSK music brass vst plugins respectively [53][54].

Every song used in the system was edited to three tempos. Available tempos are 80bpm, 90bpm and 100bpm. These tempos were chosen because this is the same range of tempo used during the TIMP sessions at Artez. However, due to memory restrictions in processing, only 90bpm will be available in the final prototype.

4.3.3 Click

A click track was generated using Reaper. This click track will be playing simultaneously with the music and will function as the metronome conventionally used during TIMP.

4.3.4 Sound effects

Sometimes when users hit the system successfully, a special sound effect will play. This sound will be randomly selected from one of five available special effects. These effects sounds are; The mooing of a cow, the trumpet of an elephant, the ringing of a phone and two sci-fi inspired swooping sounds. These sounds will play simultaneously with the note played by the user. Goal of these special effects is to add a surprise effect to the program, which users might find fun and motivating.

4.4 Software

The software used in this system consists of two parts. One part is the processing code running in a computer controlling the system. The other part is the Arduino software that runs on the Arduino that is housed in the system

4.4.1 Processing

40 Processing interface

This system is controlled by a multipurpose processing code. This can be divided into two sections; Adjusting settings and handling sounds. The processing sketch will also display the number of times users hit on time, missed, or hit the right note but were either early or late. A screenshot of this program can be found in figure 40.

For sound handling, the main thing processing does is play the music. This will be done by loading sound files into the processing sketch which will play after users press start. Processing will then also send a letter 's' to the Arduino, which signals the Arduino to start running its LED guiding algorithm in sync with the music. Another thing the processing does, is receive data from the Arduino when a xylophone bar is hit and translate this data into a note. Processing will then determine which sound file belongs to this note and play this file. Finally, the processing code will play the sound effect files after users hit in time a certain number of times. This number of times, named the fxTreshold in the processing code will be set randomly between 2 and 6 every time an effect plays.

Adjusting the settings can be done by clicking on screen buttons. Users can set the tempo with which the music plays and the LEDs in the system change colour. Furthermore, every LED or only the red LEDs can be switched off in order to remove all visual cues or only the negative feedback. The whole processing code can be found in Appendix B3.

4.4.2 Arduino

The main task of the Arduino code is to detect when a bar of the xylophone is hit and to show users which bars they should hit using LEDs. When a user hits one of the xylophone bars, the Arduino code will read the values of the pins to which the respective piezo transducers are connected. This value will then be sent to the processing code, together with a header denoting which note was played and another character denoting whether or not the hit was on time, late or early, or whether the wrong bar was hit. When a wrong bar is hit, and negative cues are not turned off, the red LEDs in the respective bar will also blink.

The Arduino code also guides users through a song. If visual cues are not turned off, the Arduino code will use the chord scheme of the song that is playing in processing to determine which chords are currently playing and should be shown through the green LEDs , as well as which chords are the next to be played and should be shown through the white LEDs. This chord scheme is preprogramed in the Arduino code and matches the chord scheme for The Beatles' song described earlier. The complete Arduino code can be found in Appendix B1.

5 Evaluation

This section describes the test that will be used to evaluate the system developed during this project. The first part of this test will be a performance test, which will determine how the system affects the rhythm of the subjects through the use of visual cues, as well as how the cues influence the fun and enthusiasm they experience. The second part will be a usability test, which will mainly focus on the way users experience this system.

This test will first be performed in two different settings. First, the system will be tested at the University of Twente. In this setting, subjects will be university students who volunteer as test subjects. Later, the test will be repeated at Artez during a music therapy session. Here the system will be tested by Parkinson's patients present at the session. The results obtained from the tests with university students will be mainly used in determining the clearness of the visual cues given by the system, as well as the influence on fun and enthusiasm of the system when visual cues are given. The tests with the Parkinson's patients at Artez will be more useful in determining the actual effectiveness of the system and its usability for the target group. However, due to the small population size of available Parkinson's patients, it is still deemed important for determining the effectiveness of the system to test with more people, even if those do not belong to the target population. Before testing, subjects will have to sign the consent form found in appendix C.

5.1 Performance test

This section describes the testing of the performance of the system. First, the goal of the test is described, then the method, including the various test types, and finally observations are written and a conclusion is made.

Goal

The goal of the performance side of this test is to determine how well the system performs. The three main criteria that will be measured are how the system affects the rhythm and timing of users, the fun users experience while using the system and how enthusiastically users interact with the system while using it. Furthermore the goals of the usability part of the test will focus on three main things. The first of these is whether or not the visual cues distract subjects from the music they are playing. The music should always be the most important part of the therapy and therefore the system should not take the focus away from this. The second focus point is to determine whether negative cues demotivate users. During the lo-fi test described earlier, some users noted that they might get frustrated or demotivated when a system tells them they are doing an exercise wrong. Finally, the third focus point is whether people enjoy using this system more than playing a conventional xylophone.

5.1.1 Hypotheses

The following hypotheses H1 to H8 will be tested;

H1: *"Visual cues given by LEDs are effective in showing users which notes to play."* This hypothesis is important because it shows how effective these visual cues are. This hypothesis will be tested through observations, performance measurements and survey questions.

H2: *"Visual cues allow users to time their hits more rhythmically."* This hypothesis, too, will show whether visual cues are effective in assisting users in this exercise. This hypothesis will be tested through observations and performance results.

H3: *"Visual cues cause users to be more focussed while interacting with the system."* This hypothesis is used to test whether or not the visual cues are distractive for the user. This hypothesis will mainly be tested through observations.

H4: *"The added visual guides cause users to get bored less quickly."* This hypothesis is used to test whether the interaction is interesting for users. This hypothesis, too, will mainly be tested using observations and performance test results.

H5: *"The visual cues distract users from the music that they are playing."* The music and the metronome should always be the most important part of the therapy and therefore the system should not take the focus away from them. This hypothesis will be tested using observations.

H6: *"Negative cues will demotivate users."* During the lo-fi test, some of the target users noted that they might get frustrated or demotivated from receiving negative feedback. This hypothesis will be tested using observations and survey results.

H7: *"Users will enjoy playing a xylophone more when they receive guidance from visual cues, allowing them to play along to a song more accurately."* This will help determine whether users actually enjoy playing the system more than a conventional xylophone. This hypothesis will be tested using survey question and observations.

H8: *"Surprise sound effects will motivate users to try harder while playing the guided xylophone system."* This hypothesis will be tested using observations and results from the survey.

5.1.2 Methods

Three test conditions were initially performed to test these hypotheses, with a fourth added later. Every subject will perform the "Music and metronome, no visual cues" condition, because this resembles the situation of the therapy sessions most closely. Next to this condition, subjects will either perform the "Music, metronome and visual cues" or "Music, metronome and visual cues no negative feedback" condition. The order of the two test conditions performed by one subject will be randomized, in order to prevent the effects of a learning effect. The goal of these two different tests is to determine the effect of negative feedback on the fun of the exercise. The fourth test condition is similar to the "Music and metronome and visual cues" condition, but in this condition fewer visual cues will be shown.

While performing these tests, subject will be filmed and observations will be made. These observations will help evaluate the effectiveness of the system in improving the fun of the marimba exercises, as well as the enthusiasm with which subjects hit the xylophone, and will help determine which aspects still need improvement. While doing the second, third or fourth type of test, the system will also record the performance of these test subjects. In addition to this, users will be asked to fill in a questionnaire about their experience using this system. This questionnaire will also be used to determine the usability of the system. This questionnaire, both in Dutch and in English, can be found in appendix C.

The tempo of the music played during the exercises will be set to either 90pbm for the student test group and to 60bpm for the test group at Artez. These tempos were chosen because a slower tempo was assumed to be not challenging enough for the student test group, which would lead to them getting bored whereas a faster tempo than 60bpm would be too fast for the test group at Artez due to the cognitive and physical slowness of people with Parkinson's disease.

This test was first performed with students of the University of Twente. The first sample group of these students first randomly got assigned test condition 2 and 3. The second group of students all performed condition 4. Later, test condition 4 was also performed with Parkinson's patients at Artez. All subjects, except the Parkinson's patient group, all performed condition 1 as well for reference. The order of performed test conditions was randomized for every subject, as to prevent a learning effect. The Parkinson's patients were unable to perform more than one test condition, however, because these people all have experience playing a xylophone, this is not deemed a problem.

5.1.2.1 Condition 1: Music and metronome, no visual cues

During this test condition, subjects will be asked to play along to a song using the system. A metronome will also be playing. This setting resembles the way a xylophone is used in conventional music therapy sessions. Therefore, it helps in determining a baseline performance level, to which the other two tests scenarios can be compared.

5.1.2.2 Condition 2: Music, metronome and visual cues

During this condition, subjects will again be asked to play along to a song using the system. In addition to the song, a metronome will also be playing and rhythmic visual cues will be given by the system. These visual cues will also guide subjects to certain notes, which they are supposed to play. White LEDs will suggest which notes subjects should play next. Green LEDs will show which notes should currently be hit and will blink on a correct hit. Red LEDs are not lit, but will blink when a subject hits a wrong note. A sound effect will play on every third well timed note a subject plays.

5.1.2.3 Condition 3: Music, metronome and visual cues (no negative feedback.)

During this conditions, subjects will again be asked to play along to a song using the system. In addition to the song, a metronome will also be playing and rhythmic visual cues will be given by the system. These visual cues will also guide subjects to certain notes, which they are supposed to play. White LEDs will suggest which notes subjects should play next. Green LEDs will show which notes should currently be hit and will blink on a correct hit. Red LEDs are not lit, and will not blink when a subjects hits a wrong note. A sound effect will play on every third successful hit a subject plays.

5.1.2.4 Condition 4': Like condition two, but only one note

Because test conditions 2 and 3 showed that often test subjects had trouble with the multitude of visual cues, it was decided to add a fourth condition. This condition is similar to condition two, but instead of showing three notes every bar of music, only one will be shown. This way, the amount of visual cues will be limited. To support this claim hypotheses H4' and H4" will be added.

H4': *"Decreasing the amount of visual cues makes it simpler for users to use this system."* This hypothesis will be tested using performance measurements and observations.
H4": *"Decreasing the amount of visual cues will increase the enjoyment of users using this*

system." This hypothesis will be tested using performance measurements, observations and survey results.

5.1.3 Results

In this section, the results from the tests described in the previous section will be discussed. First, the observations will be described and discussed. Then, the performance measurements will be described and discussed. Finally, the survey results will be elaborated on.

5.1.3.1 Observations

Student test group conditions 2 and 3.

The following test subjects performed conditions 1 and 2 or 3 in the following order;

Subject no.	First test type	Second test type
1	1	2
2	3	1
3	1	2
4	3	1
5	2	1
6	1	3
7	1	2
8	3	1
9	2	1
10	3	1
11	1	2
12	1	3
13	2	1
14	3	1
15	1	2
16	2	1
17	1	3
18	1	2
19	3	1
20	2	1
21	1	2

During these test sessions, various observations were made. While performing condition 1, six subjects showed a bored facial expression and uninterested body language, whereas six other subjects either exclaimed that they felt stupid performing this test or showed uneasy laughter. In two cases, subjects said that they felt like a little child. In ten of these cases, test subjects eventually lost interest in the system. For three of these subjects, this happened after twenty seconds, for four subjects, after thirty second and for another three subjects, after a minute. Four subjects exclaimed or showed confusion before starting to play the system during this test, with two of them complaining that they did not know what to do. When condition one was performed after condition 2 or 3, subjects would sometimes start in a similar fashion, rhythmically hitting notes, but they would eventually give up on this. This behaviour was found in three test subjects.

This uninterested behaviour was almost completely absent during conditions 2 and 3. These two conditions are discussed simultaneously, because the interaction with the system during these tests was very similar and the negative feedback provided by the red LEDs did not seem to affect test subjects in any way. During this condition, only one subject got bored and wanted to stop before the test had finished. On the other hand, 10 subjects looked really focussed while playing the system in a way that was not observed in the previous condition. This was deducted from their stern facial expression, with their eyes fixed on the system. Their body language also suggested more focus than during condition one, with most subjects looking less relaxed and holding the mallets close to the xylophone's bars.

In this user group, the rhythm with which the users played varied greatly. In this test group, only three subjects had the notion of hitting exactly on the beats they were expected to, which were beat 1 and 3. In contrast, seven test subject played rhythmically, but on count 2 and 4. This suggest it took most users some time to process which lights were green and that these users were not able to use the white LEDs to anticipate which notes would become green. This could be caused by the number of LEDs which were on at a single time, which seemed to be overwhelming to most users, but this will be discussed later. Finally, eight subjects played the system arrhythmically, with five of these people playing every suggested note one by one focussing more on hitting every green note than doing so rhythmically. One of these users also did not distinguish between green and white notes, but just hit everything that was lit up.

Another interesting aspect shown during these conditions was the confusion caused by the LEDs. 14 subjects had trouble deciding which bars to hit and process which bars were currently alright to hit and which bars would soon be alright to hit. This was caused by the amount of visual cues given. Because 6 LEDs were on at the same time, often subjects were overwhelmed by the amount of input they were receiving, resulting in them not knowing which notes to hit and sometimes playing the wrong ones. For this reason another test condition with additional hypotheses was added, these will be explained later.

Student test group condition 4.

The following test subjects performed test condition 4 and 1 (listed as 5 here) in the following order;

Subject no.	First test type	Second test type
22	1	4

23	4	1
24	4	1
25	1	4
26	1	4
27	4	1
28	4	1
29	1	4
30	1	4
31	4	1
32	1	4
33	4	1
34	1	4
35	1	4
36	4	1
37	4	1
38	1	4
39	1	4
40	4	1
41	1	4
42	1	4

For this test group, during condition 1, ten subjects lost interest in the system before finishing the test. Eight of these subjects got bored with the system after 30 seconds and two subjects lost interest after a minute. Two of these subjects wanted to stop before the test had ended. Four test subject showed confusion before starting to play notes because they did not know what to play. Fourteen of these subjects again showed awkward laughter, suggesting they felt stupid while performing this test condition, while six subjects showed boredom in the same way the previous test group showed.

In contrast to the previous test group, however, test subjects from this group had less trouble following the visual cues, with as much as sixteen subjects having no trouble following them at all. Four subjects, however, at one point hit a wrong note, after which they needed a few seconds to get back into playing. Again, subjects seemed to be more focussed than during test condition 1 and four subjects even were smiling more. In comparison to conditions 2 and 3, users performing condition 4 also played more rhythmically. In this case, fifteen subjects exactly timed their hits on counts 1 and 3, with only one subject playing on counts 2 and 4, which during the previous test conditions almost every subject did. Furthermore, no subjects played the system totally arrhythmic.

However, in this simpler test condition, confusion was still caused by the visual cues. At some point during the song, the chord did not change, which resulted in the visual cue remaining at the same note. This confused most every user, even if they did not have trouble following the visual cues during the rest of the test.

Artez test group

During the test session at Artez observations were also made. These subjects performed test condition 4, but it must be noted that the tempo was set to 60bpm for these tests instead of the 90bpm tempo used for the student test group. This was done because the faster tempo was expected to be too high for the people from the therapy group. These people noted that they found using the system quite challenging at this tempo already, therefore this decision was justified.

Every subject from this test group was able to follow the directions of the visual cues. However, every subject - except one - did not rhythmically time their hits (Note; these are observations. Objective measurements will be discussed later.) They were more preoccupied with hitting the right notes when they were green, which was doable for all of them. The only situation in which the visual cues proved to be troublesome was again when the chord did not change between two bars, which caused both the white and the green LED to be on the same note at the same time. When this happened, subjects did not know what to do and instead did not play the note.

One thing that should be noted is the stance in which people use this system when it is placed too low. If this is the case, users will stand hunched over, which is bad for their posture. Therefore such a system should be placed on a surface that's high enough for the user to maintain a good posture. Furthermore, the music therapist noted that this was more a focus exercise than a physical exercise.

Sound effects effect

Between the three conditions during which sound effects could play, no noticeable difference in how users responded to them was found. In total, nine subjects did not respond at all when a sound effect played, six subjects laughed or smiled after a sound effect played and seven other subjects were confused or distracted by the sound effect. Furthermore, for almost every subject, the novelty of the sound effects wore off after hearing them a couple of times, after which these subjects no longer responded to them.

During the tests at Artez, the sound effects seemed to have a greater effect. They seemed to distract the users less than during the student tests. Furthermore, the sound effects seemed to motivate people. In some cases subjects were visually proud when they triggered a sound effect to play. Other effects made subjects laugh or smile. Especially the cow sound was effective in this. The occurrence of these positive effects rather than the sound effects causing confusion can be explained by the fact that these test subjects were all present in the room while another subject was using the system. Therefore they knew beforehand that the sound effects would play when they performed well, which could cause motivation.

Other

Finally, at least twelve test subjects over all these tests had trouble with getting the system to respond. One subject even was unable to get the system to play more than ten notes during the session, because they were simply not hitting the xylophone bars at all. Even though twelve subjects is only approximately 25 percent of the sample size, all these subjects can be expected to have greater physical strength than people suffering from Parkinson's disease. Therefore, the sensitivity of the system should be increased.

5.1.3.2 measurements

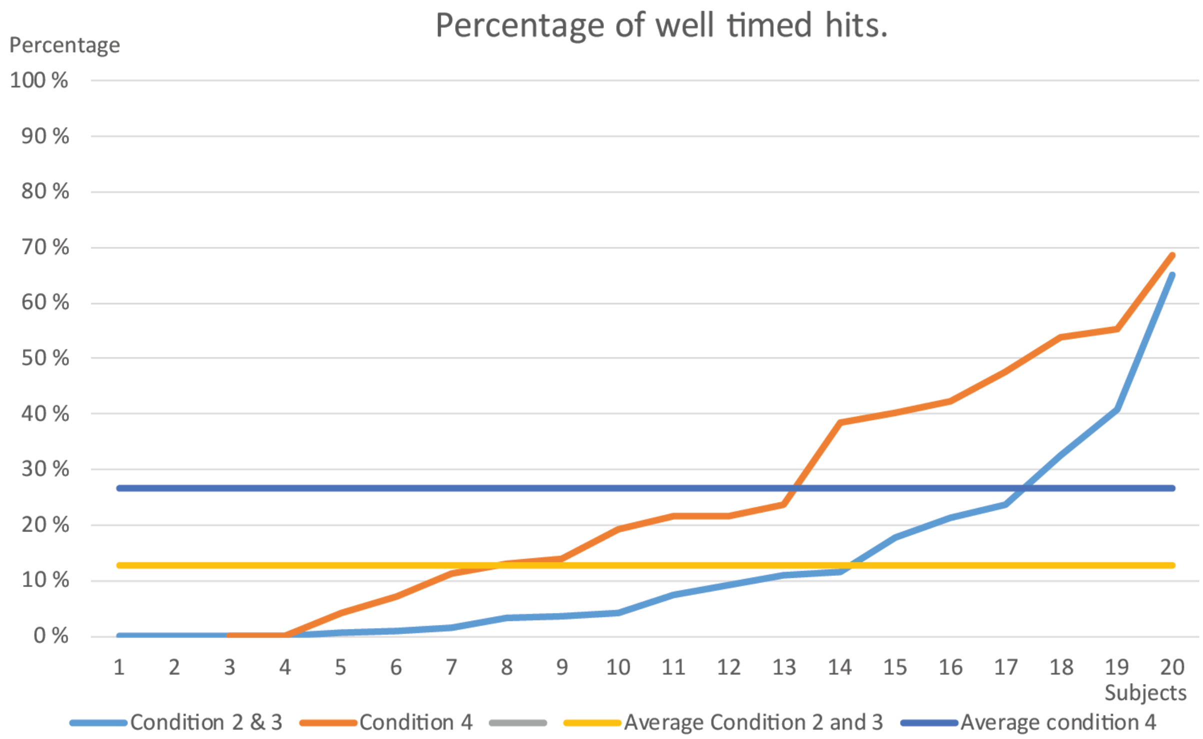
5.1.3.2.1 Student test groups.

The graphs below show the performance of the user test group during test conditions 2,3 and 4. Conditions 2 and 3 are combined, as the interaction with the system is more or less the same during these conditions, and the visual cues seemed to have no effect on subjects. Every bending point in a line denotes another test subject, the averages are a flat line. Bar graphs are also added to show the number of subjects per a certain percentage of a specific type of hits. These bar graphs give a different view of the performances of these subjects.

The following legend corresponds to the bar graphs shown in this section;

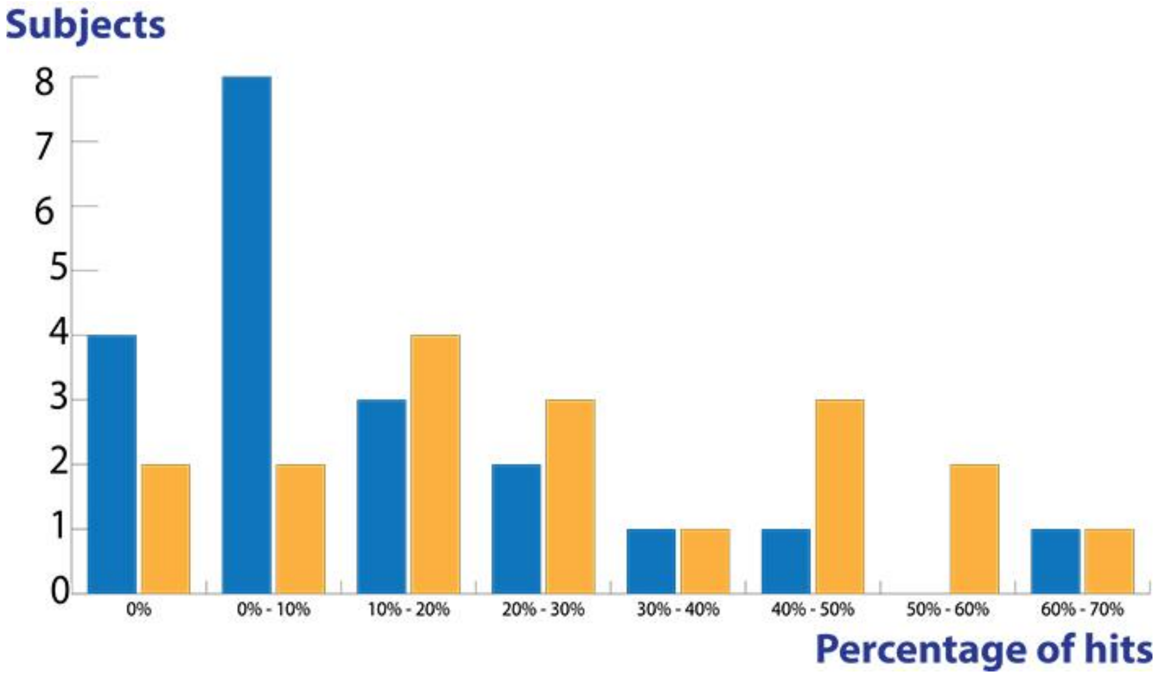
41 Legend bar graphs

Figure 42 shows the number of well-timed hits (<200ms off the mark). This percentage is quite low with an average of 12 percent for conditions 2 and 3 and a higher average of 28 percent for condition 4. This shows that exactly timing hits on the moment the LEDs change from white to green is challenging for most users. This however gets easier when the number of visual cues is decreased from three notes to one note per chord/bar of music.



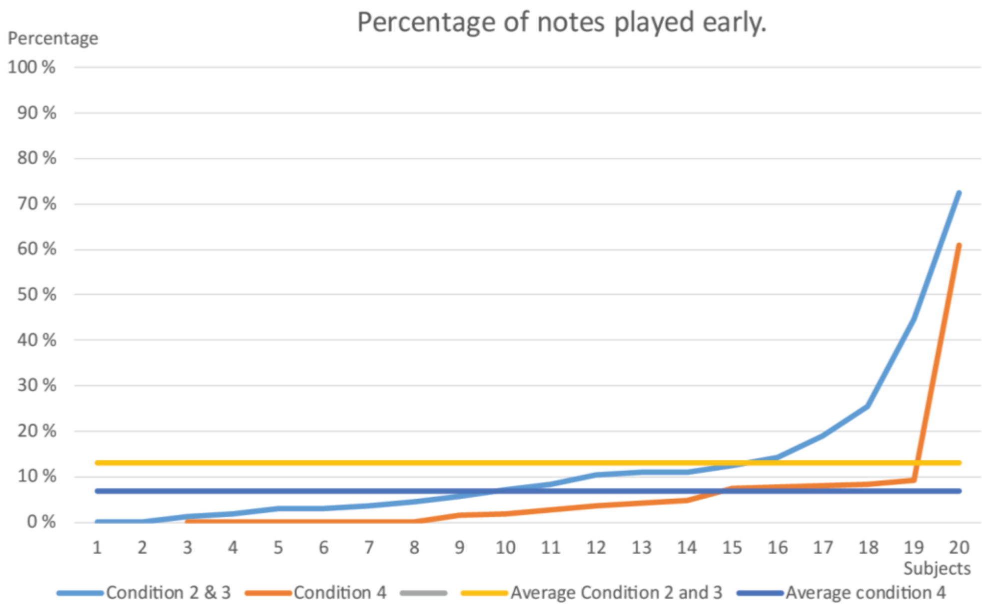
42 Well timed hits

Figure 43 shows that the distribution of well-timed hits changed between test conditions. In test conditions 2 & 3, the number of test subjects scoring a certain percentage of well-timed hits leaned more towards the lower side of the spectrum, with a high peak between 0% and 10% of their hits being well-timed. In test condition 4 this was more evenly distributed, which suggests that it was easier for most people to time their hits during this test condition.



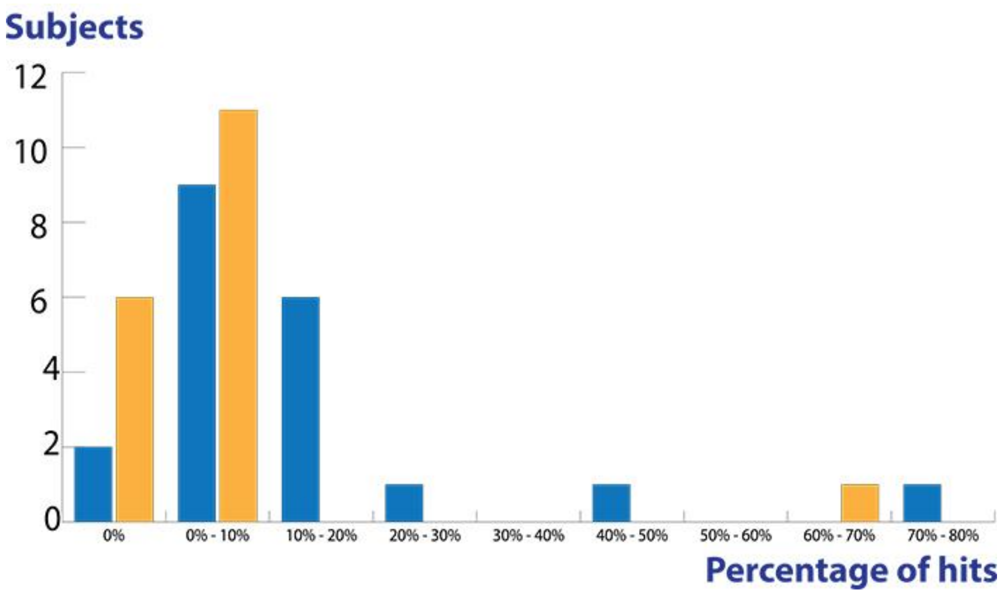
43 Subjects per percentage of well-timed hits

Figure 44 shows the percentage of notes hit early. This is when users hit a note when the LED of this note is still white. The low average for all three test conditions, with an average of 12 percent for conditions 2 and 3 and an average of 7 percent for condition 4, shows that most users were able to avoid the white LEDs most of the time. Ideally this percentage would be as low as possible, therefore these low averages are very acceptable. It has to be noted however, that there are two and one test subjects in conditions 2 & 3 and condition 4, respectively, that played a significantly higher amount of notes early than average. It could be that these subjects misunderstood the meaning of the LEDs. Without these high values, the average notes played early would be even higher.



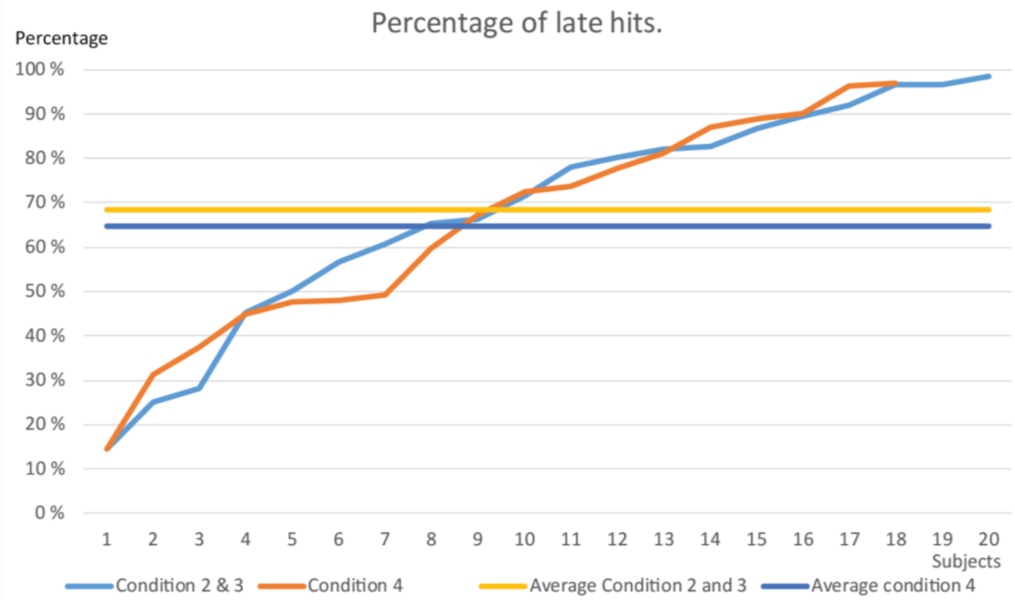
44 Notes played early

Figure 45 shows that the distribution between condition groups shifted a little in this case as well. In test conditions 2 and 3, most subjects played between 0 and 10 percent of their notes early. A smaller, but still significant number of subjects played between 10 and 20 percent of their notes early. This shifted for test condition 4, with the majority of test subjects playing between 0 and 10 percent of their notes early. Furthermore, a far larger number of subjects played 0 percent of their notes early than during test conditions 2 and 3. This shows an obvious improvement in test condition 4 over test condition 2 and 3 for the usability of the visual cues. It has to be noted, however that for both tests there are some significant outliers with subjects playing as much as 70 percent of their notes early. This could be caused by these specific subjects having trouble timing their hits or misunderstanding the visual cues.



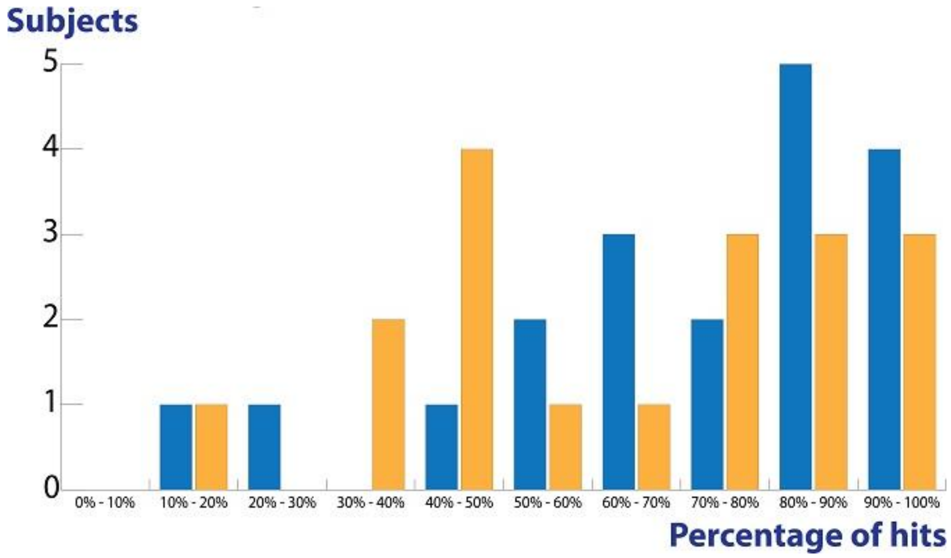
45 Subject per percentage of early hits.

Figure 46 shows the number of notes played later than they were supposed to. This percentage is quite high in every test condition. This too shows that it is hard for users to time their hits on the exact moment that the LEDs on a note change from white to green. On the other hand, it also shows that users do not have much trouble using visual cues to determine which notes to hit. Furthermore, it shows that, although users seemed to have much more trouble using multiple visual cues, as was the case in tests 2 and 3, they still performed well in this condition..



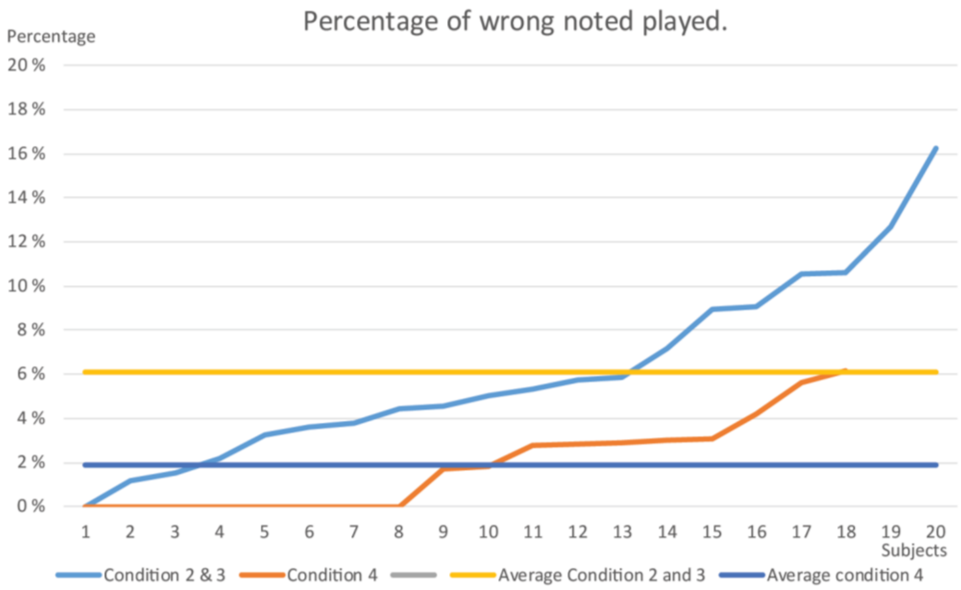
46 Notes played late

Figure 47 again shows a shift in distribution for the test subjects for this condition. Where during test condition 2 and 3, the number of subjects playing notes late was somewhat normally distributed around 80 to 90% of their hits. This shows that a lot of subjects under these conditions had trouble correctly timing their hits. This shifted towards a more equal distribution for test condition 4. This suggest that it is easier for subjects to not play notes late when the number of visual cues is decreased.



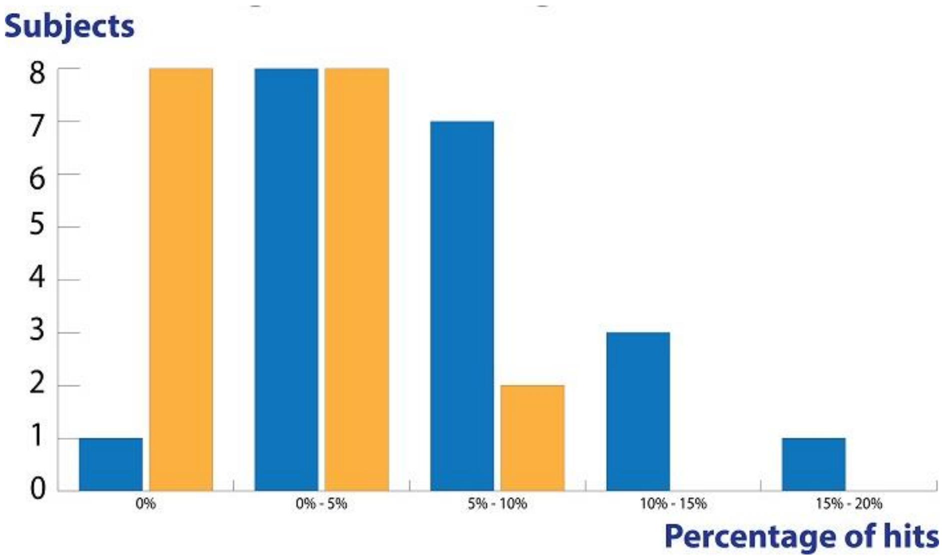
47 Subjects per percentage of late hits.

Figure 48 shows the percentage of wrong notes. The averages for both test show, that users rarely hit wrong notes. The very low average of 2 percent of condition 4 shows that lesser visual cues lowers this percentage even further than it was for conditions 2 and 3.



48 Wrong notes played.

Figure 49 shows a decrease in wrongly played notes for condition 4. This suggests that a decrease in visual cues makes it somewhat easier for people to aim their hits to a correct note, or at least to not hit a wrong note. For all test conditions, however, the percentage of wrongly hit notes is quite low already. This suggests that it is doable for most subjects to avoid notes they should not hit.



49 Subjects per percentage of wrong notes hit

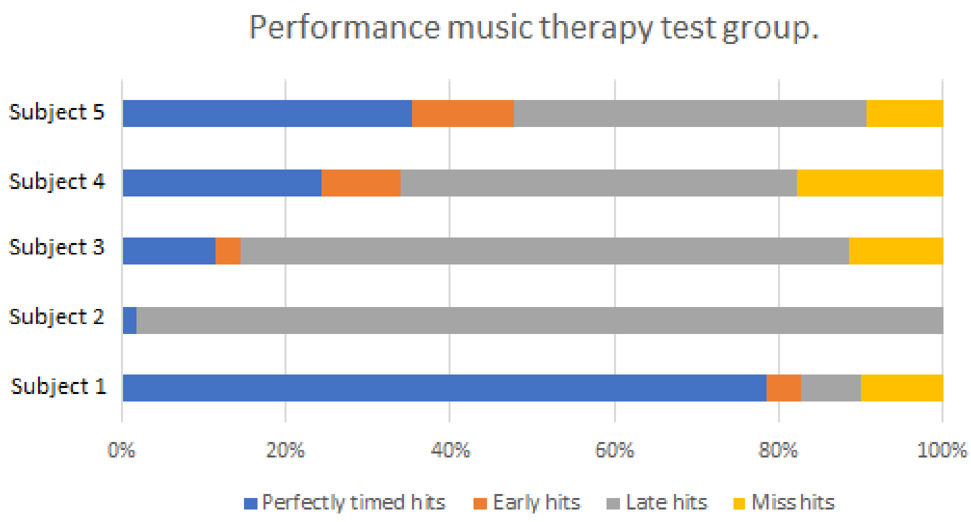
5.1.3.2.2 Statistical significance

For all these graphs, it was tried to determine the statistical significance. For all these graphs there would be a null hypothesis H0; *"The groups are equal"* and an alternative hypothesis H2; *"The groups are not equal."* This would help determine if there is a statistical difference between the two conditions. In order to test this, the Mann Whitney U Test was applied. This test was chosen because the data found during the user tests does not have a normal division. Therefore, more conventional tests such as the t-test could not be applied. The Mann Whitney U Test, however, can be applied to nonparametric data such as is used in this case.

The outcome of this test, which was done with a significance level of 0.05, was for every set of data - Well timed hits, early hits, late hits and missed hits – that there was no difference between the two conditions, thus the null hypothesis being true. This however, could be doubted, because there is a clear difference between some of the averages found earlier, such as in the percentage if wrongly hit notes. Furthermore, it should be noted that this statistical test proves to be unreliable with a small group of samples, as was the case here. Therefore these statistical results could be questioned.

5.1.3.2.3 Parkinson's patient test group.

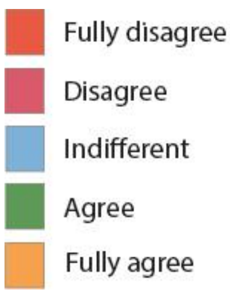
Like said before, these subjects all only performed condition 4. Results for this group can be found in figure 50. Performance within this group greatly varies. Especially subjects one and two are interesting outliers. Subject one perfectly timed almost 60 percent of their hits, whereas subject 2 only hit correct notes, but played 98 percent of them later than on the exact moment the LEDs switched colour. This might indicate that the lights changed too quickly for this person. The other subjects all performed similarly, playing most notes right, but late and only hitting at most 18 percent wrong notes.



50 Music therapy test group results (please note; the legend shown earlier does not apply for this figure)

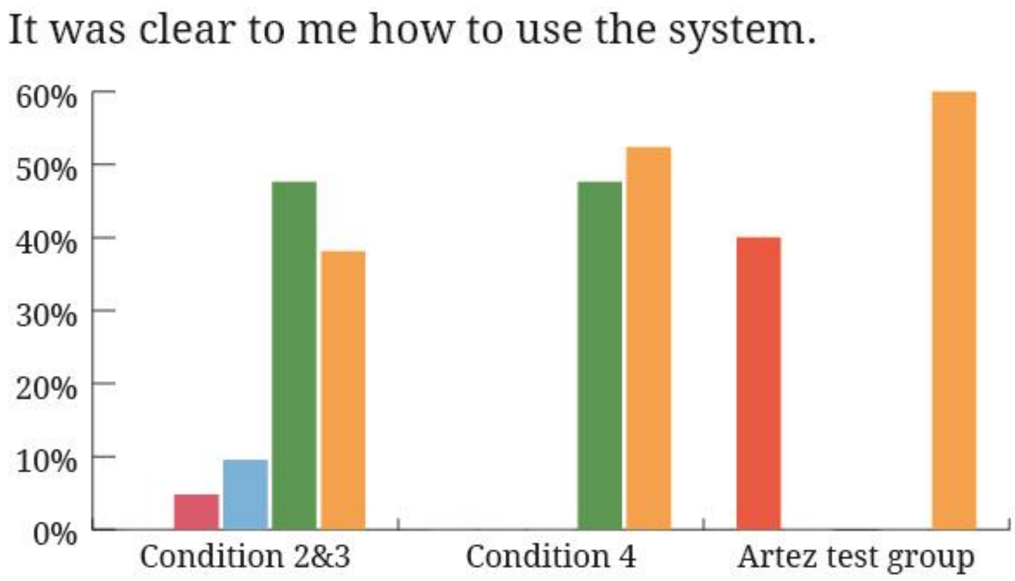
5.1.3.2 Survey results

In this section the results of the survey will be discussed. These results will be presented using bar graphs. The legend of these bar graphs can be found in figure 51. The survey questions were all statements, which will be described later. Test subjects were asked to note to what degree they agree with these statements on a scale from 1 to 5 with 1 being “fully disagree” and 5 being “fully agree.” The Artez test group referred to in the bar graphs is the group of Parkinson’s patients at the music therapy sessions described before.



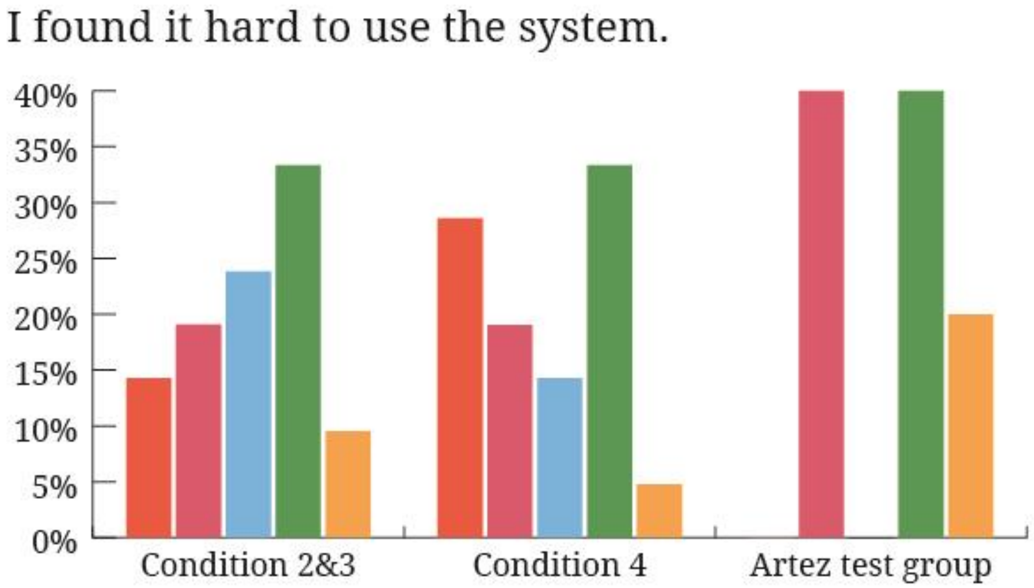
51 Legend survey results

The first survey question was *“It was clear to me how to use the system.”* In the graph in figure 52 can be seen that in the student test group most subjects had no problem understanding the system. 85 percent of subjects agreed with this statement for test conditions 2 and 3, with 100 percent of subjects giving a positive answer to this statement. The test music therapy test group was more divided, with 60% of subjects noting that they had no problem understanding the system and 40% claiming that they did not understand the system.



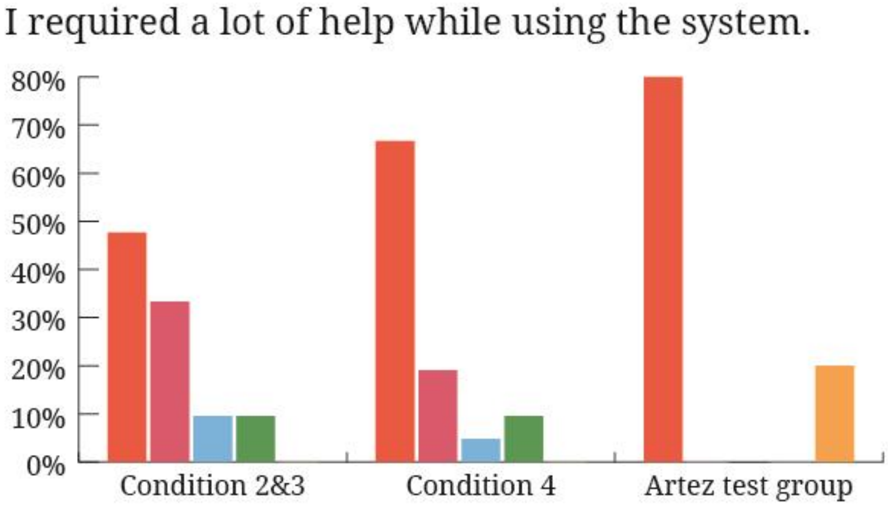
52 Results question 1

The second statement was *“I found it hard to use the system.”* This statement was met with very differing answers, of which a representation can be found in figure 53. Almost as many subjects stated they did not find the system hard to use as the number of subjects stating they found it hard to use. For condition 2 and 3, this amount is almost perfectly balanced, with approximately 45 percent of subjects agreeing with the statement and 35 percent of subjects disagreeing with the statement. This balance shifted a little towards disagreement in condition 4, with only 40 percent of subjects agreeing to the statement versus approximately 50 percent disagreeing. The Artez test group also mainly agrees with the statement, suggesting these subjects found the system hard to use.



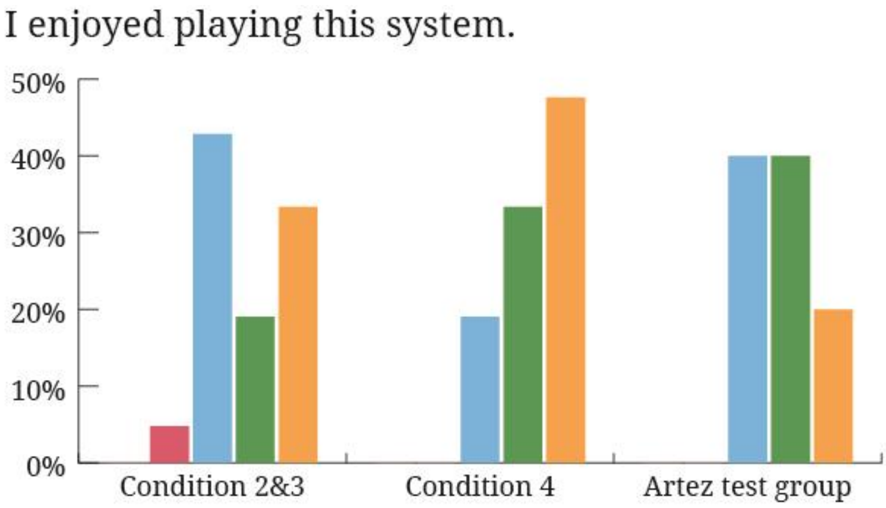
53 Results question 2

The third statement was *“I required a lot of help while using the system.”* The answers to this statement are summarized in figure 54. Most subjects answered negatively to this question, which means they did not need a lot of help. This suggests that the system can be well used by everybody with only minimal instruction.



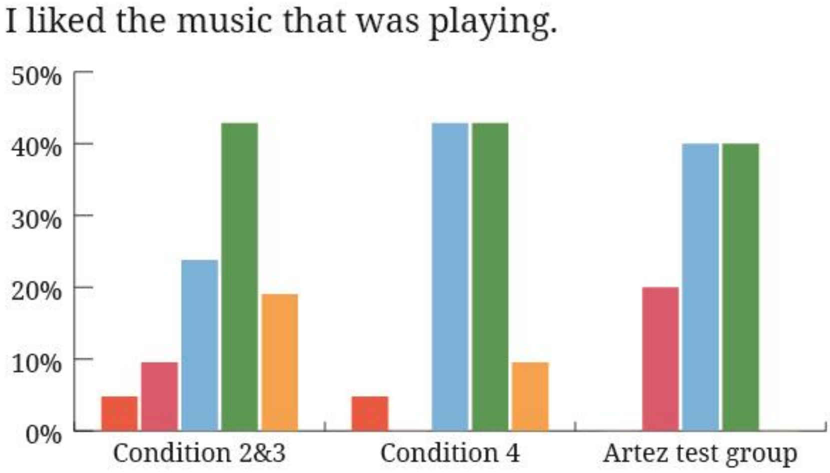
54 Results question 3

The fourth statement *"I enjoyed playing this system."* was met with generally positive responses. The summarized answers to this question can be found in figure 55. It must be noted, however, that during test conditions 2 and 3, 42 percent of test subjects claimed to be indifferent towards the system, with approximately 55 percent of test subjects claiming they enjoyed playing this system. During test condition 4, more subjects claimed to enjoy their time spent with the system, with more than 80 percent of subjects giving a positive answer. The Artez test group also in general was positive about their usage of the system, but here, too, a large group of test subjects claimed they were indifferent (40 percent.)



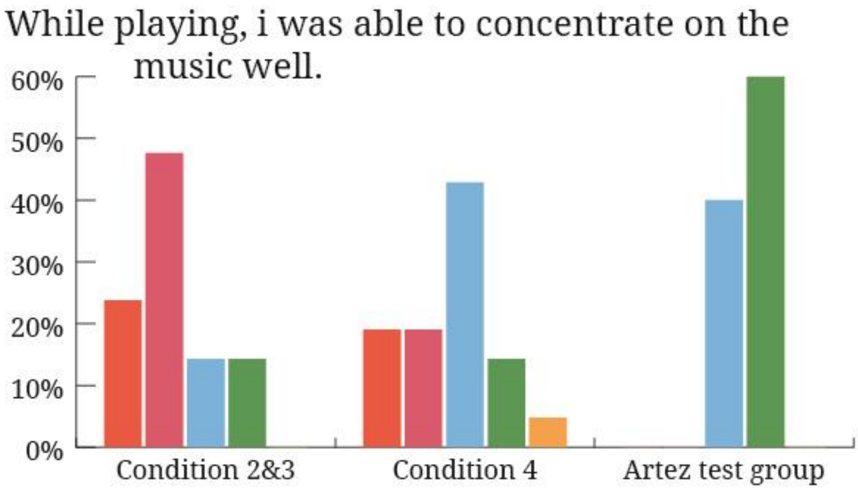
55 Results question 4

The fifth statement was *"I liked the music that was playing."* Responses to this statement are summarized in figure 56. Although not too important for the interaction with the system, this could explain if and why some subjects like or dislike the interaction with the system. When someone does not like the music, it can be expected they did not like the overall experience with the system either. However, this does not seem to be the case, as this statement was met with either generally positive responses, or subjects being indifferent.



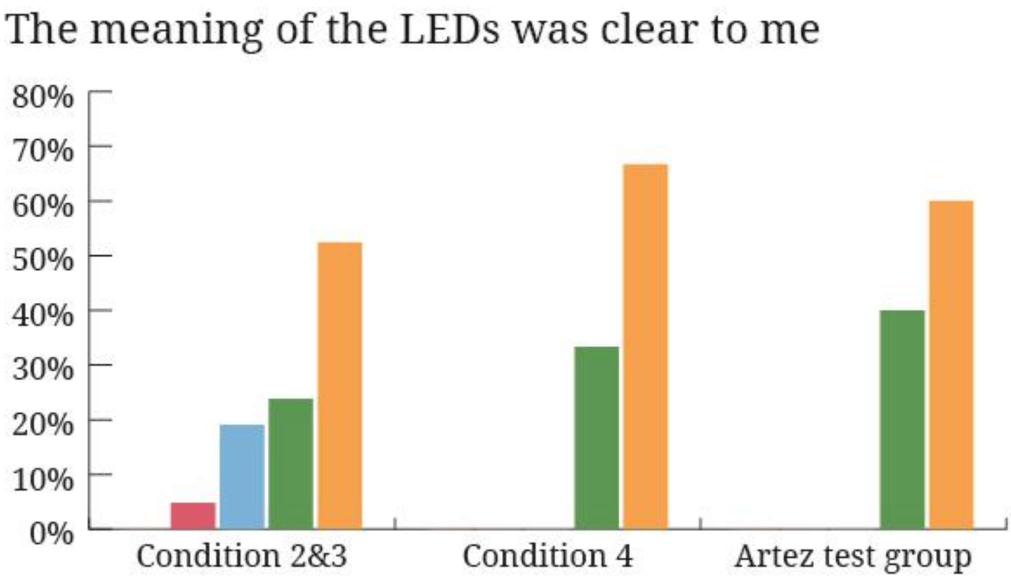
56 Results question 5

The sixth survey question was *"While playing, I was able to concentrate on the music well."* The results for this question can be found in figure 57. It is important that the music remains the most important aspect of the theory, therefore the system should not distract from this too much. For all student test groups however, the responses to this statement were generally quite negative with people noting that they were not able to focus on the music well. On the other hand, the Artez test group seemed to have less trouble with this, with 60 percent of subjects claiming they did not have any trouble. This could be due to the fact that these people will have more experience performing such exercises and therefore were able to focus more easily..



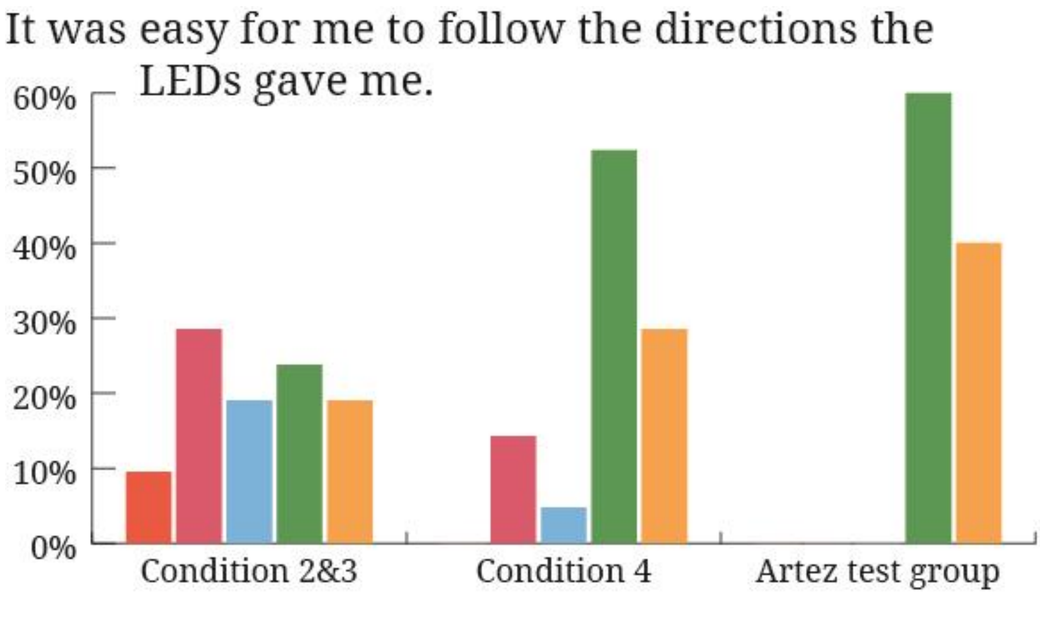
57 Results question 6

The seventh question was *“The meaning of the LEDs was clear to me.”* The results for this question can be found in figure 58. Responses to this was generally positive, which suggests that there was no confusion about the meaning of the LEDs.



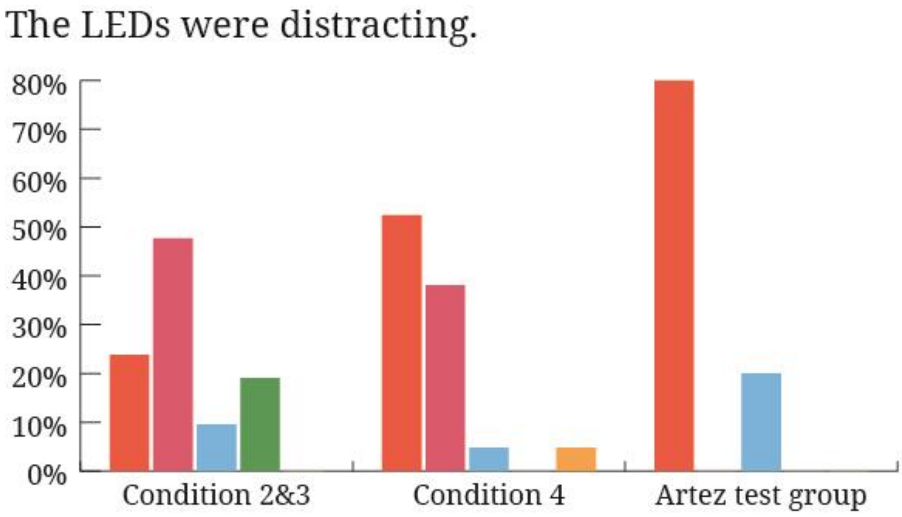
58 Results question 7

The eight statement was *“It was easy for me to follow the directions the LEDs gave me.”* Results for this statement can be found in figure 59. This statement was met with mixed responses especially in the student test group performing test conditions 2 and 3. This could be caused by the multitude of LEDs, which often caused confusion. This claim can be supported by the fact that subjects claimed to have less trouble following the questions in both the condition 4 student test group and the Artez test group, who also performed a test where less visual cues were shown.



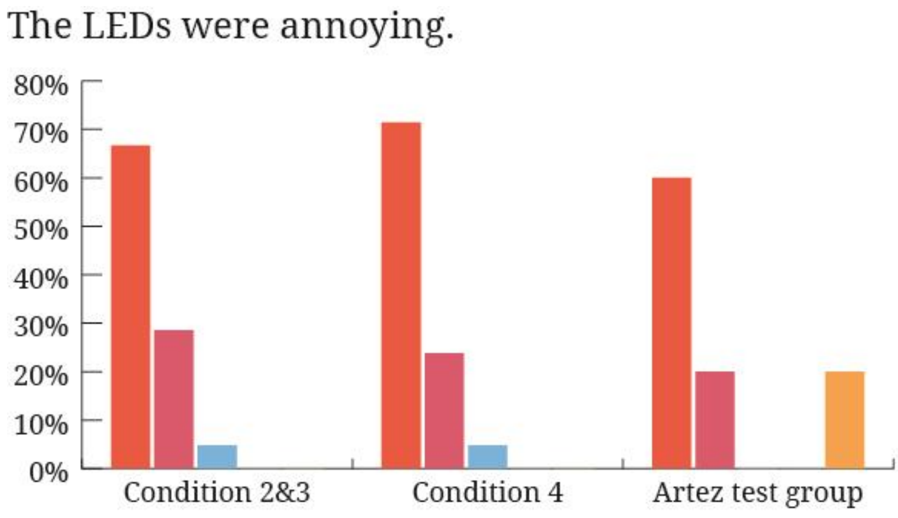
59 Results question 8

Statement nine was *"The LEDs were distracting."* Results for this question can be found in figure 60. This statement was met with generally negative responses, which shows that subjects did not feel that the LEDs were distracting them. No significant differences are noted between the group of subjects performing test conditions 2 and 3 and the group of subjects performing condition 4. Therefore it is can be assumed that the negative feedback from the red LEDs has no impact on the interaction with the system.



***60** Results question 9*

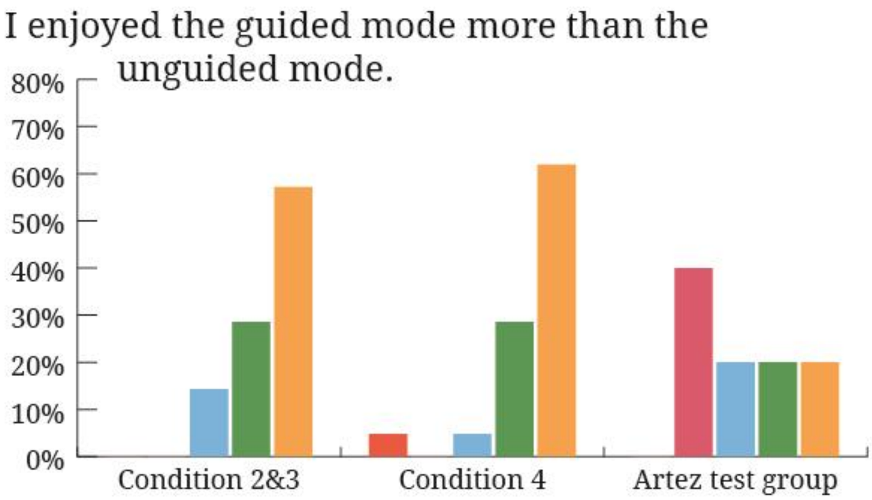
The tenth statement was *"The LEDs were annoying."* Results for this statement can be found in figure 61. This statement too was met with generally negative responses, which suggests subjects did not find the LEDs annoying. Again, there is no difference between the group of subjects performing test conditions 2 and 3 and the group of subjects performing condition 4. This supports the claim that the negative feedback from the red LEDs has no significant impact on the interaction with the system.



***61** Results question 10*

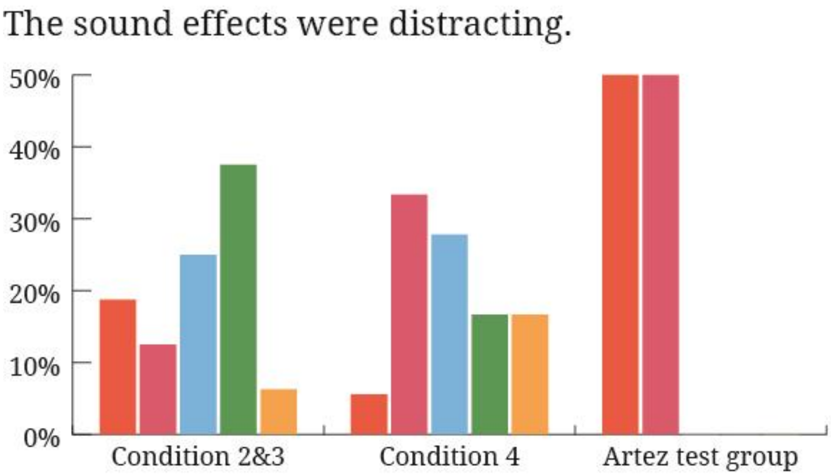
Statement eleven was *"I enjoyed the guided mode more than the unguided mode."* This was important to test, because it shows whether or not users actually enjoy playing such a system more when receiving visual guidance. Results for this question can be found in figure 62.

Interesting is that, while the student user test group was generally positive about this, the Artez test group answered this question with mixed responses. 40 percent of these subjects were positive about using the system, whereas another 40 percent claimed they did not like using the system.



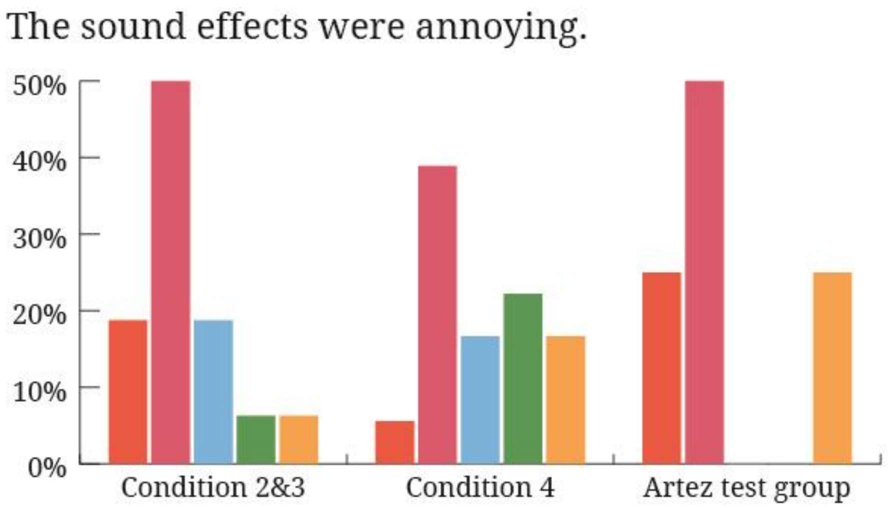
62 Results question 11

The final three statements were about the sound effects that played every time users scored multiple successful hits. The first of these statements was *"The sound effects were distracting."* Results for this statement can be found in figure 63. The Artez test group replied mostly negative to this statement, meaning they did not feel distracted by the sound effects. The student test groups, however, had a more mixed response to this statement, with almost as much subjects claiming they felt distracted as claiming they did not feel distracted by the sound effects in all three test conditions.



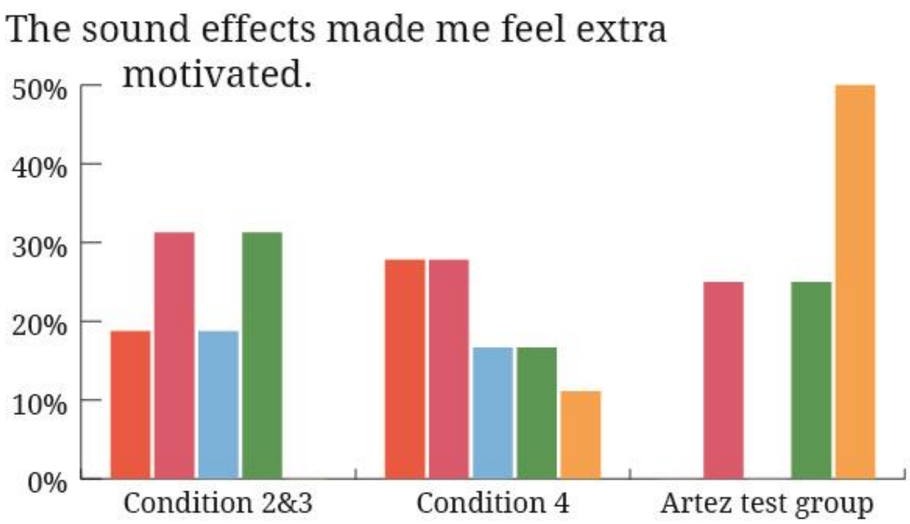
63 Results question 12

The second statement about sound effects was *"The sound effects were annoying."* Results for this statement can be found in figure 64. Again, the Artez test group mostly claimed they did not feel distracted by the sound effects, with only 20% of subjects (one subjects) saying that they did feel distracted. The student test group again gave a mixed response to this question, but the majority of subjects in this group also responded negatively to this statement. Therefore, the sound effects can be assumed to be not too distracting.



64 Results question 13

The final statement was *"The sound effects made me feel extra motivated."* Results for this statement can be found in figure 65. This statement was in the student subject group met with mixed responses, leaning towards the negative side. This suggests that these people were not motivated by the sound effects, which is in agreement with the observations made. The Artez group replied to this statement more positively, which also is in line with the observations made during this test session.



65 Results question 14

Sound effects

Some remarks were made about the sound effects. Two test subject noted that the sound effects were a bit distracting because they did not fit the music. One subject specifically mentioned that they hated the sound effects. Another subject claimed that knowing that the sound effects are going to play on hitting a right note will motivate you, otherwise they are distracting.

Other

Other remarks made by test subjects are about the LEDs and the sensitivity of the system. Four subjects noted that the multitude of LEDs made it hard to follow them. This supports the observations made earlier. In addition to this, two subjects noted that the LEDs are too bright. Furthermore, one subject mentioned the red LEDs as being distracting, because they give you one more cue to focus on. (this was during condition 4). And finally, two test subjects noted that they thought the system should be more sensitive.

6. Conclusion

These results and observations can help reflect on the hypotheses given earlier.

H1: *“Visual cues given by LEDs are effective in showing users which notes to play.”*

Observations and survey results made during users tests show that visual cues can be effective in showing which notes users should play. The meaning of the colours of the lights was clear in both test subject groups and most users had no trouble finding which notes they were to hit. Measurements made during test conditions 2, 3 and 4 support these claims, with only a small percentage of hits being made on a wrong note. However, it has to be noted that when a lot of visual cues are given, this can confuse users. This can lead to them requiring more time to process the meaning of these cues, leading to a decrease in their rhythmicality.

H2: *“Visual cues allow users to time their hits more rhythmically.”*

From observations and measurement results can be concluded that visual cues affect the rhythm with which subjects hit the system in various ways. When three visual cues per chord were shown, like during test condition 2 and 3, often subjects did not time their hits rhythmically to make sure they hit all or any right note. This rhythmic timing was increased when the number of visual cues was decreased to one. However, in both cases subjects were more focussed and more goal oriented than during the test condition wherein no visual cues were shown.

H3: *“Visual cues cause users to be more focussed while interacting with the system.”*

Observations made of the student test group support this hypothesis. Body language of these users suggested they were more focussed during the guided test than during the unguided test. Furthermore, users tended to lose interest in the unguided test very quickly, which did not happen during the guided test.

H4: *“The added visual guides cause users to get bored less quickly.”*

Observations made during the user tests support this hypothesis. During the unguided test, a big percentage of users got visually bored very quickly, with some of them even wanting to quit after some time. Others eventually got more interested in the specifics of the system, such as whether or not it was actually playing a scale etc., than in playing the system. These distractions were not present during the guided test.

H4’: *“Decreasing the amount of visual cues makes it simpler for users to use this system.”*

Performance tests and observations made support this hypothesis. Users seemed to have less trouble following the visual cues when only one LED was on per chord at any time, instead of three. The measurements made during these test support this, with a higher average of perfectly timed hits and a lower average of missed hits during the test condition in which only one visual cue was given.

H4”: *“Decreasing the amount of visual cues will increase the enjoyment of users using this system.”*

The information collected during the tests do not give a concrete answer to this statement. Observations, test results and surveys all do not give evidence that allows us to claim this hypothesis to be true, but it also does not give evidence that allows us to reject the alternative hypothesis. A slightly higher percentage of test subjects from the condition 4 test group claimed to enjoy their time using the system more than the conditions 2 & 3 test group, but this difference is not significant enough to support any concrete claims about this improvement.

H5: *“The visual cues distract users from the music that they are playing.”*

This hypothesis is both true and false. Survey results show that the student test group was unable to focus on the music very well, with mixed results leaning towards the majority of them feeling distracted. The Artez test group, on the other hand, claimed they were able to focus on the music well. This could either be due to the tempo with which the test was performed being lower, or due to the fact that these people have more experience playing a xylophone, which might make the interaction more natural for them.

H6: *“Negative cues will demotivate users.”*

During the users tests, there was no observable difference between the test group performing the test condition with and the test group performing the test condition without visual cues. Therefore, it can be assumed that the negative cues from the red LEDs have no impact on the users of this system. This means the alternative hypothesis fails to be rejected.

H7: *“Users will enjoy playing a xylophone more when they receive guidance from visual cues, allowing them to play along to a song more accurately*

Survey results suggest this hypothesis to be true. In the student test group in all three test conditions, the majority of subjects claimed that they enjoyed playing the guided mode more than playing the unguided mode. It has to be noted, however, that the Artez test group answered this question with mixed opinions, with as many people claiming they did not enjoy the guided mode more as people claiming they did enjoy the guided mode more.

H8: *“Surprise sound effects will motivate users to try harder while playing the guided xylophone system.”*

Observations made during the student test group suggest this hypothesis be untrue. Most users from this group did not respond at all to the sound effects and if they responded, they only did so the first couple of times such a sound effect triggered by them. Most of them also noted that they did not feel extra motivated by the sound effects. The Artez test group, however, responded completely differently to these sound effects. They seemed to enjoy them much more and also seemed proud when they triggered one. 75 percent of test subjects from this group that triggered a sound effect, also claimed that they felt more motivated by them.

7. Recommendations

Finally, some recommendations for a follow up research can be made. The first of these recommendations is to test with a bigger subject group. Firstly, the sample size of test subject was too small to be representative for the entire population to which these test subjects belong. Secondly, during the statistical analysis of the results, the subject group proved to be too small for analysis using statistical tests. Thirdly, the test group consisting of people with Parkinson’s disease was too small to give a clear idea of their experience with the system and how usable it was for them. Therefore, for a following research, the number of test subject should be greatly increased and more tests should be performed with people from the actual target user group; people with Parkinson’s disease.

The second recommendation is to improve the interaction with the system. Firstly, a better way of detecting impact than piezo transducers should be used. These piezo transducers worked, but they were not sensitive enough. This lead to a lot of people having problems with triggering a response from them, which is especially troublesome for Parkinson’s patients, who have decreased muscle strength. Therefore, some other system should be devised, perhaps something with an electric circuit that will be completed when someone hits one of the xylophone bars.

The third recommendation is that the system should be adjustable to the needs of the users. People like variety and therefore a variety of songs should be added to the system for the users to choose from. Furthermore, the system should offer different tempos that can be set to the needs and wishes of the user and should be adjustable during the playing of a song. This way, the challenge can be increased after the user got some time to adjust and acquaint themselves with the interaction.

Fourthly, the visual cues could be applied in other, more interesting ways. Visual cues have proven to be effective as a rhythmic trigger and are useable by most people, as long as they are used in moderation. However, the usage of visual cues in this project is fairly basic and they could be applied in more interesting, more meaningful ways.

Finally, the music therapist noted that this system was an example of a cognitive exercise rather than physical exercise. The goal of TIMP is physical exercise and therefore it might be interesting to find similar ways of applying the visual cues described in this research in ways that match better with the goals of TIMP. For example, instead of putting them in a xylophone, the visual cues could be used similarly in a collection of drums. Visual cues then would guide users towards a certain drum which would sound good with the music they are playing along to. These drums could be placed away from each other, so users have to walk over to them in order to be able to hit them. This could combine the cognitive exercise provided by this system with the physical exercise of TIMP.

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Appendix A1 Arduino code lo-fi prototype

Note: this code is basically the knock sensor example code found on Arduino.cc

```
/* Knock Sensor
 * (cleft) 2005 D. Cuartielles for K3

 * edited by Scott Fitzgerald 14 April 2013
 */



int ledPin = 13;
int knockSensor = 0;
byte val = 0;
int statePin = LOW;
int THRESHOLD = 200;
int del = 250;


void setup() {
 pinMode(ledPin, OUTPUT);
 Serial.begin(9600);
}


void loop() {
  val = analogRead(knockSensor);
  if (val >= THRESHOLD) {
    statePin = !statePin;
    digitalWrite(ledPin, statePin);
    Serial.println("a");
delay(del);  // we have to make a delay to avoid overloading the
serial port
}}
```

Appendix A2 Processing v3 code lo-fi prototype

```
import processing.serial.*;
import processing.sound.*;

//new sound and image
SoundFile snare;
PImage bg;

//new serial port
Serial port;

//default string input
String input = "";

//for serial connection line end
int end = 10;

boolean playOnce; //boolean that checks if the sound is playing


//Create the ArrayList of Waves
ArrayList<Wave> waves = new ArrayList<Wave>();

int time = 7;
// time = 1 ------  pussy mode
// time = 4 ------  25 pbm
// time = 7 ------  50 pbm
// time = 40 -----  gabber mode
// time = 100 ----  speedcore



//The Wave Class
class Wave {
  //The distance from the wave origin
  int circleRadius = 550;
  int timer = 0;

  //Color
  color strokeColor;

  int g = 255;

  Wave() {


    strokeWeight(20);



    //Green stroke
    strokeColor = color(0, g, 0);
  }


  void update() {
    //increase timer
    timer ++;
    //Green to black
    g -= 2;
    strokeColor = color(0, g, 0);
```

```
    //Set the Stroke Color
    stroke(strokeColor);

    //Draw the ellipse
    ellipse(8 + width/2, height/2 - 3, circleRadius, circleRadius);
  }

  boolean dead() {
    //Check to see if this is all the way out
    if (timer > 80) {
      //If so, return true
      return true;
    }
    //If not, return false
    return false;
  }
}



void setup() {

  snare = new SoundFile(this, "snare.mp3");

  port = new Serial(this, Serial.list()[0], 9600);
  port.clear();


  bg = loadImage("snare.jpg");
  size(640, 617);

  //Set all ellipses to draw from the Center
  ellipseMode(CENTER);
}


void draw() {
  while (port.available() > 0) {
    input = port.readStringUntil(end);


    if (playOnce) {
      snare.play();
      playOnce = false;

      Wave w = new Wave();
      //and Add it to the ArrayList
      waves.add(w);
    }
  }

  port.clear();
  playOnce = true;
  background(bg);
  noFill();


  //Run through all the waves
  for (int i = 0; i < waves.size(); i ++) {
    //Run the Wave methods
    waves.get(i).update();
```

```
    //Check to see if the current wave has gone all the way out
    if (waves.get(i).dead()) {
      //If so, delete it
      waves.remove(i);
    }
  }
}
```

Appendix A3 Processing code v5 lo-fi prototype

```
import processing.serial.*;
import processing.sound.*;

//new sound and image
SoundFile snare;
PImage bg;

//new serial port
Serial port;

//default string input
String input = "";

//for serial connection line end
int end = 10;

boolean playOnce; //boolean that checks if the sound is playing
boolean isHit;
boolean start;


//Create the ArrayList of Waves
ArrayList<Wave> waves = new ArrayList<Wave>();
ArrayList<Hit> hits = new ArrayList<Hit>();

int time = 7;
// time = 1 ------  really slow
// time = 4 ------  25 pbm
// time = 7 ------  50 pbm

class Hit {

  //radius of hits
  int hitRadius;

  int b;
  int r;

  color hitColor;

  boolean miss;

  Hit() {
    hitRadius = 200;
    b = 255;
    r = 255;
    miss = true;

    if (miss) {
      hitColor = color(0, r, 0);
    } else if (!miss) {
      hitColor = color(0, 90, b);
    }
  }


  void updateHits() {

    b -= time;
    r -= time;
```

```
    println(miss);

    if (miss) {
      hitColor = color(r, 0, 0);
    }
    if (!miss) {
      hitColor = color(0, b, 0);
    }

    noStroke();
    fill(hitColor);
    ellipse(8 + width/2, height/2 - 3, hitRadius, hitRadius);
    noFill();
  }
}

//The Wave Class
class Wave {
  //The distance from the wave origin
  int circleRadius = 550;

  //Color
  color strokeColor;

  int g = 255;

  Wave() {


    strokeWeight(20);

    //Green stroke
    strokeColor = color(0, g, 0);
  }


  void update() {
    //increase timer
    circleRadius -= time;
    //Green to black
    g -= 2;
    strokeColor = color(0, g, 0);


    //Set the Stroke Color
    stroke(strokeColor);

    //Draw the ellipse
    ellipse(8 + width/2, height/2 - 3, circleRadius, circleRadius);
  }

  boolean dead() {
    //Check to see if this is all the way out
    if (circleRadius < 5) {
      Wave w = new Wave();
      waves.add(w);
      //If so, return true
      return true;
    }
    //If not, return false
    return false;
  }
}
```

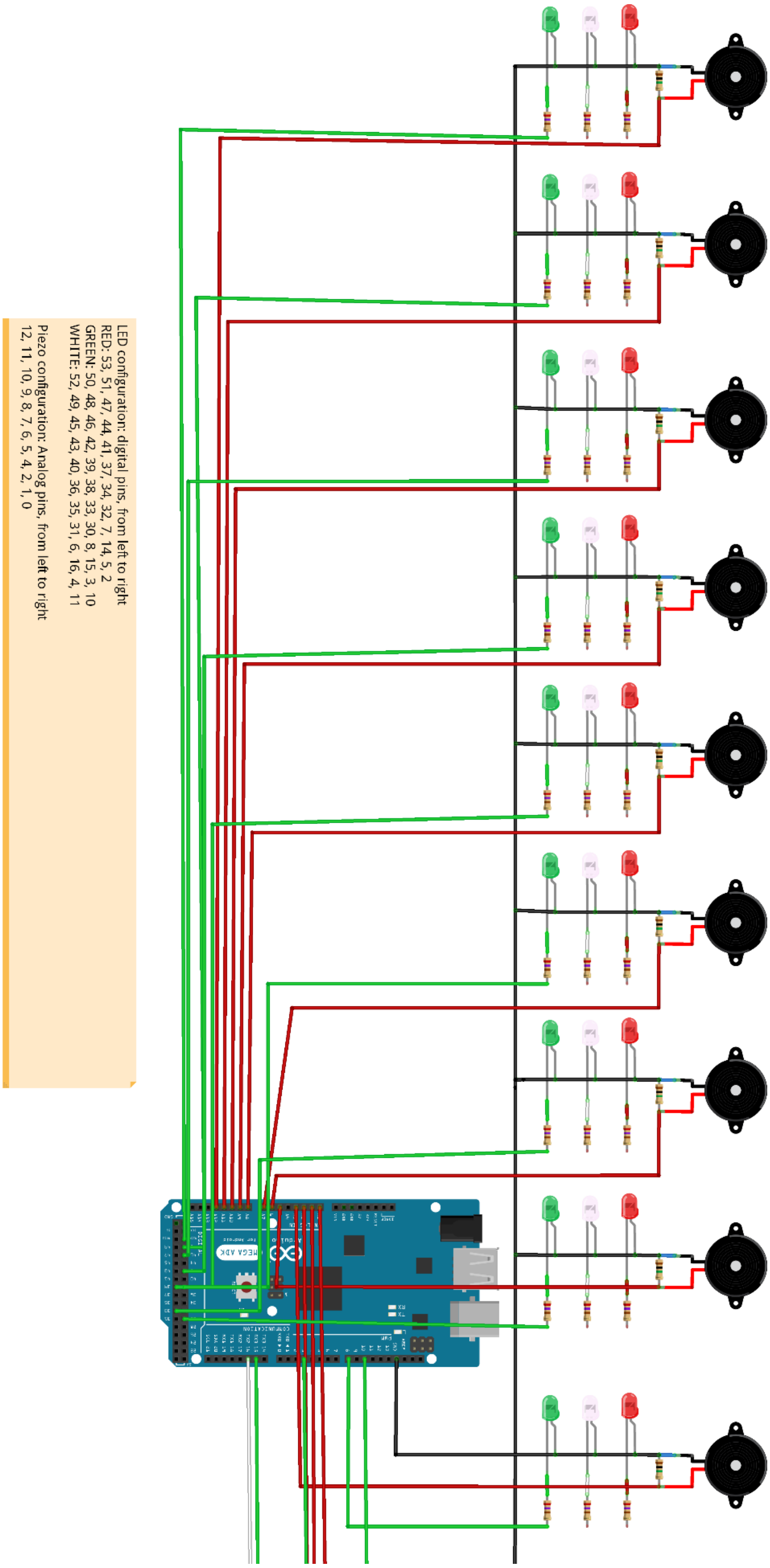
```
void setup() {

  snare = new SoundFile(this, "snare.mp3");

  port = new Serial(this, Serial.list()[0], 9600);
  port.clear();


  bg = loadImage("snare.jpg");
  size(640, 617);

  //Set all ellipses to draw from the Center
  ellipseMode(CENTER);
}


void draw() {

  //start the program by clicking the mouse
  if (mousePressed) {
    //Create a new Wave
    if (!start) {

      Wave w = new Wave();
      //and Add it to the ArrayList
      waves.add(w);

      start = true;
    }
  }

if (hits.size() > 0) {
      for (int i = 0; i < waves.size(); i ++) {
        //Run the Wave methods
        //Check to see if the current wave has gone all the way out

        for (int j = 0; j < hits.size(); j ++){
        if (waves.get(i).circleRadius < hits.get(j).hitRadius) {
          hits.get(j).miss = false;
        }
        }
      }
    }

  while (port.available() > 0) {
    input = port.readStringUntil(end);




    if (playOnce) {
      snare.play();
      playOnce = false;

      //check if hit is timed well
      if (isHit) {
        fill(255, 90, 90);
      } else {
        fill(90, 255, 90);
      }
```

```
      isHit = false;



      //create new hit circle
      Hit h = new Hit();
      hits.add(h);

      noFill();
    }
  }

  port.clear();
  playOnce = true;
  background(bg);
  noFill();




  //Run through all the waves
  for (int i = 0; i < waves.size(); i ++) {
    //Run the Wave methods
    waves.get(i).update();

    //Check to see if the current wave has gone all the way out
    if (waves.get(i).circleRadius < 5) {
      waves.remove(i);
      Wave w = new Wave();
      waves.add(w);
      //If so, return true
    }
  }


  for (int i = 0; i < hits.size(); i ++) {
    //Run the Wave methods
    hits.get(i).updateHits();

    //Check to see if the current wave has gone all the way out
    if (hits.get(i).b < 20) {
      hits.remove(i);
    }
  }
}
```

Appendix B1 Diagram of electronics

Note: there are three more piezo/Led elements that are not on the diagram, due to space limits. These should be added below the image.

Note: the Red and White LEDs are not connected in the image. This was done to keep the image readable. They should be connected to the pins in the yellow note.



Appendix B2 Arduino code

First tab

```
//set bpm here. 90BPM used for user test.
int bpm = 90;

//booleans that check whether (negative) cues are turned off
boolean noCues = false;
boolean noNegative = false;

//use sharps, not flats, capitals for maj chords, lowercase for minor
//dont use 7th chords etc. The software does not know them.

//let it be structure:
// 3x Verse
// Chorus
// 2x Verse
// Chorus
// Verse
// End
//verse = "C", "G", "Am", "F", "C", "G", "F", "C"
//Chorus = "Am", "C", "F", "C", "C", "G", "F", "C"
//End = "F", "C", "G", "C"
String LetItBe[] = {"empty", "empty", "Empty", "Empty",
"C", "G", "a", "F", "C", "G", "F", "C", "C", "G", "a", "F", "C", "G", "F", "C",
"C", "G", "a", "F", "C", "G", "F", "C",
"a", "C", "F", "C", "C", "G", "F", "C",
"C", "G", "a", "F", "C", "G", "F", "C", "C", "G", "a", "F", "C", "G", "F", "C",
"a", "C", "F", "C", "C", "G", "F", "C",
"C", "G", "a", "F", "C", "G", "F", "C",
"F", "C", "G", "C"};

//placeholder songs
String SongTwo[] = {"E", "F", "G", "Ash"};
String songThree[] = {"A", "A"};


//arrays with LED pins
/////////////////C,  C#, D,  D#, E,  F,  F#, G,  G# A,  A# B
byte Green[] = {50, 48, 46, 42, 39, 38, 33, 30, 8, 15, 3, 10};
byte White[] = {52, 49, 45, 43, 40, 36, 35, 31, 6, 16, 4, 11};
byte Red[]   = {53, 51, 47, 44, 41, 37, 34, 32, 7, 14, 5, 2};

//pointer for pin arrays.
byte *pins[] = {Green, White, Red};

//needed to prevent sending hits multiple times.
boolean playOnce[12];
signed long playOnceTimer[12];

//array with piezo pins
int Piezo[] = {12, 11, 10, 9, 8, 7, 6, 5, 4, 2, 1, 0};

//last number sets key state. Order: green (current), white (next),
//red (wrong), previous. 0 = false, 1 = true.
byte keyC[]   =   {0, 0, 0, 0}; byte keyCsh[] =   {0, 0, 0, 0};
byte keyD[]   =   {0, 0, 0, 0}; byte keyDsh[] =   {0, 0, 0, 0};
byte keyE[]   =   {0, 0, 0, 0}; byte keyF[]   =   {0, 0, 0, 0};
byte keyFsh[] =   {0, 0, 0, 0}; byte keyG[]   =   {0, 0, 0, 0};
byte keyGsh[] =   {0, 0, 0, 0}; byte keyA[]   =   {0, 0, 0, 0};
byte keyAsh[] =   {0, 0, 0, 0}; byte keyB[]   =   {0, 0, 0, 0};
```

```
byte *keys[] = {keyC, keyCsh, keyD, keyDsh, keyE, keyF, keyFsh, keyG, keyGsh, keyA,
keyAsh, keyB};

//variables that make the red LEDs blink when a wrong key is hit.
boolean miss[12];
int misstimer[12];

//headers sent when notes are played
//will be translated to sound by arduino
char noteHeader[] = {'A', 'B', 'C', 'D', 'E', 'F',
                     'G', 'H', 'I', 'J', 'K', 'L'
                    };

//treshold values for piezo elements.
int treshold[] =    {200, 200, 200, 200, 200, 200,
                     50, 100, 100, 200, 80, 150
                    };

//needed for sending the letter S to processing
//which confirms that the song has started playing.
boolean songPlaying;

//pointer to the song array
String *songs[] = {LetItBe, SongTwo, songThree};

//default song is Let It Be (playing = 0)
int songlength = 70;
int playing = 0;

//makes sure the system only starts playing once.
boolean start;

//determines the interval between note changes.
int interval = 120000 / bpm;
signed long timer = 0;

//accuracy, default is 8
int accuracy = 8;
int respTime;

//placeholder for how far the song has progressed.
int progression = 0;


void setup() {
  //start serial connection
  Serial.begin(9600);

  // sets all LED pins to output
  for (byte i = 0; i < 3; i++) {
    for (byte j = 0; j < 12; j++) {
      pinMode(pins[i][j], OUTPUT);
    }
  }


}

void loop() {
  if (!start) {
    if (Serial.available() > 0) {
      //function that reads the settings from the serial communcation
      //can be found in tab serial_communication
      serialRead();
```

```
    }
  }
  else if (start) {

    //play lights and end program when song is over
    //can be found in tab Lights
    playLights();

    //detect piezo activity and send notes to processing.
    //can be found in tab serial_communication
    playNote();

  }
}
```

Lights tab

```
void playLights() {
  //make red lights blink if user has hit the wrong bar
  setRed();
  //if progression is not longer than the length of the song
  if (progression < songlength) {

    //if the song has moved to the next bar.
    if (millis() > timer + interval) {

      //makes the song also start playing in processing
      if (!songPlaying) {
        //send an S, so the song starts playing on time
        Serial.println('S');
        songPlaying = true;
      }
      //reset all the lights on every chord change.
      resetLight();

      //and make the lights go out.
      for (byte i = 0; i < 3; i++) {
        for (byte j = 0; j < 12; j++) {
          digitalWrite(pins[i][j], LOW);
        }
      }

      //move to next chord
      progression ++;

      //find current chord
      findChord(songs[playing][progression]);
      //find next chord
      findNextChord(songs[playing][progression + 1]);

      //turn on the LEDs that should be bright
      setLights();

      //make timer sync
      timer = millis();
    }
  }

  //if the song has ended. make all green and white LEDs light up to illustrate the
song end.
  if (progression >= songlength) {
    for (byte i = 0; i < 3; i++) {
      for (byte j = 0; j < 12; j++) {
```

```
        digitalWrite(pins[i][j], LOW);
      }
    }
    for (byte i = 0; i < 2; i++) {
      for (byte j = 0; j < 12; j++) {
        digitalWrite(pins[i][j], HIGH);
      }
    }
    //and stop the code.
    stop();
  }
}


//function that stops the sketch by creating an infinite loop
void stop()
{
  while (1);
}

//makes red lights blink
void setRed() {
  for (byte i = 0; i < 12; i++) {
    //first check if these keys are not green or white
    if (keys[i][0] == 0) {
      if (keys[i][1] == 0) {
        keys[i][2] = 1;
      }
    }
    //and determine whether negative cues arent turned of
    //and if all cues arent turned off
    if (!noNegative && !noCues)  {
      //determine if users have hit the wrong bar.
      if (miss[i]) {
        //make them blink.
        if (misstimer[i] < 60) {
          digitalWrite(Red[i], HIGH);
        }
        if ((misstimer[i] > 60) && (misstimer[i] < 120)) {
          digitalWrite(Red[i], LOW);
        }
        if ((misstimer[i] > 120) && (misstimer[i] < 180)) {
          digitalWrite(Red[i], HIGH);
        }
        if ((misstimer[i] > 180) && (misstimer[i] < 240)) {
          digitalWrite(Red[i], LOW);
        }
        if ((misstimer[i] > 240) && (misstimer[i] < 300)) {
          digitalWrite(Red[i], HIGH);
        }
        if (misstimer[i] > 300) {
          digitalWrite(Red[i], LOW);
          miss[i] = false;
        }
        misstimer[i] ++;
      }

    }
  }
}



void setLights() {
```

```
  //this functions makes some LEDs light up.

  for (byte i = 0; i < 12; i++) {
    //if no cues should be given turn everything off again.
    if (noCues) {
      resetLight();
    }

    //make them bright
    //green leds
    if (keys[i][0] == 1) {
      digitalWrite(Green[i], HIGH);
    }
    else if (keys[i][0] == 0) {
      digitalWrite(Green[i], LOW);
    }

    //white leds
    if (keys[i][1] == 1) {
      digitalWrite(White[i], HIGH);
    }
    else if (keys[i][1] == 0) {
      digitalWrite(White[i], LOW);
    }
  }
}

//resets the value for every light, so the new chord can be determined.
void resetLight() {
  for (int i = 0; i < 12; i++) {
    for (int j = 0; j < 3; j++) {
      keys[i][j] = 0;
    }
  }
}


//function that gives feedback by blinking all LEDs when something
//is selected in processing sketch
void blinkLight() {
  for (int i; i < 12; i++) {
    digitalWrite(Green[i], HIGH);
    delay(10);
    digitalWrite(Green[i], LOW);
    digitalWrite(Green[i], HIGH);
    delay(10);
    digitalWrite(Green[i], LOW);
  }
}
```

Check hit tab

```
void CheckHit(int i) {
  //Serial.println(pins[1][i]);[
  //if light is green and within responsetime; send hit
  if (keys[i][0] == 1 && millis() < (timer + respTime)) {
    Serial.println('P');
  }
  //else send late
  else if (keys[i][0] == 1 && millis() > (timer + respTime)) {
    Serial.println('R');

  }

  //if before hit, but within response time; send hit
```

```
  if (keys[i][1] == 1 && millis() > (timer + interval - respTime)) {
    Serial.println('P');
  }
  //else before responsetime, send miss
  else if (keys[i][1] == 1 && millis() < (timer + interval - respTime)) {
    Serial.println('Q');
  }

  //if red pin is hit; miss
  else if (keys[i][2] == 1) {
    Serial.println('N');
    miss[i] = true;
    misstimer[i] = 0;
  }

}


//send the header corresponding to the played bar
//to processing together with the force of the hit.
void playNote() {
  for (int i = 0; i <= 11; i++) {
    int val = analogRead(Piezo[i]);
    if (val > treshold[i]) {
      if (!playOnce[i]) {
        Serial.print(noteHeader[i]);
        Serial.print(val);
        CheckHit(i);
        playOnce[i] = true;
        playOnceTimer[i] = millis();
      }
    }
    if (millis() > playOnceTimer[i] + 400) {
      playOnce[i] = false;
    }
  }
}
```

Find chord tab

```
void findChord(String name) {

  //This function determines which lights should
  //be bright for which chords

  //major
  if (name.equals("A")) {
    keyCsh[0] = 1; keyA[0] = 1; keyE[0] = 1;
  }
  if (name.equals("Ash")) {
    keyAsh[0] = 1;  keyD[0] = 1;  keyF[0] = 1;
  }
  if (name.equals("B")) {
    keyB[0] = 1;  keyDsh[0] = 1; keyFsh[0] = 1;
  }
  if (name.equals("C")) {
    keyC[0] = 1; keyE[0] = 1; keyG[0] = 1;
  }
  if (name.equals("Csh")) {
    keyCsh[0] = 1;   keyF[0] = 1;   keyGsh[0] = 1;
  }
  if (name.equals("D")) {
    keyD[0] = 1;   keyFsh[0] = 1;   keyA[0] = 1;
  }
  if (name.equals("Dsh")) {
```

```
    keyDsh[0] = 1;   keyG[0] = 1;   keyAsh[0] = 1;
  }
  if (name.equals("E")) {
    keyE[0] = 1;   keyGsh[0] = 1;   keyB[0] = 1;
  }
  if (name.equals("F")) {
    keyF[0] = 1;   keyA[0] = 1;   keyC[0] = 1;
  }
  if (name.equals("Fsh")) {
    keyFsh[0] = 1;   keyAsh[0] = 1;   keyCsh[0] = 1;
  }
  if (name.equals("G")) {
    keyG[0] = 1;   keyB[0] = 1;   keyD[0] = 1;
  }
  if (name.equals("gsh")) {
    keyGsh[0] = 1;   keyC[0] = 1;   keyDsh[0] = 1;
  }


  //minor
  if (name.equals("a")) {
    keyC[0] = 1; keyA[0] = 1; keyE[0] = 1;
  }
  if (name.equals("ash")) {
    keyAsh[0] = 1;  keyCsh[0] = 1;  keyF[0] = 1;
  }
  if (name.equals("b")) {
    keyB[0] = 1;  keyD[0] = 1; keyFsh[0] = 1;
  }
  if (name.equals("c")) {
    keyC[0] = 1; keyDsh[0] = 1; keyG[0] = 1;
  }
  if (name.equals("csh")) {
    keyCsh[0] = 1;   keyE[0] = 1;   keyGsh[0] = 1;
  }
  if (name.equals("d")) {
    keyD[0] = 1;   keyF[0] = 1;   keyA[0] = 1;
  }
  if (name.equals("dsh")) {
    keyDsh[0] = 1;   keyFsh[0] = 1;   keyAsh[0] = 1;
  }
  if (name.equals("e")) {
    keyE[0] = 1;   keyG[0] = 1;   keyB[0] = 1;
  }
  if (name.equals("f")) {
    keyF[0] = 1;   keyGsh[0] = 1;   keyC[0] = 1;
  }
  if (name.equals("fsh")) {
    keyFsh[0] = 1;   keyA[0] = 1;   keyCsh[0] = 1;
  }
  if (name.equals("g")) {
    keyG[0] = 1;   keyAsh[0] = 1;   keyD[0] = 1;
  }
  if (name.equals("gsh")) {
    keyGsh[0] = 1;   keyB[0] = 1;   keyDsh[0] = 1;
  }
}
```

Find next chord tab

```
void findNextChord(String name) {

  //This function determines which lights should
  //be bright for which chords

  //major
  if (name.equals("A")) {
    keyCsh[1] = 1; keyA[1] = 1; keyE[1] = 1;
  }
  if (name.equals("Ash")) {
    keyAsh[1] = 1;  keyD[1] = 1;  keyF[1] = 1;
  }
  if (name.equals("B")) {
    keyB[1] = 1;  keyDsh[1] = 1; keyFsh[1] = 1;
  }
  if (name.equals("C")) {
    keyC[1] = 1; keyE[1] = 1; keyG[1] = 1;
  }
  if (name.equals("Csh")) {
    keyCsh[1] = 1;   keyF[1] = 1;   keyGsh[1] = 1;
  }
  if (name.equals("D")) {
    keyD[1] = 1;   keyFsh[1] = 1;   keyA[1] = 1;
  }
  if (name.equals("Dsh")) {
    keyDsh[1] = 1;   keyG[1] = 1;   keyAsh[1] = 1;
  }
  if (name.equals("E")) {
    keyE[1] = 1;   keyGsh[1] = 1;   keyB[1] = 1;
  }
  if (name.equals("F")) {
    keyF[1] = 1;   keyA[1] = 1;   keyC[1] = 1;
  }
  if (name.equals("Fsh")) {
    keyFsh[1] = 1;   keyAsh[1] = 1;   keyCsh[1] = 1;
  }
  if (name.equals("G")) {
    keyG[1] = 1;   keyB[1] = 1;   keyD[1] = 1;
  }
  if (name.equals("gsh")) {
    keyGsh[1] = 1;   keyC[1] = 1;   keyDsh[1] = 1;
  }

  //minor
  if (name.equals("a")) {
    keyC[1] = 1; keyA[1] = 1; keyE[1] = 1;
  }
  if (name.equals("ash")) {
    keyAsh[1] = 1;  keyCsh[1] = 1;  keyF[1] = 1;
  }
  if (name.equals("b")) {
    keyB[1] = 1;  keyD[1] = 1; keyFsh[1] = 1;
  }
  if (name.equals("c")) {
    keyC[1] = 1; keyDsh[1] = 1; keyG[1] = 1;
  }
  if (name.equals("csh")) {
    keyCsh[1] = 1;   keyE[1] = 1;   keyGsh[1] = 1;
  }
  if (name.equals("d")) {
    keyD[1] = 1;   keyF[1] = 1;   keyA[1] = 1;
  }
  if (name.equals("dsh")) {
```

```
    keyDsh[1] = 1;   keyFsh[1] = 1;   keyAsh[1] = 1;
  }
  if (name.equals("e")) {
    keyE[1] = 1;   keyG[1] = 1;   keyB[1] = 1;
  }
  if (name.equals("f")) {
    keyF[1] = 1;   keyGsh[1] = 1;   keyC[1] = 1;
  }
  if (name.equals("fsh")) {
    keyFsh[1] = 1;   keyA[1] = 1;   keyCsh[1] = 1;
  }
  if (name.equals("g")) {
    keyG[1] = 1;   keyAsh[1] = 1;   keyD[1] = 1;
  }
  if (name.equals("gsh")) {
    keyGsh[1] = 1;   keyB[1] = 1;   keyDsh[1] = 1;
  }
}
```

Serial communication tab

```
void serialRead(){
char data = Serial.read();
      if (data == 's') {
        start = true;

        //calculate the interval during which users can hit the Xylophone
        respTime = interval/accuracy;
        //sync the timer with the passed time. else the LEDs dont change in sync
with the music
        timer = millis();
      }

      //receive pbm settings from processing
      if (data == 'r'){
        blinkLight();
        bpm = 80;
      }
      if (data == 't'){
        blinkLight();
        bpm = 90;
      }
      if (data == 'n'){
        blinkLight();
        noCues = true;
        noNegative = false;
      }
      if (data == 'o'){
        blinkLight();
        noNegative = true;
        noCues = false;
      }

      //receive song settings from processing
      if (data == 'u'){
         blinkLight();
         playing = 1;
         //songlength of array LetItBe is 68
         songlength = 68;
         Serial.print("LetitBe - song length = ");
         Serial.println(songlength);
      }
      if (data == 'v'){
         blinkLight();
```

```
      Serial.println("songtwo");
      playing = 2;
      songlength = 4;
    }
    if (data == 'w'){
     blinkLight();
     Serial.println("songthree");
     playing = 3;
     songlength = 2;
    }
}
```

Appendix B3 processing code.

First tab

```
import processing.sound.*;
import processing.serial.*;


////////////////////////////////////////////
/// various ints and some longs below here///
////////////////////////////////////////////

//newline is used for serial communication
int NEWLINE = 10;

//bpm sets the tempo, default tempo is 100bpm
int bpm = 100;

//number of frames by which a note is delayed
int noteDelay = 400;

//integer that is used to check which song is selected
int songSelect = 0;

//use these to see if keys are actually hit heavy enough
int treshold[] =    {100, 100, 80, 100, 100, 100,
                     50, 100, 100, 100, 80, 80
                    };

//store the number if hits, misses, late hits and early hits.
int isHit, isEarly, isLate, isMiss;

//int that starts the song on incoming sign
int startSong = 0;

//integers that count the number of hits to the playing of a special effect.
int fxCounter;
int fxTreshold;

//timer
long timer[] = new long[12];

//boolean that makes sure a note is not playing twice at the same time.
boolean playOnce[] = new boolean[12];


/////////////////////////
//SoundFiles below here//
/////////////////////////

//array that will store the soundfiles
final static SoundFile[] notes = new SoundFile[12];

//load marimba sounds
SoundFile C, Csh, D, Dsh, E, F, Fsh, G, Gsh, A, Ash, B;

//load clicktracks
SoundFile click80bpm, click90bpm, click100bpm;

//load let it be
SoundFile letitbe80bpm, letitbe90bpm, letitbe100bpm;

SoundFile sfx[] = new SoundFile[5];
```

```
//soundFile that will hold the playing song.
SoundFile song;
//click will hold the clicktrack
SoundFile click;


//////////////////////////////////////////
//these are necessary for the serialEvent function
//////////////////////////////////////////
String buff = "";
char noteHeader[] = {
  'A', 'B', 'C', 'D', 'E', 'F',
  'G', 'H', 'I', 'J', 'K', 'L'
};

//value is currently not used
int value[] = new int[12];
boolean noteHit[] = new boolean[12];

///////////////////
//lots of buttons//
///////////////////
int buttStartloc[] = {width + 650, height + 200};
int startText[] = {width + 660, height + 240};
int buttStartdim[] = {90, 60};
boolean startHover = false;  //boolean for mouse hover

//bpm 80 button stuffs
int bpmALoc[] = {width + 180, height - 65};
int bpmAtext[] = {width + 185, height - 25};
int bpmAdim[] = {90, 60};
boolean bpmAhover = false;  //boolean for mouse hover

//bpm 100 button stuffs
int bpmBLoc[] = {width + 180, height + 23};
int bpmBtext[] = {width + 185, height + 62};
int bpmBdim[] = {90, 60};
boolean bpmBhover = false;  //boolean for mouse hover

//song A button
int songAloc[] = {width - 70, height - 65};
int songAtext[] = {width - 65, height - 25};
int songAdim[] = {230, 60};
boolean songAhover = false;  //boolean for mouse hover

//song B button
int songBloc[] = {width - 70, height + 23 };
int songBtext[] = {width - 65, height + 62};
int songBdim[] = {230, 60};
boolean songBhover = false;  //boolean for mouse hover

//song C button
int songCloc[] = {width - 70, height + 110};
int songCtext[] = {width - 65, height + 150};
int songCdim[] = {230, 60};
boolean songChover = false;  //boolean for mouse hover

//no cues button
int noCueLoc[] = {width + 400, height + 110};
int noCueText[] = {width + 405, height + 148};
int noCueDim[] = {150, 60};
boolean noCueHover = false;  //boolean for mouse hover
```

```
//no red lights button
int noRedLoc[] = {width + 400, height };
int noRedText[] = {width + 405, height + 38};
int noRedDim[] = {180, 60};
boolean noRedHover = false;  //boolean for mouse hover


//colors
color blueC = color(44, 87, 117);
color blueC2 = color(24, 65, 95);
color redC  = color(220, 90, 0);
color redC2 = color(148, 56, 29);
color yelC  = color(182, 153, 61);
color yelC2 = color(148, 119, 29);

//start serial port
Serial port;

void setup() {
  //set window size
  size(900, 400);

  //load note sound files.
  C   = new SoundFile(this, "C.mp3");
  Csh = new SoundFile(this, "Csh.mp3");
  D   = new SoundFile(this, "D.mp3");
  Dsh = new SoundFile(this, "Dsh.mp3");
  E   = new SoundFile(this, "E.mp3");
  F   = new SoundFile(this, "F.mp3");
  Fsh = new SoundFile(this, "Fsh.mp3");
  G   = new SoundFile(this, "G.mp3");
  Gsh = new SoundFile(this, "Gsh.mp3");
  A   = new SoundFile(this, "A.mp3");
  Ash = new SoundFile(this, "Ash.mp3");
  B   = new SoundFile(this, "B.mp3");

  //load let it be with a clicktrack
  letitbe90bpm = new SoundFile(this, "LetItClick90bpm.mp3");

  //load special effect sounds.
  sfx[0] = new SoundFile(this, "sfxCow.mp3");
  sfx[1] = new SoundFile(this, "sfxElephant.mp3");
  sfx[2] = new SoundFile(this, "sfxFlange.mp3");
  sfx[3] = new SoundFile(this, "sfxRing.mp3");
  sfx[4] = new SoundFile(this, "sfxLaser.mp3");

  //song is placeholder for the playing song
  song = letitbe90bpm;

  //put notes in an array
  notes[0] = C;
  notes[1] = Csh;
  notes[2] = D;
  notes[3] = Dsh;
  notes[4] = E;
  notes[5] = F;
  notes[6] = Fsh;
  notes[7] = G;
  notes[8] = Gsh;
  notes[9] = A;
  notes[10] = Ash;
  notes[11] = B;

  //make effects play after between 2 or 5 succesful hits.
```

```
  fxTreshold = (int(random(3, 6)));

  //start serial port
  port = new Serial(this, Serial.list()[0], 9600);

  //blue background
  background(blueC);

}

void draw() {
  background(blueC);

  //button stuff
  updateButtons();

  //when enough succesful hits have been scored
  //play a sound effect
  if (fxCounter == fxTreshold) {
    int fx = int(random(5));
    sfx[fx].play();
    fxCounter = 0;
    fxTreshold = (int(random(3, 6)));
  }


  //play notes when something is sent to processing.
  while (port.available () > 0) {
    serialEvent(port.read()); // read data

    for (int i=0; i<12; i++) {
      if (value[i] > treshold[i]) {
        //check if note is not already playing, to prevent bounce
        if (!playOnce[i]) {
          playNote(i);

          //set note has played in the bast half second
          playOnce[i] = true;
          timer[i] = millis();
        }
      }
      if (millis() > timer[i] + 400) {
        playOnce[i] = false;
      }
      value[i] = 0;
    }
  }
}

//send something to arduino if a button is pressed.
void mousePressed() {
  //send data on button press
  sendData();
}
```

Draw stuff tab

```
//draw the start button
void drawStart() {
  if (startHover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(buttStartloc[0], buttStartloc[1], buttStartdim[0], buttStartdim[1]);

  textSize(32);
  fill(255);
  text("Start", startText[0], startText[1]);
}


//draw the first tempo bpm selection button
void drawBpmA() {
  if (bpmAhover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(bpmALoc[0], bpmALoc[1], bpmAdim[0], bpmAdim[1]);

  textSize(23);
  fill(255);
  text("80 BPM", bpmAtext[0], bpmAtext[1]);
}

//draw the second bpm button
void drawBpmB() {
  if (bpmBhover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(bpmBLoc[0], bpmBLoc[1], bpmBdim[0], bpmBdim[1]);

  textSize(23);
  fill(255);
  text("90 BPM", bpmBtext[0], bpmBtext[1]);
}

//draw the first song selection button
void drawSongA() {
  if (songAhover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(songAloc[0], songAloc[1], songAdim[0], songAdim[1]);

  textSize(23);
  fill(255);
```

```
  text("Let It Be", songAtext[0], songAtext[1]);
}

//draws the second song button
void drawSongB() {
  if (songBhover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(songBloc[0], songBloc[1], songBdim[0], songBdim[1]);

  textSize(25);
  fill(255);
  text("", songBtext[0], songBtext[1]);
}

//draws the third song button
void drawSongC() {
  if (songChover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(songCloc[0], songCloc[1], songCdim[0], songCdim[1]);

  textSize(23);
  fill(255);
  text("", songCtext[0], songCtext[1]);
}

void drawNoCues() {
  if (noCueHover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(noCueLoc[0], noCueLoc[1], noCueDim[0], noCueDim[1]);
  textSize(23);
  fill(255);
  text("zet LEDs uit", noCueText[0], noCueText[1]);
}

void drawNoRed() {
  if (noRedHover) {
    fill(redC2);
  } else {
    fill(redC);
  }
  //draw the button
  stroke(255);
  rect(noRedLoc[0], noRedLoc[1], noRedDim[0], noRedDim[1]);
  textSize(22);
  fill(255);
  text("Geen rode LEDs", noRedText[0], noRedText[1]);
}
```

```
//function that draws the text outside the buttons
void drawText() {
  textSize(20);
  fill(255);


  text("Geraakt", 750, 25);
  text("/Hit  :         " + str(isHit), 750, 45);
  text("Gemist", 750, 80);
  text("/Missed   :  " + str(isMiss), 750, 100);

  text("Te vroeg", 750, 135);
  text("/Too early : " + str(isEarly), 750, 155);
  text("Te laat", 750, 190);
  text("/Too late  :  " + str(isLate), 750, 210);

  textSize(20);
  text("Tempo", 280, 25);
  text("Gekozen", 280, 210);
  text("tempo:", 280, 235);
  textSize(17);
  text(bpm, 280, 260);

  textSize(20);
  text("kies liedje", 30, 25);
  text("Gekozen liedje:", 30, 300);
  textSize(17);
  if (songSelect == 0) {
    text("U heeft niks geselecteerd", 30, 325);
    text("You did not select a song", 30, 350);
  } else if (songSelect == 1) {
    text("Let it Be", 30, 325);
  } else if (songSelect == 2) {
    text("liedje c", 30, 325);
  } else if (songSelect == 3) {
    text("liedje d", 30, 325);
  }
}
```

Play note tab

```
void playNote(int i) {
 //check if C is not already playing, else play

   notes[i].play();
   noteHit[i] = false;
   port.clear();
}
```

Serial communication tab

```
//This function is based on the graphWriter processing sketch
//Written by Edwin Dertien for the course programming and physical computing
void serialEvent(int serial)
{
  try {    // try-catch because of transmission errors
    if (serial != NEWLINE) {
      buff += char(serial);
    } else {
      // The first character tells us note is played
      char c = buff.charAt(0);
      //b will store the letter denoting whether the hit was on time, miss, late or
early.
```

```
      char b = buff.charAt(buff.length() - 2);
      // Remove note from the string
      buff = buff.substring(1);
      //Discard the carriage return at the end of the buffer
      //get force of hit.
      buff = buff.substring(0, buff.length()-2);
      // Parse the String into an integer
      for (int z=0; z<noteHeader.length; z++) {
        if (c == noteHeader[z]) {
          value[z] = Integer.parseInt(buff);
        }
      }
      //check whether it was a hit, a miss or late or early.
        if(b == 'P'){
          isHit ++;
          fxCounter++;
        }
        else if(b == 'Q'){
          isEarly ++;
        }
        else if(b == 'R'){
          isLate ++;
        }
        else if(b == 'N'){
          isMiss ++;
        }
       // P = Hit
       // Q = Early
       // R = Late
       // N = miss

      buff = "";         // Clear the value of "buff"
    }
  }
  catch(Exception e) {
    println("no valid data");
  }
}

//send data to arduino
//when clicking respective buttons.
void sendData(){
  if (startHover) {
    //send lowercase s, which starts the program
    song.play();
    //click.play();
    port.write(115);
    println("sent s");
  }
  if (bpmAhover){
    //send lowercase r, sets bpm to 80
    bpm = 80;
    port.write(114);
    println("sent r");
  }
  if (bpmBhover){
    //send lowercase t, sets bpm to 80
    bpm = 90;
    port.write(116);
    println("sent t");
  }
  if (songAhover){
    //send lowercase u, selects first song
    port.write(117);
```

```
    songSelect = 1;
    println("sent u");

  }
  if (songBhover){
    //send lowercase v, selects second song
    port.write(118);
    songSelect = 2;
    println("sent v");
  }
  if (songChover){
    //send lowercase w, selects third song
    port.write(119);
    songSelect = 3;
    println("sent w");
  }
  if (noCueHover){
    port.write(110);
    println("Sent n");
  }
  if (noRedHover){
    port.write(111);
    println("sent  o");
  }
}
```

Update tab

```
void updateButtons() {

  drawStart();
  drawBpmA();
  drawBpmB();
  drawSongA();
  //drawSongB();
  //drawSongC();
  drawNoCues();
  drawNoRed();
  drawText();


  if (over(buttStartloc[0], buttStartloc[1], buttStartdim[0], buttStartdim[1]) ) {
    startHover = true;
  } else {
     startHover = false;
  }

  if (over(bpmALoc[0], bpmALoc[1], bpmAdim[0], bpmAdim[1])){
    bpmAhover=true;
  }
  else {
    bpmAhover = false;
  }

  if (over(bpmBLoc[0], bpmBLoc[1], bpmBdim[0], bpmBdim[1])){
    bpmBhover=true;
  }
  else {
    bpmBhover = false;
  }

  if (over(songAloc[0], songAloc[1], songAdim[0], songAdim[1])){
    songAhover=true;
  }
  else{
```

```
    songAhover = false;
  }

  if (over(songBloc[0], songBloc[1], songBdim[0], songBdim[1])){
    songBhover=true;
  }
  else{
    songBhover = false;
  }

  if (over(songCloc[0], songCloc[1], songCdim[0], songCdim[1])){
    songChover=true;
  }
  else{
    songChover = false;
  }
  if (over(noCueLoc[0], noCueLoc[1], noCueDim[0], noCueDim[1])){
    noCueHover=true;
  }
  else{
    noCueHover = false;
  }

  if (over(noRedLoc[0], noRedLoc[1], noRedDim[0], noRedDim[1])){
    noRedHover=true;
  }
  else{
    noRedHover = false;
  }

}


boolean over(int x, int y, int width, int height)  {
  if (mouseX >= x && mouseX <= x+width &&
      mouseY >= y && mouseY <= y+height) {
    return true;
  } else {
    return false;
  }
}
```

Appendix C1 Consent form - Dutch

Titel onderzoek: Enhanced music therapy

Verantwoordelijke onderzoeker: Timo te Velde

In te vullen door de deelnemer

Ik verklaar op een voor mij duidelijke wijze te zijn ingelicht over de aard, methode, doel en [indien aanwezig] de risico's en belasting van het onderzoek.

Ik weet dat de gegevens en resultaten van het onderzoek alleen anoniem en niet aan derden bekend gemaakt zullen worden. Evt. vragen die ik had zijn naar tevredenheid beantwoord.

[indien van toepassing] Ik begrijp dat film-, foto, en videomateriaal of bewerking daarvan uitsluitend voor analyse en/of wetenschappelijke presentaties zal worden gebruikt.

Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud me daarbij het recht voor om op elk moment zonder opgaaf van redenen mijn deelname aan dit onderzoek te beëindigen.

Naam deelnemer: **Handtekening deelnemer:**

………………………………………………… …………………………………………………

Datum: ……………………

In te vullen door de uitvoerende onderzoeker.

Ik heb een mondelinge en schriftelijke toelichting gegeven op het onderzoek. Ik zal resterende vragen over het onderzoek naar vermogen beantwoorden. De deelnemer zal van een eventuele voortijdige beëindiging van deelname aan dit onderzoek geen nadelige gevolgen ondervinden.

Naam onderzoeker: Handtekening onderzoeker:

………………………………………………… …………………………………………………

Datum: ……………………

Appendix C2 Consent form - English

Title of research: Enhanced Music Therapy

Researcher: Timo te Velde

To be filled in by subject

I hereby declare that I have been informed in a manner which is clear to me about the nature and method of this research. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the experiment at any time.

If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact Timo te Velde; email: t.tevelde@student.utwente.nl

If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, dr. ir. J.F.C. Verberne, P.O. Box 217, 7500 AE Enschede (NL), telephone: +31 (0)53 489 3700; email: j.f.c.verberne@utwente.nl).

Name subject **Signature Subject**

……………………………………………………. …………………………………………………….

Date: …………………….

To be filled in by researcher.

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.’

Name researcher **Signature Researcher**

……………………………………………………. …………………………………………………….

Date: …………………….

Appendix C3 Survey test sessions – English

Answer to what extent you agree with the following statements.

1 = Strongly disagree
5 = Strongly agree

Vraag	1	2	3	4	5
It was clear to me how to use the system.					
I found it hard to use the system.					
I needed a lot of help while using the system.					
I enjoyed using this system.					
I liked the music that played while using the system.					
While using the system, I was mainly focussing on the music.					
The meaning of the LEDs was clear to me.					
It was easy for me to follow the directions the LEDs gave me.					
The LEDs were distracting me.					
The LEDs were annoying me.					
I enjoyed the guided mode more than the unguided mode. (The guided mode being the one wherein the LEDs showed you what to do.)					

Indien geluidseffecten gehoord:

Vraag	**1**	**2**	**3**	**4**	**5**
The sound effects were distracting me.					
The sound effects were annoying me					
The sound effects made me feel extra motivated.					

Appendix C4 Survey test session – Dutch

Geef aan in hoeverre u het eens bent met de volgende beweringen.

1 = Helemaal niet mee eens
5 = Helemaal mee eens

Vraag	1	2	3	4	5
Ik vond het duidelijk hoe ik het systeem moest gebruiken.					
Ik vond het systeem moeilijk te gebruiken.					
Ik had veel hulp nodig tijdens het gebruik van het systeem.					
Ik vond het leuk om het systeem te gebruiken.					
Ik vond de muziek waarmee ik mee speelde leuk.					
Ik kon mij tijdens het gebruik goed op de muziek concentreren.					
Ik vond het duidelijk wat de lichtjes betekenden.					
Ik vond het makkelijk om de aanwijzingen van de lichtjes te volgen.					
Ik vond de lichtjes afleidend.					
Ik vond de lichtjes vervelend.					
Ik vind dit systeem leuker om te bespelen dan een echte xylofoon.					

Indien geluidseffecten gehoord:

Vraag	**1**	**2**	**3**	**4**	**5**
Ik vond de geluidseffecten storend					
Ik vond de geluidseffecten afleidend.					
Ik voelde mij extra gemotiveerd door de geluidseffecten					