A Study in Infrasound and Game Performance

By

Kim Young Hornshøj Hansen

Aalborg University Cph, spring 2013

Table of Content

1. Introduction and Motivation

There are a number of reasons to why people play video games, to be entertained for a few hours, to let off some steam or for other personal reasons. Some like playing a game to challenge themselves in terms of skills and performance. Today the scene of eSports[1] has grown to a large competitive scene, and is still growing even bigger. In the professional leagues in various games, the difference between winning and losing usually comes down to a very thin margin. One faulty move or a moment of unawareness can make the difference of finishing 1st or 2nd. Competitive players always looks for that edge that can lift them above the rest and help them perform better than their opponent.

In this present study I will look into how performance can be affected with the use of sound, within a game environment. My angle in this study will be with the use of sound and how it can affect the human body. The purpose is to use sound to affect the performance of participants playing a game. In the present study I research the field of infrasound and previous studies and experiments done within that area. Previously conducted experiments and tests, have shown that infrasound can induce physiological feedback that is related to fear and anxiety like states, and thus has physiological alternating effects such as heart rate, blood pressure and induce psychosomatic effects like nausea, dizziness, drowsiness and fatigue (1) (2) (3). This is due to what is called psychoacoustics. Psychoacoustics is a branch of science that concerns the effects of sound towards the human body. Psychoacoustics properties of sound and infrasound will also addressed in this study. In the initial research, section 2.1, I look into Joshua Leeds description of psychoacoustics. In section 2.4.2 I look into the nervous system of the human body to gather knowledge of how our body physiology reacts to stimuli.

The purpose is to exposure participants in a test to infrasound, while playing a game that challenges their hand to eye coordination. Physiological measurements and overall in game performance will be analyzed to determine if infrasound has any effect on the players' performance.

As mentioned my angle will be to use sound as a manipulator to the human body in order to affect a player's performance.

Going into this an initial problem statement can be stated as:

"Can sound be used to affect the performance of a player, in a video game setting?"

[1] eSports(Electronic Sports) is the term used for competitive play within video games.

2. Initial Research

Looking to affect the human body and player performance with the use of sound, initial research areas of interests would be how sound is perceived and how the human body is affected by sound.

A well known problem we find in e.g. work and study environments are unwanted sounds, better categorized as noise. Noise has a distracting effect on most people which can affect people at a cognitive level, impairing their mental performance. According to Kjeld Fredens, a doctor and brain researcher, the noise in open work environments is harmful to our ability to concentrate when we have to perform complicated tasks. Kjeld Fredens says a reason that people get distracted is because humans in general are not good at multitasking. Multitasking is only the way to go when working with routine work, but when the work requires that you immerse yourself, like reading or a work that requires precision and accuracy; too much focus is needed to a sufficient level of multitasking can be beneficial (4). In regards to noise the human ear is especially attuned to perceive human speech and therefore unwanted speech can be very distracting to most people (5). The well known experiment by Edward C. Cherry, 1953, proved that humans have the ability to focus on a specific sound source, like a single voice, amongst many; also known as the 'Cocktail Party Effect' or selective hearing. However, even with this ability, irrelevant speech that is not in our focus is still monitored to some degree and is still a distraction (6). In a experiment research from Cambridge University's Journal *'Psychological Medicine', 2001,* a research was conducted involving 340 children aging from 8-11 years in four school exposed to high level of chronic aircraft noise Leq[2] > 66 dB(a) and a matched control group across four schools exposed to a low level of chronic aircraft noise Leq < 57dB(a). In their findings it was concluded a strong association with high level exposure to noise and a high level of annoyance found in children. Furthermore, suggestive findings that high level of chronic aircraft noise has an impairing effect on the children's performance in reading and long-term memory recognition. Thus high exposure to, in this case, chronic aircraft noise suggests poorer cognitive performance compared to low exposure (7).

2.1. The Power of Sound

This section will look into the ability of sound and how it is relevant to this study.

2.1.1. Psychoacoustics

Psychoacoustics is a branch of scientific studies that concerns our perception of sound and music. It is a study that involves how we listen to sound and how it affects us on a psychological (regards the mental aspect of the human) and physiological (regards the living system, the human body itself). In the book by Joshua Leeds, *The Power Of Sound* (8), who is a researcher, educator and music composer, he talks about psychoacoustics' ability to affect our psychology and physiology. He stresses a distinction between psychological and neurological perception. Leeds describes an example of a psychological reaction to sound as:

"A song or melody associated with childhood, a teenage romance, or some peak emotional experience creates a memory-based psychological reaction"

[2] Leq is the "Equivalent Continuous Noise Level" which is the average noise level of a long-term noise. In this case the Leq was measured over 16hours.

Leeds bases his research on the findings of Dr. Alfred Tomatis(1920-2001), who reasoned that there is a strong correlation between people's ability to listen and their ability to learn. To further explain this Leeds explains in his book active listening and passive hearing. Leeds has established concepts for designing psychoacoustics applications.

- **Intentionality**
- **Resonance**
- **Entrainment**
- **Pattern Identification**
- **Sonic Neurotechnologies**

The first bullet, **intentionality** is simply to design the application, e.g. sound or composed soundtrack, for one specific purpose. Resonance is one of the most important concepts to understand. He explains it as a chain of vibration. In basics whenever there is motion some pressure and frequency is produced, which basically makes up the very basics of any sound. Leeds explains the chain of vibration as: all atomic matter vibrates, thus there is a motion – whenever there is motion there is a frequency. That frequency is what creates sound, which sometimes can be inaudible.

Returning to the design concepts; **resonance** is the phenomenon that occurs when a vibrating/oscillating system response with relative maximum amplitude to an external vibrating source affecting it. Mechanical resonance is one aspect of resonance and is when a physical body is exposed to a force. The pick of a string of a guitar will obviously produce a sound, if we were to analyze that sound in a frequency spectrum, we would see different frequency ranges response with relative maximum or peaks in amplitude. The lowest of the peaks frequencies is what we call the fundamental frequency; the other peaks will be the fundamental frequency's value multiplied with whole integers and is that system's resonant frequencies or resonance frequencies. An example of a natural occurrence of resonance happened in the 1940, the Tacoma Narrows Bridge at Puget Sound Washington began to resonate at its resonance frequency due to strong winds hitting it amplifying its swing. In the end the bridge swung so violently that it ripped itself apart, destroying it. In an experiment it was discovered that exposure to low frequent sound, in this case <35Hz at over 70dB the windows and furniture in a Japanese wooden house, started to resonate due to the exposure, which produced secondary sounds that was audible (9).

As before mentioned, when a sound is produced its fundamental frequency, also known as the first harmonic, will be the highest peak in amplitude the second harmonic will be at the frequency where the value of an integer multiple of fundamental frequency. For every harmonic the energy of will be a little less and a little less (10).

Leeds continues by explaining **entrainment** as an aspect of resonance. In psychoacoustics, entrainment can affect the rhythms in the body, like heart rate, respiratory rate and influence our brainwaves. A simple example of entrainment given is when listening to music is to move to it, tapping feet, bobbing head or similar movements that matches the rhythm heard. This is because rhythm possesses the ability to affect our nervous system. He states that if the nervous system is not resonating with a rhythm, it will not have a psychoacoustic effect on us - he continues to explain his next concept which is **Pattern identification**. **Pattern identification** is a process in where our brain seeks to analyze and identify a pattern e.g. a visual or an auditory pattern. When our brain is trying to identify what we see and hear, we use active listening and active looking which are also the modes used when we look or listen to teachers for learning and understanding. Once the pattern has been established and identified we switch our modes to passive, which is referred to as hearing and seeing. In regards to the auditory aspect, the active listening is the mode where our nervous system is stimulated and the passive mode is a neutral state, or as Leeds puts it as a 'discharging' state.

2.2. Infrasound

There is an aspect of sound which has spiked an interest in psychoacoustic responses. Infrasound is said to be able to interfere with many aspects of our body. Infrasound is the branch of sound that lies in the bottom of the sound frequency scale and is inaudible to the average human ear. The average human ear has been estimated to be able to register sound within 20Hz to 20,000Hz frequency range (10) – Where Infrasound is sound below the audible frequency range for the human ear from 0 to 20Hz. Above the audible threshold of human hearing(above 20kHz) is ultrasound.

Lower sound frequencies have a relative long wavelength which makes it capable of traveling vast distances, compared to very high frequency sound waves. Furthermore, long wavelengths have the property of penetrating objects due to the low absorption rate (11). As an example, listening to speech or music from behind closed doors, the frequencies heard are the lower frequencies because their wavelength allows them to penetrate objects easier than shorter wavelengths. In a following section 2.4 State of the Art, I will look further into previous work in the field of infrasound, to get a better understanding what infra sound is capable of.

2.3. Sound Reflection and Absorption.

When working with sound it is very important to understand how sound behaves in the environment. Depending on what you want the environment should be designed to support that. Common issues when working with sound is how to control and direct it. Like a scene, you want to be able to control the lighting and control it for a specific purpose. Sound behaves in various aspects much like light does. Like light projected onto a surface, the surface will be absorbing, reflecting, scattering the incoming energy. A completely reflecting surface will reflect the same energy as it was given. However, there will always be an amount of energy lost from each reflection. Projecting on to a diffuse surface will cause the incoming energy to scatter and reflect in all directions. An absorbing surface will absorb some of the incoming energy and as a result of that less energy will be reflected off it, figure 1 (12).

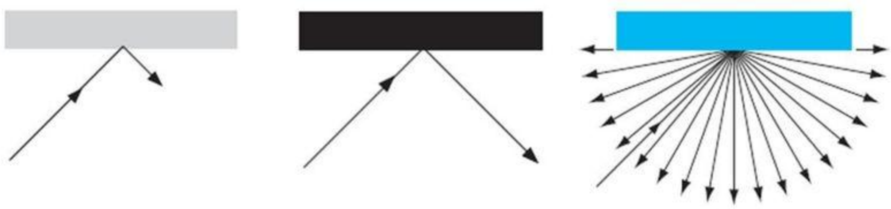


Figure 1, Left most figure is an absorbing surface, reflecting less energy compared to the input given. Middle figure is a reflecting surface, where input and output is very similar. Right most figure, is a diffuse surface, scattering the incoming energy.

The amount of absorption and reflection of sound projected onto an object depends on what material the object is made of. Sound absorptive materials are commonly fibrous and porous objects which has a low stiffness value. The purpose of the absorptive material is to absorb by reducing the amplitude of the sound reflected off it. Hard, rigid and high density materials like concrete reflects a high amount of sound energy, where materials like acoustic tiles (the soft pads often used in sound studios to absorb and prevent reverberation of sound) are made of soft and lower density materials. Depending on what you want to achieve the design of the room and its interior is very important. If you want a pure sound of a voice a high level of absorbing would be ideal, where in a concert hall want to use slightly more reflective materials to get the right reflection and amplification of the musical instruments to create a rich and colorful sound. There are different parameters to the absorption coefficient of an object. The more significant parameters are thickness and density of the object. The density of the material helps to absorb the mid and high frequencies and less on the lower frequencies. As before mentioned low frequencies have a relative long wavelength and an impressing ability to penetrate objects and travel long distances, making the density of the material less effective absorbing low frequency sounds. However, studies have shown that thickness of the material is highly effective when it comes to absorption of low frequencies, but insignificant in absorbing high frequency waves (13). An interesting finding is compression of material. Bernard Castagnede et al. (14), bring to attention in their paper that compression of materials does not have an effect on the effectiveness of absorption, that it actually decreases the sound absorption. It relates to the fiber size and thickness of the material. Thinner fibers in a material increase the sound absorption because of an increase in the airflow resistance in the material; compressing the materials does not change the size of the fibers and decreases the thickness of the materials due to compression.

In an article, Ulrike Wegst, looks into the correlation between Young's Modulus, which describes the stiffness of elastic materials, and the density of a wooden material. A higher value of elastic modulus will indicate higher level of stiffness of a material. Figure 2, shows the relation between Young's Modulus and the density of different materials.

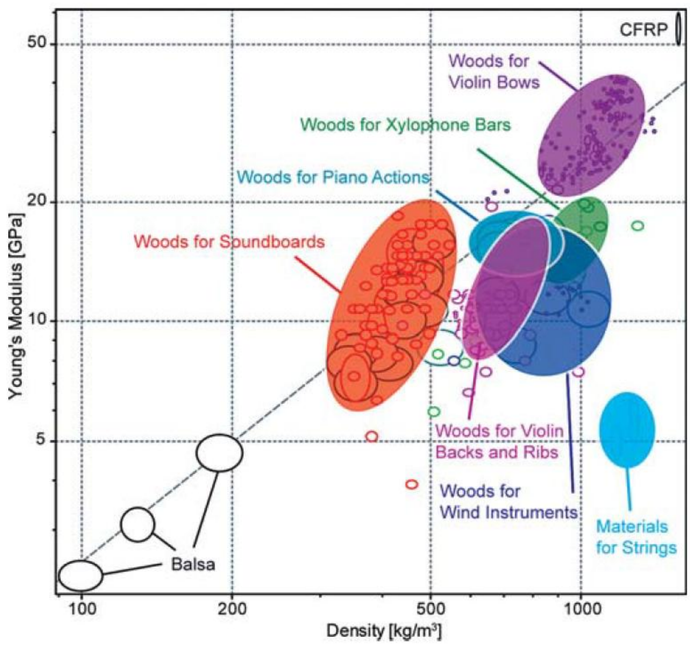


Figure 2 show a relation between Young's Modulus and the density of materials.

It can be seen that the density (kg/m^3) of the different materials is relative to the stiffness stated by Young's Modulus (15). For sound reflection hard surfaces are more effective than e.g. soft porous surfaces.

Thin hard surfaces will only reflect the higher frequencies, in order to reflect the lower frequencies the thickness needs to be increased (16). This seems to argue against previous mentioned parameters of absorption, but as previously mentioned absorption is a reduction of the amplitude of the reflected sound. Talking about absorption is more of a dampening effect of the reflected sound. Sound will always be reflected off the surface of the object and some will penetrate the object – but the sound might not go all the way thought, if the material has a high absorption coefficient.

2.4. State of the Art

This section will look into previous work done in the field of infrasound. As before mentioned infrasound is sound frequencies below the audible threshold of the human ear, which is below 20Hz. In a review of literature regarding infrasound from 2001, several findings from experiments are presented (1). One experiment(Broner, N. 1978) looked into the effects of low frequency noise and his findings concluded that noise in the frequency range just above the audible threshold of the human ear, 20-100Hz compared to frequencies in the range of infrasound, are much more harmful to the ear at equal SPL[3] at 127-133dB. That lead him to conclude that the danger connected to infrasound has been much over-rated, and that the only effect within this given experiment was infrasound at this level was an annoyance and much less a harmful factor.

In an article by Tyrrell Burt, 1996, he describes an investigation of a building suspected of sick building syndrome (SBS) (2). Symptoms of SBS include discomfort in forms of headache, irritation of eyes, throat and nose, coughing, dizziness and nausea (3) (17). The building was cleared for chemical and microbiological incidents. Physical factors found were the strongest indicators of SBS, poor air quality and thermal conditions were some of the most significant indicators. Several of the factors that could suggest SBS were corrected, but it barely helped the symptoms. Many of the symptoms experienced surfaces due to influence of the central nervous system, which is responsible for some of the before mentioned symptoms of SBS, fatigue, headaches, decreased ability to concentrate and nausea. In the article Tyrrell Burt mentions that vibrations at 7 Hz has been shown to be the frequency that disrupts the ability to concentrate and the cause of tiredness, headache and nausea, which matches the frequency found in several of the rooms in the suspected building. He goes on to say that frequencies around 8Hz is the most dangerous and that it can cause overload of the heart and lead to a heart attack. The source to the vibrations found in the office rooms were caused by the ventilations. It was suggested that repeated and long-term exposure to the infrasound produced in the ventilations, triggered the responses found in the reported cases in the office building.

In 1997 a study in Bulgaria which involved 1063 residents, with families living in apartments and other multifamily building. The purpose was to study the effects of acoustic conditions in multifamily buildings on the people living there. The findings showed that there was a statistically significant increase in reports and complaints of psychosomatic symptoms, which includes the feeling of weakness, fatigue and restlessness, compared to people exposed to lower levels of noise and infrasound. Similar effects were found in an experiment in 1984, where test participants were exposed to infrasound at 6 and 16Hz at pressure levels just 10dB above the hearing threshold. Another experiment exposed 40 participants to infrasound at 14

[3] Sound Pressure Level

and 16Hz at high sound pressure levels of 125dB. Decrease in alertness and blood pressure levels while an increase in heart rate was observed in the experiment (1).

An experiment by Karpova, el. al. (1970) exposed participants to infrasound of 5 and 10Hz at level of 100 and 135dB for 15minutes. In that short period of time the participants reported feeling of fatigue, weakness, apathy, drowsiness and depression. Furthermore, pressure in the ears, loss of concentration and feeling of vibrations of the internal organs was reported. It was also observed that within the first minutes of exposure the heart rate was increased as well as a significantly lowered respiration rate (18). Another discovery was the contraction of the heart was weakened, which is similar to the findings by Danielsson A. and U. Landstrom in 1985.

Other studies regarding infrasound shows that while being exposed to infrasound can affect a person's body sway. In an experiment test participants were exposed to infrasound frequencies at 5 and 16Hz for a short period of time, which caused significant body sway at the time of switching between opening and closing of the eyes. The pre-exposure experiment was to focus their vision on small object placed one meter away from the participant eyes. The participants were to stare at the object for 45seconds and then close their eyes for the same period of time. While closed they were to stare at the after-image of the object they looked at while with open eyes. In this experiment the participants' eyes were tracked to see if there would be involuntary eye movement differences between the pre-exposure phase and during the phase of actual exposure to infrasound. For the exposure phase the participants were exposed to infrasound and noise, while performing the same task as in the pre-exposure phase for 3 minutes. The amplitude of involuntary eye movement was significantly higher when exposed to infrasound than to noise, especially when eyes were closed. It is suggested that the effects are caused by an excitement/stimulus of the vestibular system. Three reflexes are affected the ocular, spiral and vegetative reflex. A figure 3 taken from H. Takigawa et al. 1988, describes the chain of influence from infrasound to the effect caused to the vestibular system (9).

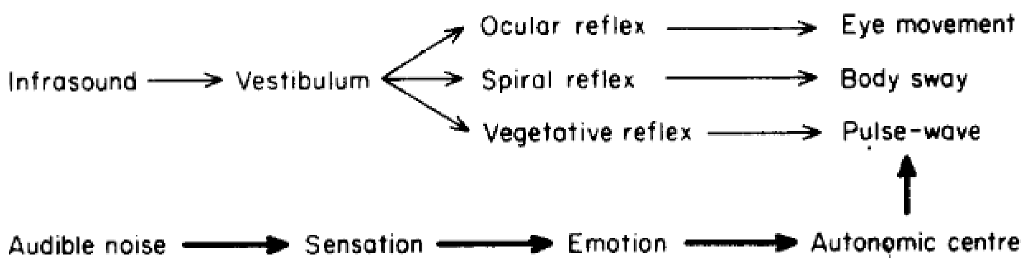


Figure 3 the chain reaction caused by infrasound to the vestibular system, and its effect.

M. Evans and W. Tempest, did a study of infrasound and noise in transportation, and discovered that low frequency sound <32Hz and above 120dB, which is the intensity which can be found in cars driving with windows open, can cause involuntary eye movement. Such movement is also called nystagmus and is when the eyes make an involuntary "jump". Furthermore, they also report findings of sensations of swaying and conclude that infrasound does in fact cause discomfort in the sense of swaying and nystagmus. It was also discovered in their findings the higher the SPL were the more rapid the nystagmus triggered and that the frequency of 7Hz was the most effective frequency for this (19). On the contrary a study in 1991, by A. Kawano et al. also investigated the suspicion of transportation producing low frequency noise within the infrasound frequency range. Long distance truck drivers are while driving exposed to infrasound at SPL of 115 dBA, showed no significant symptoms or effects caused by infrasound, suggesting that exposure to 115dBa unspecified infrasound frequencies, has no effect on the human body (1).

So far looking at the studies and experiments previously done it can be said that there is wide diversity in the findings reported. It is very difficult to conclude whether infrasound has an effect on the human body or if there is other aspect that interferes with the findings. However, looking across the state of the art and literature found, detailed experiment setups and how the experiments were conducted seem to be a common absence. Therefore it is difficult to rule anything out between the various findings since it is impossible to replicate any of the experiments conducted to a precise degree due to the lack of information. Furthermore, different frequencies and intensity levels were used across the different experiments, and even in some cases, extreme environmental conditions were a factor too, e.g. an experiment was conducted using infrasound at 16Hz at 125dB, exposed to test participants in a specially created pressure chamber (1). Even though many of the experiments reported no effect due to exposure of infrasound, I cannot discard the reported findings from other experiments, and must therefore assume that there is a possibility that infrasound can trigger the mentioned effects e.g. increased blood pressure, respiratory rate, nausea, drowsiness, tiredness etc. However, the mentioning of infrasound can cause death, is highly doubtful, since no source confirms that it could be a distinct possibility or any occurrence of this. Furthermore, concentration difficulty, tiredness, nausea, headaches and nystagmus are some of the finding which occurred by exposing participants to frequencies around 7 and 8 Hz, which is the frequency range used in several experiments. The effect of infrasound also tend to be more significant at higher intensities rather than at low intensity. The resident experiment in Bulgaria, the aircraft noise at children's schools and in transportations suggests that higher intensities produce greater effects.

According to Joshua Leeds sound can affect us by stimulating the nervous system, which he says is the basis for psychoacoustic effects that it starts in our nervous system. In a following section, section 2.4.2 The Nervous System; I will go a little bit further into the nervous system. Leeds goes on to mention that sound and music is capable of influencing our brainwaves. Alex Davies, receiver of the BFA[4] Honours, looked into the bio effects of sound. He mentions in connection to infrasound that the most significant effects caused by infrasound are found in the frequency range around 7Hz and that at this particular frequency range corresponds to the median brainwave pattern, the alpha brain waves (11) (20).

2.4.1. Brainwaves

In this section I will look into the aspect of brainwaves. Studies and sources states that infrasound is most effective/harmful at 7Hz, a few argues that it corresponds the frequency our alpha brain waves operate at. Our brain operates at various frequency ranges which have been categorized into groups, alpha- beta- delta- and theta-brainwaves. Depending on which state our body is in the brain produces a particular set of brain waves. E.g. when calm and relaxing the amount and activity of the alpha brainwaves are increased,

[4] Bachelor in Fine Arts Honours

where stress related states like tension and restlessness are connected to the beta brainwaves. Going though several sources it could be seen that the range of the brainwaves tend to vary a little (21) (22) (23). Table 1 shows a division of the frequencies and their properties.

Brainwave	Frequency range	Properties and state
Delta	0.1-4Hz	These brainwaves are of the lowest frequency and are active when in an unconscious state e.g. when in deep sleep.
Theta	4-7Hz	Theta brainwaves are linked to the state of creativity, light sleep and dreaming. Theta waves also worsen reaction time.
Alpha	7-12Hz	Alpha brainwaves are active when we are in a relaxed, but yet awake and aware. A decrease in alpha waves will make it more difficult for our brain to relax. A low activity in alpha brainwaves can help induce anxiety, tension, fear and stress.
Beta	13-40Hz	The beta brainwaves are produced when our body is highly alert and in a state of peak performance. Opposite to alpha brainwaves, beta brainwaves are increased in stressful situations, and are decreased when relaxed. The beta waves are active when we are in the state of fear, anxiety, agitated, nervous and stress.

Table 1, list the key aspects of each of the brainwaves.

This aspect of brainwaves should be taken lightly since there are no highly credible sources to be found on this area. However, it could help indicating why infrasound at 7Hz has been found to be the most effective frequency when looking at the physiological aspect. Disrupting the alpha brainwaves robs the brain's ability to relax and induces a more stressful state, and the beta brainwave activity increases. It is mentioned that beta waves are active when our body is in a highly alert state and about to perform at high level. This corresponds to the 'fight-or-flight' state, which is a state our body enters when presented to an imminent threat. It is a reaction that is made by our nervous system, which Joshua Leeds suggests can be affected by sound.

2.4.2. The Nervous System

The nervous system is a very complex system of every living body. In the human body we talk about several nervous systems. The larger nervous systems are:

- The Central Nervous System
- The Peripheral Nervous System
- The Somatic Nervous System
- The Autonomic Nervous System

The central nervous system considers the brain and spinal cord; this is the core of our nervous system. Connected to the central nervous system is the peripheral nervous system which mainly consists of nerves and goes though our entire body. Based on the peripheral nervous system as well as the central nervous system we have the somatic nervous system. The somatic nervous system regards all of your conscious aspects of your body, e.g. movement of your body; furthermore the somatic nervous system handles the interpretation of your sensory input, as well as memories. To divide conscious from unconscious you can say, that everything you can feel, remember and done by free will can be interpreted as conscious actions.

The unconscious aspect regards the autonomic nervous system which is the part of the nervous system that, as the name, automatically responds, thus, it is the nervous system that lies beyond our conscious and controllable responses. Bodily functions like digestion and heart rate regulations are controlled by the autonomic nervous system, as is arousal. These are all reaction we have no direct control over. The autonomic nervous system is further divided into two categories, the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system is connected to physical activity, and is the system that releases hormones and agents into our body and by doing so, that the sympathetic nervous system prepares the body to handle various physical challenges, e.g. by raising our heart and respiratory rate which affects subsequently processes in the body. The other part of the autonomic system is the parasympathetic nervous system; this particular system handles emotional reactions, anger, fear, happiness and together with the sympathetic system is able to form the fight-or-flight, which is an uncontrollable primal response to imminent danger, as well as a response to an emotional reaction. It can sometimes be difficult to definitely say which nervous system acts right now, because they sometime can overlap or reacts upon each other. A simple act of you accidently kicking a chair, the pain you feel if registered by the nerves in the peripheral system, which signals your central nervous system and that you instinctively retract your foot back, is considered to be a response in the somatic system, since it is a conscious movement, but it is all in all an involuntary movement, that we have no control over (24).

This provides basic knowledge about the nervous system and how our body reacts to various stimuli, based upon our nervous system. Stimulating the autonomic nervous system appears to be the key to physiological feedback in the previous experiments mentioned in state of the art. This indicates that if there would be a physiological response to infrasound exposure the response would not be controllable by the test subjects, since it is an unconscious automated response by the nervous system, given that they do not perform other activities that would be able to affect their physiology.

2.4.3. Fight-or-Flight

Going over what has been discussed so far. According to Joshua Reeds, sound and music possess the ability to affect us. When sound has a psychological or physiological effect on us, it is called a psychoacoustic effect. If the nervous system is not stimulated, there will be no reaction toward that sound and it no effect occurs. However, if a sound successfully affects us, it starts at the core of our body, at the nervous system. As a result of that the rhythms of our body can be affected, e.g. the heart rate, respiratory rate and even the brainwaves are said to be affected.

Infrasound has been proven and disproven over and over to have physiological effects on the human body. Since there is no definite conclusion to this, I will assume that the reported effects **can** happen under the right conditions. Some of the noticeable effects reported in experiments, discussed in state of the art, section 2.4, where human subjects have been exposed to infrasound are:

- Increase in heart rate
- Similar effects found in sick building syndrome
    - Headache
    - Irritations of eyes
    - Coughing
    - Nausea
    - Dizziness

- Sense of weakness
- Restlessness
- Fatigue
- Loss / difficulties concentrating
- Nystagmus (involuntary eye movement)
- Compromised ability to balance / increased body sway
- Altering blood pressure level

Many of these responses are caused by infrasound and are a reaction by the nervous system, and are uncontrollable by us consciously. It is mainly our autonomic and the connected sympathetic and parasympathetic nervous systems that controls our body's reactions and regulates our physiology based on how it is stimulated and which sensations are perceived. For example if infrasound is able to induce a feeling or sensation of fear in an individual the body will respond as it being threatened and preparing the body to deal with it. This is the fight-or-flight response. When the fight-or-flight response activates the body releases several hormones including stress hormones (e.g. cortisol) and adrenalin into the bloodstream, this for example causes increased heart rate and blood pressure, pupil dilatation, tensed up muscles, increased blood-glucose levels (24) (25) (26). This can help indicate that the responses reported in the previous experiments could have been due to a sensation of fear or similar response that could have helped the physiological feedback to alter.

According to sources found on the effects on fight-or-flight, pupil dilation also occurs when, in this case, presented to a threat, and is another trait that indicates a change in a person's emotional state. Moffat & Kiegler, 2006, did a study in music and emotion. The idea was to show video game trailers with different emotional background music - and at key trailers record the physiological alternations in the test participants. Measuring heart rate, pupil dilation and galvanic skin-response, Moffat & Kiegler (27) concluded that sound and music is able to induce a change in people's emotional state, and that physiological data is capable of showing such a change. However, with measurements like these it is not possible to distinguish between emotions of similar traits.

2.5. Final Problem Statement

It is still uncertain if infrasound has an effect on the human body or not. Assuming that the reported effects can happen and infrasound is able to affect the human body there is a strong indication that the effect is of a negative nature, an impairing effect. Many of the effects can be linked to responses found when the body is in a fear and anxiety related state. The found literature also indicates if the body were to respond to infrasound it is an automated response and not controllable by the individual and the response would be measureable through physiological feedback, e.g. heart rate, blood pressure, pupil dilation and galvanic skin-response among other self reported effects, like concentration difficulties, tiredness and nausea. Nystagmus or involuntary eye movement is also a found to be an induced effect caused by infrasound. However, if infrasound is capable of inducing physiological states similar to fear, can the body, based on the fight-or-flight response, increase its performance?

From this a final problem statement can be drawn.

"Playing a game, can effects of infrasound significantly influence the performance of the player?"

3. Analysis

A common field of interest from the state of the art is the physiology aspect, many of the experiment relied on physiological reading (bio-feedback) and self-reports from the participants for data gathering. In the analysis I will look closer into the physiology of the human and bio-feedback.

3.1. Emotions

This section will look briefly into emotions and how they can be defined. This is done because there will be many findings that will surround the aspect of emotions. We are able to feel several types of emotions and sensations like happiness, sadness, anxiety, fear, joy, worried and so on, but what is an emotions and how do we define one from another e.g. happiness and joy. Paul Ekman has in his studies come up with a a set of criteria which needs to be fulfilled before a feeling can be categorized as a basic emotion (28) (29) (30).

Table 2 below lists the nine criteria Ekman has established for when we can fit a feeling into a basic emotions.

	Basic with regard to:	
	Distinctive States	Biological Contribution
1.Distinctive universal signals	X	X
2.Presence in other primates		X
3.Distinctive physiology	X	X
4.Distinctive universals in antecedent events	X	X
5.Coherence among emotional response		X
6.Quick onset		X
7.Brief duration		X
8.Automatic appraisal		X
9.Unbidden occurrence		X

Tabel 2 shows Ekman's table of Characteristics to categorize Basic Emotions

The emotions Ekman have categorized as the basic emotions are:

- Anger
- Fear
- Sadness
- Enjoyment
- Disgust
- Surprise

All basic emotions share the nine criteria above. Some of the most relevant points from Ekman's framework of basic emotions is that emotions has distinctive physiology, which support the conclusion of Moffat & Kiegler, that physiological feedback is able to indicate chances in people's emotional state. The second point is that emotions have a quick onset and are of a brief duration. Elaine Fox, 2008, also defines emotions are brief but adds that in order for provoke an emotional reaction the event causing it has to have a significance personal relation and meaning to the individual, Fox's definition is:

"A relatively brief episode of coordinated brain, autonomic and behavioural changes that facilitate a response to an external or internal event of significance for the organism" (31)

This can be used to further divide emotions into categories and distinguish between emotions and moods. Fear as a basic emotion and similar to surprise are of short duration, and can be induced by something like a jump scare - but how about when we feel fearful for a much longer period of time? Walking home alone late at night through dark and dim streets can make most of us uncomfortable and nervous, fearing the worst. This is not considered an emotion but rather a mood, a feeling of an emotion but of longer duration. The duration of an emotional state will determine whether they're feeling is regarded as an emotion or as a mood.

3.2. Physiology

In this section will regard the physiologically feedback aspect, what can be measured and what can be derived from it.

3.2.1. Heart Rate

Heart rate, tells us about the frequency of heart beats. The purpose of the heart is to circle blood throughout the body, to keep it warm and deliver various hormones among many other agents and especially oxygen to the muscles for a number of reasons. When our body is 'inactive' or in other words at rest, some of the body's physiological variables are slower. At rest the body does not need to work nearly as hard as if it was threatened or have to perform at a high level. This means that when the body is in a state of rest and relaxation, the heart rate, respiratory rate and levels of stress related hormones among other agents should be at a lower level. However, the various variables are not the same for everyone. The heart rate, also known as the pulse depends on many variables e.g. age, sex and physical condition of the body. At younger ages the heart rate would normally be higher than when older. However, for athletic people the heart rate would be even lower. Below is a chart showing the classification of age and the average heart rate range for men and women (32).

Resting Heart Rate(Men)						
Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	49-55	49-54	50-56	50-57	51-56	50-55
Excellent	56-61	55-61	57-62	58-63	57-61	56-61
Good	62-65	62-65	63-66	64-67	62-67	62-65
Above Average	66-69	66-70	67-70	68-71	68-71	66-69
Average	70-73	71-74	71-75	72-76	72-75	70-73
Below Average	74-81	75-81	76-82	77-83	76-81	74-79
Poor	82+	82+	83+	84+	82+	80+

Table 3 shows a chart of the heart rate for men, classified into age and level of fitness/physical condition.

Resting Heart Rate(Women)						
Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	54-60	54-59	54-59	54-60	54-59	54-59
Excellent	61-65	60-64	60-64	61-65	60-64	60-64
Good	66-69	65-68	65-69	66-69	65-68	65-68
Above Average	70-73	69-72	70-73	70-73	69-73	69-72
Average	74-78	73-76	74-78	74-77	74-77	73-76
Below Average	79-84	77-82	79-84	78-83	78-83	77-84
Poor	85+	83+	85+	84+	84+	84+

Table 4 shows a chart of the heart rate for women, classified into age and level of fitness/physical condition.

From these tables (table 3 and 4) it can be seen that women in general have a little higher heart rate than men and that people's physical condition and age affects the heart rate. However, age seems to have a less significant impact on the heart rate according to this table, where level of physical fitness is much more significant. Furthermore, people who smoke and drink alcoholic drinks and coffee, usually have a significant higher heart rate and blood pressure and also influenced heart rate (33) (34).

The lowest heart rate you will achieve is when you are at rest and relaxed. There is a method to estimate a person's max HR[5]. The best method to measure and estimate a person's max HR is to have it clinically measured. However, there is a more simple calculation that can be used as an indication to what a max HR should be, it is called age prediction heart rate formula.

For women:

$$Women: 226 - age = MaxHR$$

For men:

$$Men: 220 - age = MaxHR$$

It is a very simple, however not totally precise but it can give an indication, of a person's max HR. Again it can be seen that the women's starting point is a little bit higher than men's, due to a slightly faster heart rate. The gap between a rested heart rate and max HR is the heart rate reserve (HRR). For a 25 year old male, an estimated max HR is, (220 – 25), 195 BPM, and at a rested state has a HR of 65 BPM, then the heart rate reserve would be, (195-65), 130 HRR.

A healthy heart is as mentioned a heart that has a relative low BPM, this means that the heart is strong and can sufficiently pump the necessary amount of blood through the body, at rather low effort. Furthermore, a steady rhythm is indicates a healthy heart.

Physical effort, change of emotional state and preparation reaction by the nervous system are among the factors that can alternate the HR. As mentioned it is a reaction that is made to deliver more blood and agents to the part of the body that needs it to deal with whatever situation the organism may face. A parameter knows as HRV[6] is used to indicate irregularity in heart rhythm amongst other symptoms. Irregular heart rhythm would typically show when we are nervous, scared, stressed and similar sensations. It is sometimes known as atrial flutter or heart flutter, and basically it means abnormality of the heart's rhythm. Such a condition and can be provoked by caffeine, alcohol, drugs, medicine, illnesses in the heart or in the general body. Abnormalities in the heart rhythm are for the most part present when the heart beats rapidly (35). If Atrial flutter can be induced during exposure to infrasound it will indicate that a person is affected and the body might react to a degree as it would in some of the above mentioned states and sensations.

3.2.2. Blood pressure

Blood pressure is tells us about the pressure of blood the heart pumps through the body. Unlike heart rate, blood pressure does not vary the same way with age in adult life. When measuring blood pressure you will

[5] Heart Rate
[6] Heart Rate variability

consult two numbers e.g. 140/90. The first number is called **systolic** which is tells the blood pressure when the heart beats and actually pumps blood. The second number is called **diastolic** and is the pressure when the heart expands after contraction - both numbers measured in mmHg (millimetres of mercury). A normal blood pressure for an adult person, at the age of 18 and over, would be:

$$< 120/< 80$$

Above each respective number, the pressure would be considered to be a high blood pressure (HBP) which is also known as hypertension, however in stages which is shown on figure 4 below, figure below:

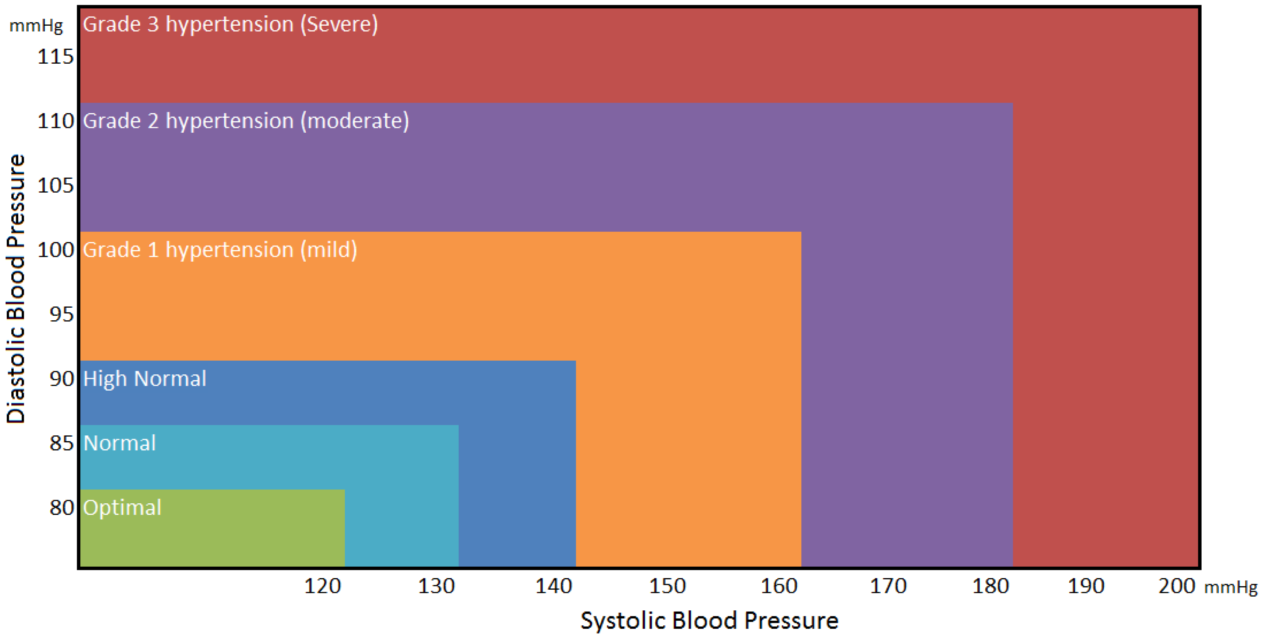


Figure 4, shows the classification of blood pressure (hypertension)

The blood pressure level still alters depending on the state of the body. When we are at sleep the blood pressure would be lowered compared to a rested yet awake state. Illnesses, excitement, nervousness and sensation that activate the body will cause the blood pressure to increase. Also like heart rate, it is affected by foods, drinks, smoking and physical body condition (36). The same goes for low blood pressure. A low blood pressure would have numbers 90/60 or less, low blood pressures can cause dizziness, nausea and people to faint. Low blood pressure can also occur when people feel higher level of anxiety and fear, and following fear is most of the physiology discussed before, heart rate etc.

To sum up blood pressure, changes either increase or decrease compared to a measurement from a rested and relaxed state can used to indicate emotional changes. It should be noted that blood pressure can change very rapidly therefore carefully timed and considerations should be taken when taking measurements.

3.2.3. Galvanic Skin Response

In the previous mentioned experiment by Moffat & Kiegler the use of galvanic skin response (GSR) or skin conductance level (SCL) was used to measure emotional change in test subjects. It measures the ability of the skin to conduct electricity and is measured from the fingers. When we are worried, nervous, anxious, tense and fearful we will get cold and sweaty hands and this is what can be measured with GSR. A higher level of GSR/SCL will indicate a higher level of strain to the body in regards to fear like sensations and discomfort. Also a personal experience with a GSR measurement and past test using such a measurement device showed conclusive data that when people felt fearful and anxiety, their GSR values went up (37).

Mandryk & Atkins, 2007, writes in their article that GSR is:

"Galvanic skin response is linear correlate to arousal and reflects both emotional responses as well as cognitive activity." (38)

3.2.4. Pupil Dilation

As has been previously mentioned, Moffat & Kiegler used equipment to look for pupil dilation during the test of whether music could induce emotional changes in people. Their conclusion was that pupil dilation can be a useful tool, but alone it is not possible to conclude anything with certainty. However, as before mentioned by cross analysis of several parameters together with a strong indication of emotional changes can be drawn, but firmly concluding an emotion proves difficult since many emotional states shares similar reaction.

3.3. Pre-Testing

Before going into designing the final test it is wise to perform a pre-test. The purpose of this pre-test is to test the equipment and to make observations whether infrasound can produce measureable results within the chosen physiological branches, heart rate, irregular heart rate, blood pressure and GSR.

The infrasound will be generated by the use of the software Pure Data[7] and outputted by a sub-woofer (Genelec LSE Series 7071A), further description of the set up can be found in the Design and Implementation, section 4.0. The ideal frequency has not been determined, however, the frequency of 7Hz has so far been the most common frequency used in experiments, with both reported effects and no effect on humans. At this point it is unknown how much the sound system is capable. To produce low frequency at high sound pressure levels requires a high quality sound system. Therefore testing of sound equipment is also necessary.

The room used for the testing is a sound proofed room, with thick padded walls. This room reduced the reflection of sound and has a high absorption level of sound. Items in the room such as furniture, tables, chairs and interior can help the sound to resonate in the room.

In previous experiments lack of information about the test subjects participating in the experiments seems to be a common issue. Reviewing references and sources about physiology it can be said that the life style, physical condition and health has a very big impact on people's physiology. Therefore, I will pay attention to the participants’ condition and habits. The areas of interest are

[7] http://puredata.info/

- Smoking
- Level if physical activity
- Have not had alcoholic drinks within the day
- Has not been drinking drinks of tea, soda or coffee within a respectable time.
- Have not been physical active within the hour
- Not taking medicine
- Have a 'normal' heart - no heart diseases
- Must not be ill
- 18-30 of age

All these factors are, to a degree, controllable parameters and are all able to influence physiological conditions to a significant degree according to research.

For this test the measurements that will be taken are blood pressure, pulse and galvanic skin response. A health monitor kit called 'Cooking Hacks: e-Health Sensor Platform kit' for Arduino and Raspberry Pi contains several sensors capable of measuring the needed physiology. To measure heart rate participants has to be fitted with a sensor on the tip of the finger, see figure 5. However this device had been discarded due to fact that it will be disruptive towards the test subjects' ability to use their fingers when playing a game, thinking of the final test, which will influence them negatively when performing.

Figure 5 shows the e-Health device for measuring pulse.

Instead an 'AND Blood Pressure Monitor' device will be used to read the pulse and blood pressure the same time, see figure 6, thus, it is one sensor less to connect to the test subject. Because our physiology can be affected by many things and can change significantly even when faced with everyday situations it is important not to make the test participants feel uncomfortable. Therefore, as few connected sensors to the test participants will be desirable, also minimal invasive sensors would be preferable.

Figure 6 AND Blood Pressure Monitor

To measure the GSR, the e-Health kit also includes a set of sensors capable of measuring that. However, due to difficult planning of getting and using the kit in the test phases, I made it myself. Description of the self made device and the software running it will be presented in section 4.3, Arduino and Processing application, in Design & Implementation.

In a paper by G. Yannakakis et al. they look into the correlation between heart rate, electrodermal activity and player experience (39). Electrodermal activity (EDA) is the same as galvanic skin response previously discussed. They looked into W. Boucsein, 1992 (40), and his research on electrodermal activity, stating that EDA/GSR reflects a person emotional responses and cognitive activity. Their approach was to have participants play three FPS games, wearing the measurement devices for heart rate and GSR. Every five minutes the game was paused and the participants were asked to answer a questionnaire within seven. The questionnaire is the iGEQ (in game experience questionnaire) which is designed to measure game experience in seven dimensions.

- Positive affect
- Negative affect
- Challenge
- Tension
- Flow
- Immersion
- Competence

In their findings and analysis of the data they found correlation between all three parameters (HR, GSR and iGEQ). They note an interesting finding concerning the heart rate. A higher minimum, average and maximum heart rate were observed when participants felt negative affects and tension, according to the questionnaire. This could indicate frustration in the players. However, when the participants felt positive affect and reported higher values of flow, competence, immersion and challenge lower minimal, average and maximum HR were recorded. This can indicate familiarity and comfort with the game has an effect on the measurements. Considerations were also taken towards the type of test subjects participating in the test. Gamers of various experience levels from novice, intermediate and hardcore. Hardcore gamers rated much less on the negative dimensions, while expressing a higher level of enjoyment by rating higher on positive dimensions; while novice gamers rated higher in the negative dimensions and lower on positive dimensions (39). This sparks the thought that the extreme cases in such an experiments, very inexperienced and highly experience players are highly and hardly influenced in various aspects due to their level of experience. In this case novices being highly sensitive to negative affect and less affected by positive, while hardcore gamers hardly affected by negative affects and highly sensitive to positive affect.

3.3.1. Pre-test method

The method and procedure of the pre-test will consist of pre and on-the-fly measurements. Since the test location will usually be a little walk away, the participants will be asked fill out a questionnaire and relax for a little while 5-10 minutes to get their heart rate and physical condition to a resting state, and to give them a little time to get comfortable in the test environment. The participants will be informed about the test before coming to the test room, furthermore, while relaxing they will be informed about what is going to happen and how it will go down. This is done to eliminate suspense the participants might have.

Before the first stage of the test, A, while the participant relaxes, blood pressure, heart rate will be measured initially two times, with 1-2 minutes in between. If pulse and blood pressure varies drastically, another measurement will be taken after 1-2 minutes. This is done to get measurement as close to the participants resting state, when the participant becomes “stable” the first stage of the test beings. When all sensor and measurement devices are ready, this takes about 30-40seconds, recording of GSR (which takes an average of 200 samples over approximate 12seconds), blood pressure and pulse are taken at the beginning of the test, then after two and four minutes. Afterwards, the participants are informed the same procedure will be conducted, with one addition which is the infrasound, stage B of the test. Before starting the readings the infrasound needs to be started, this takes around one minute before the sound is started and calibrated to 16Hz and at 64dB in the location where the participants sits. The SPL was measured with a sound pressure meter, see figure 7. The sound pressure can vary several dB depending on where you are in the room; therefore the sound pressure will be checked each time for every test participant. After calibration GSR, blood pressure and pulse will be measured again at the beginning for the test, after two minutes and again after four minutes. As the blood pressure and pulse measurement takes approximately 30 seconds it will, counting calibration time, sensor start up, expose each participant for just over 6minutes in total.

Figure 7, shows the sound pressure meter used to calibrate sound pressure before the test.

Usually when having more than one condition in a test, e.g. A and B condition, one would use the ‘within participant’ method. Alternating between each participant, which stage of the test they will be trying first.

Every first participant will try the A condition and the B condition afterwards, where every second participant will try the B condition first and A second. This is to eliminate bias and learning curve between the two stages. However, in this test using the 'within participants' design is not an option. Due to the possible effects of infrasound can linger for an unknown time after exposure; this will be further elaborated upon in the discussion and conclusion section 6.

Before doing the test, the GSR sensors were tested, to see how they will behave when completely relaxed. The graph below shows three tests of a person wearing the sensors on his/her fingers for 5 minutes. Each average is printed every 12 seconds. The purpose is to see if just by putting on the sensors will increase the conductivity/the amount of sweat produced under the bands. As can be seen the values on figure 8 increases and decreases from reading to reading, and in the last minutes has a decrease in GSR value. This indicates that simply wearing the bands do not has a serious influence on the readings over time.

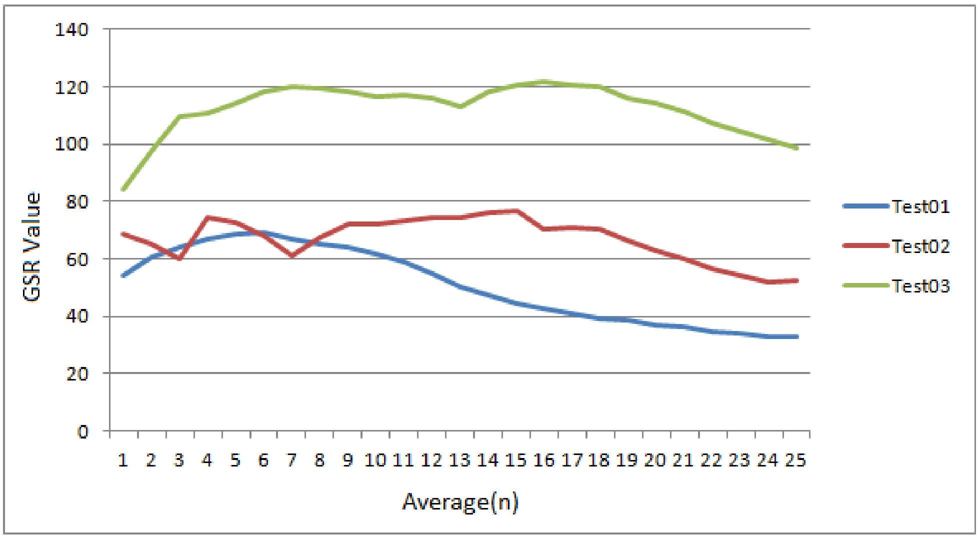


Figure 8, shows the values of a 5minutes test, wearing the GSR sensors.

The room used for the test was a sound proof, with padded walls with few hard surfaces present in the room. As the infrasound was played, it 'gathered' in 'zones' where the SPL was higher than elsewhere in the room; especially the corners and near walls in the room the SPL was significantly higher. By moving no more than one meter out of a zone, the SPL could drop up to 3dB. The participants were placed in such a zone, to receive the highest amount of sound pressure, without pushing the sound system too much. As mentioned the frequency produced was 16Hz at 64dB, going any lower in frequency would strain the sound system even more, and at some frequencies made the room sing/shake which was a disturbance outside experiments taking place at the same time. Therefore the frequency and SPL used was the deemed a fitting setting under the circumstances.

The participants answered the questionnaire about their condition and habits (See appendix A on the CD for the written answers). None of the participants suffered or was aware of any heart condition and had no illnesses. Three of the ten was female and the age ranged from 19-28. Amongst the participants two smokers were recorded (participant #4 and #7). None of the participants were in very poor physical condition, however one rated herself very little active (participant #9). No one has been physical active with the last hour, besides the walk down to the lab. Some of the participants have had drinks of tea, coffee or soda during the day, but respectable time since last drink (1< hour), and no alcoholic drinks were included. From the personal data participant #4, #7 and #9 had one or more points of interest. Looking at the data test participant #4, who have had a smoke approximately 1hour before, did not seem to be highly influenced by smoking, blood pressure and heart rate were optimal. As for #7 and #9, had very similar recordings, both close to the upper boarder of normal physiology, thus considered to have a normal blood pressure, however, slightly high heart rate, compared to some of the other participants. Comparing to the heart rate chart shown above on table 3 and 4, they rank average for #7(male) and just above average for #9(female) in physical condition in respect to heart rate.

The table below, table 5, the averages of the data collected from the participants (n=10), where A is resting phase and B when exposed to sound. The participants were all known to me, with the thought that they would feel more relaxed and comfortable around me even in a testing environment.

Participant	Systolic(A)	Diastolic(A)	HeartRate(A)	GSR(A)	Systolic(B)	Diastolic(B)	HeartRate(B)	GSR(B)
#1	94	61	63,50	17,57	94,4	52,33	66,60	28,15
#2	109	75	75,50	61,39	110,66	75	73,33	87,31
#3	108,25	64	78,75	38,12	106,33	60,33	76,33	43,12
#4	105,75	58,25	54	69,48	98,66	55,66	54,33	79,50
#5	107,50	59,50	68,75	49,31	107	60	66,66	53,11
#6	126,75	64,50	64,25	37,23	127	63,66	65,66	51,27
#7	127	79	74,75	57,45	125,33	74,33	73,33	60,26
#8	110,50	61,25	54,50	35,63	111	61,33	56,66	28,88
#9	126	83,50	70,25	132,54	131	80,66	71,33	118,47
#10	125,50	65,50	63,25	64,32	126	64,66	65,66	68,46

Table 5, shows the data in average from the participants in the pre-test.

Participant	Systolic	Diastolic	HeartRate	GSR
#1	+0,40	-8,70	+3,16	+10,58
#2	+1,66	0	-2,17	+25,92
#3	-1,92	-3,67	-2,42	+5
#4	-7,09	-2,59	+0,33	+10,02
#5	+0,50	+0,5	+2,09	+3,80
#6	+0,25	-0,84	+1,41	+14.04
#7	+1,67	-4,67	-1,42	+2,81
#8	+0,50	+0,08	+2,16	-6,75
#9	+5,00	-2,84	+1,08	-14,07
#10	+0,50	-0,84	-2,41	+4,14
Average	-0,287	-2,354	0,245	5,549
T-Test	0,96	0,56	0,95	0,68

Table 6 shows the differences from test A (the resting state) to test B (when exposed to infrasound) for each test participant, as well as an average in change.

As can be seen from these numbers, on table 6, there is only very small changes from test A to B. No change is great enough to be able to conclude anything from. The only parameter that is somewhat consistent is the increase in GSR. However, the changes are so small that it can be influenced by almost everything. Based on previous experiments results of exposure to infrasound should show within the first minutes of exposure. Some of the participants through self reports mentioned dizziness, fatigue and tiredness. Other than the self reports, no indication was found that infrasound in this experiment was affected, on a measureable scale within blood pressure, heart rate and GSR. Calculating a T-Test (p=0.05) shows that there is no statistically difference between the two tests.

A source of error could be the frequency and the intensity. However, with the environment and the testing situation it was deemed that the set up used, was the optimal at the given time. Further experimentation with frequency and intensity of SPL could perhaps induce more measureable results. For this set up and from the results collected the conclusion is that infrasound at 16Hz with a 64db SPL does not affect the physiology. However, with reports of some of other known symptoms like dizziness, fatigue and tiredness, somatic symptoms, indicate that infrasound could have immeasurable effects. Therefore for the final test, influence on performance can still be possible.

The success criterion for the test and product is a significant difference in performance between the baseline performances to when exposed to infrasound.

Based on the pre-test, there should not be much difference in physiological measurements between the two stages based on infrasound exposure. However, in the final test the participants are challenged by a game which, based on previous experiments, should increase physiological measurements compared to resting state measurement, due to being challenged.

4. Design & Implementation

In this section the design and implementation of the final test and the equipment will be described.

4.1. Test Design

In the pre-test I had infrasound tested, with the purpose of observing if any physiology changes in the test participants. As stated there were only minor differences between the two stages, and not enough to be concluded as a difference. However, self reports by the participants mentioned the feeling of dizziness, fatigue and tiredness after the experiment. This leads me to think that the infrasound had some effect, but not on the physiology measured during the pre-test. Therefore in the final test, it will not be appropriate to discard the physiological readings. In the final test the participants will be challenged by a game, while being measured in the same way as in the pre-test. There is a possibility that the infrasound together with game can give measureable readings.

It is not easy to measure a player's total performance in a game, because there are several aspects that comes into play in a game, action/reaction, reaction time, opponents, decision making, strategic performance, precision, awareness, accuracy, experience and skill level of each player are influences, and what background of gaming people have. In a simple game it comes down to hand-eye coordination, there are several games that can support this. However, I feel it is necessary to eliminate as many of the immeasurable parameters as possible, thus eliminate bias and experience level differences. Initially two games were looked upon that challenges the player in a controlled game; meaning there are no influence from other players, no change in narrative, no event based actions or elements that alternates the game and task at hand. For the final test, only one game will be chosen. The first is an aim and click game[8], see figure 9. Several targets will continue to pop up randomly, the task is to aim and click at them before they disappear. This game challenges the hand to eye coordination of the participant and reaction time and accuracy is the parameters that are being tested in this game. The game requires a high level of focus because of its pace. The other is a game from SEGA and developed by SmileBit , named Type-or-Die, which is a game where the task is to type the word shown on the enemies, see figure 9. Type-or-Die challenges the players' ability to write under pressure. The game then measures the overall typing speed, time per. keystroke and accuracy.

[8] The game is available on the website www.aim400kg.ru - date visited: 14th of May 2013.

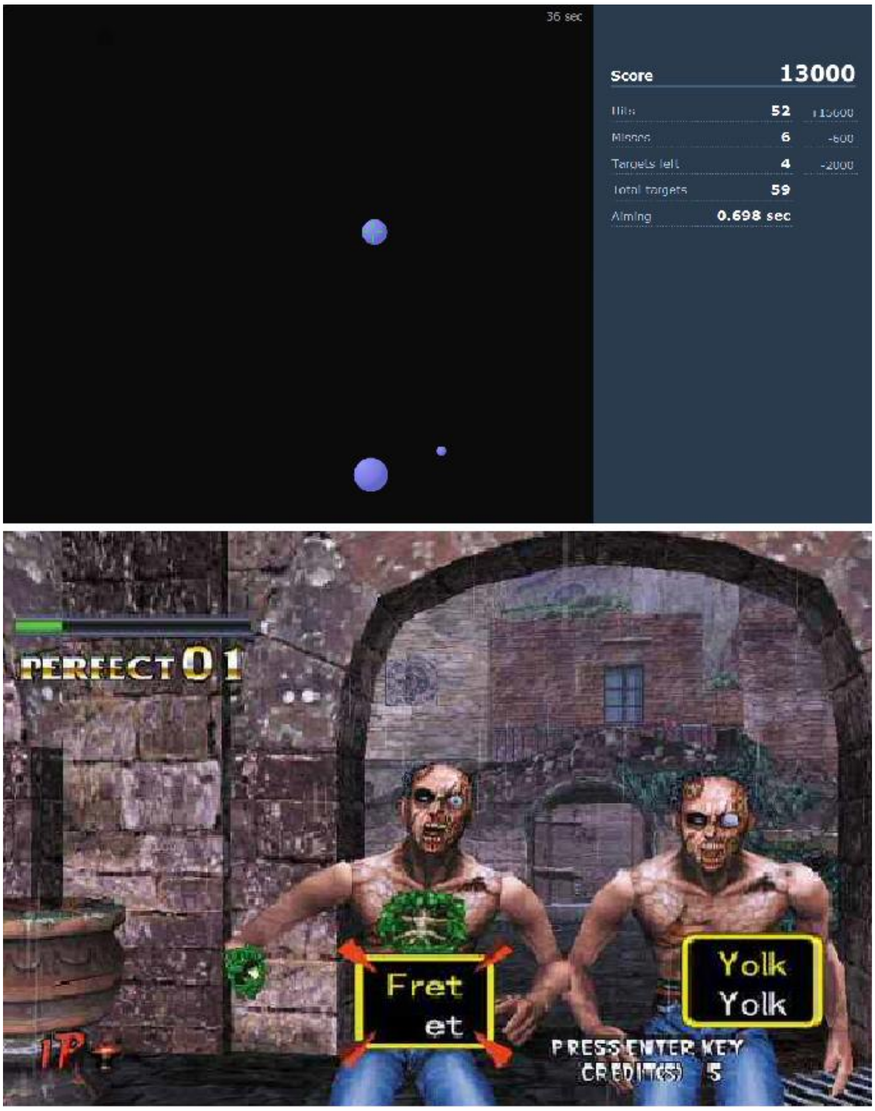


Figure 9, (Upper image) a screenshot of the aim training game and (Lower image) a screenshot of Type-or-die.

Looking the two games there are pros and cons for each.

Aim Training		Type-or-Die	
Pros	Cons	Pros	Cons
Highly challenging	Hardware learning curve(mouse)	Simple task	Muscle memory, plays a factor, less focus required.
Focuses highly on hand to eye coordination skills	Gamer background and player skill level can be a factor	Eliminates many gamer biases(gamer background)	Not very challenging
Simple task		Good data of performance	Hardware learning curve(keyboard)
Good data of performance			

Table 7 lists the pros and cons for the games.

Both games are very similar in each their aspect, one challenges the skills on a keyboard, the other with the mouse; however, the keyboard suffers from the aspect of muscle memory which comes by extensive use and practice. Muscle memory allows you to be able to execute a series of action in a specific rhythm or pattern, like when typing your own password or name into a computer, it usually being typed at the same speed and the key stroke timing is the same every time. It can be said that the same goes for aiming as well, but it is very different from typing a word and comes down to control execution and precise and fast aim. Furthermore, the Aim Training game might be more affected by the player's background within games, than Type-or-Die, but then offers a higher level of challenge and precision of performance. Both games also suffer from a learning curve problem, if the participants are not familiar with the hardware, which requires extensive use of each of them to be completely comfortable using the hardware. The mouse does have an advantage over the keyboard in that aspect, because of its option to customize its move speed and acceleration speed, where the keyboard cannot be changed. In conclusion the Aim Training game will be the game used for the final test, due to its higher level of challenge and gamer related task of hand to eye coordination.

4.2. Implementation of GSR sensors

In the final test the same equipment will be used to measure physiological feedback. It is the AND blood pressure monitor and the self-made GSR sensors. To make the sensors I used:

- An Arduino Duemilanove(atMega328)
- one 10K ohm resistor
- few meters of wire
- Aluminium foil
- Velcro for the finger bands

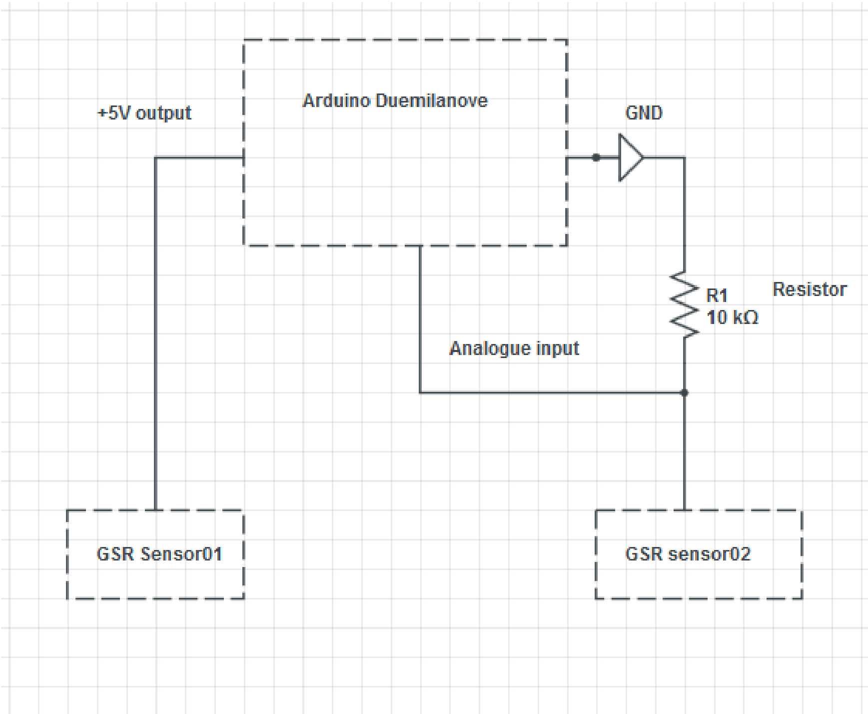


Figure 10 shows the diagram of the GSR sensors.

Figure 10 shows the diagram of the circuit to make the GSR sensors. From the Arduino the first sensor is connected directly to the +5V output. The other sensor goes from the Arduino's ground lead to a 10k ohm resistor. The analogue lead bypasses the resistor and connects with the ground wire and from that node, sensor 2 is connected. The finished product can be seen on figure 11. It is a poorly build and could be made much more presentable, however it is the functionality that comes first. From the Arduino board, the left most wire (red) is the +5V output, the middle (black) is the ground signal, the right most(yellow) is the analogue input wire. On the fingers the middle finger is connected to the +5V output wire and the index finger to the ground/analogue input wire.

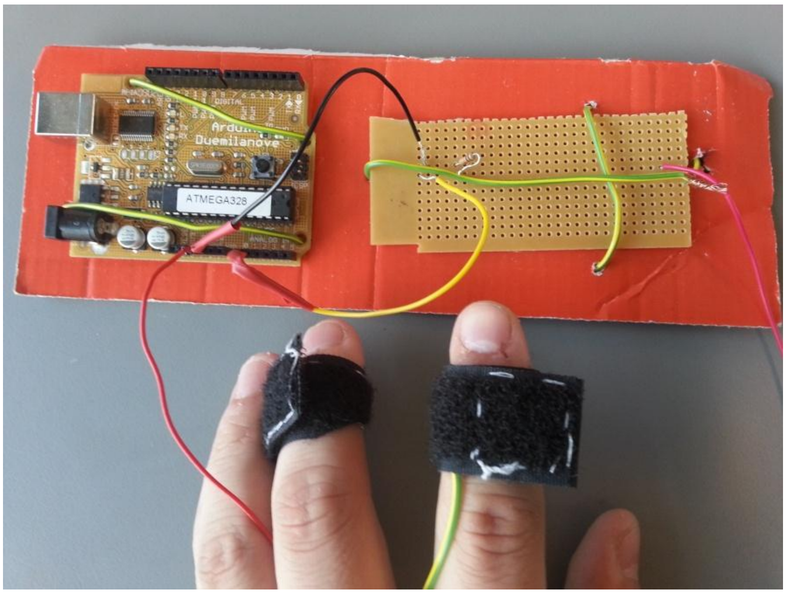


Figure 11, shows the final build of the Arduino and the GSR sensors.

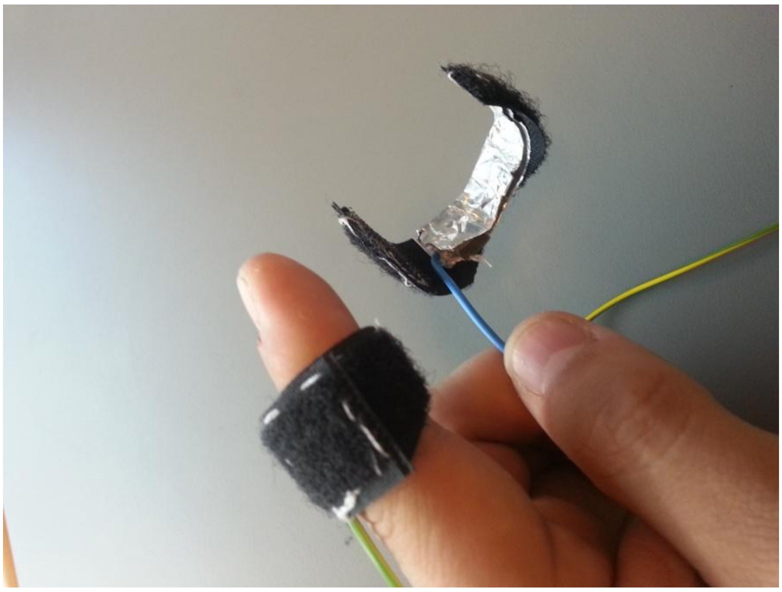


Figure 12 shows one sensor connected and the inside of the other.

The sensors themselves are made of a Velcro band with aluminum foil, which has to have contact with the skin and a stripped wire underneath, see figure 12. The aluminum foil is used to create surface and contact to the skin to get measurements.

4.3. Arduino and Processing application

The Arduino is connected to a computer through the USB-port, and runs with its own drivers provided from www.arduino.cc/ which is arduino's official website. The driver version used in an outdated 0.023version, which fits the application. Together with the Arduino, a Processing application takes the input given to the Arduino and processes them. The code for the Arduino and the Processing application is taken from an example made by Che-Wei Wang (cwwang)[9], and then modified to my own needs (41). The way it works is that one sensor, the +5V lead, sends current into one finger, and the other sensor measures the difference in current. The code is set to take a measurement every 50 millisecond which adds up to 20 reading per second. The code draws every reading into a graph, but also an average reading creating a smooth curved graph. However, there are no legends or marks on the graph telling the values recorded. Therefore I wrote a piece of code to print out in text, an average every 10 second, which are 200 readings. I suspect the internal clock to be slightly off and therefore each printed average only happens approximately every 12 second. See figure 13 for the output window of processing and example of the application output.

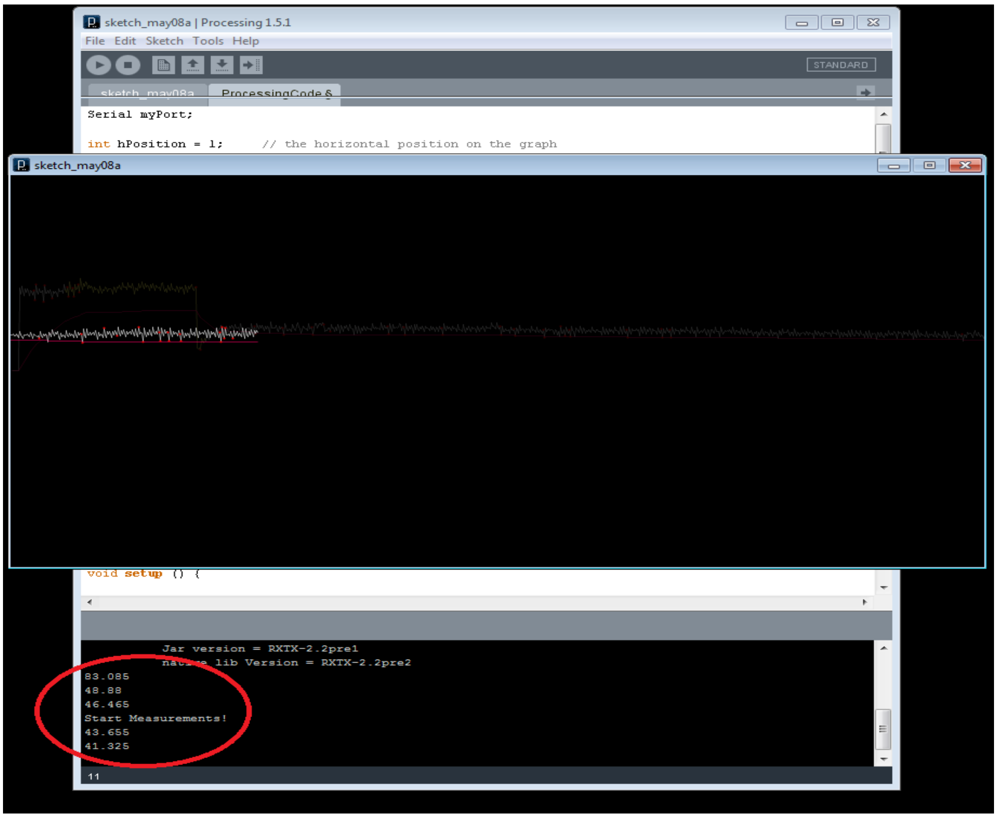


Figure 13 shows the graph drawn and the output window below, circled are the printed averages.

[9] http://cwwang.com/2008/04/13/gsr-reader/

In the application I have also included a pause/start function of the readings in case something happens and the test can be resumed without starting the test over. Furthermore, a 'write to file' function has been implemented in order to save the data collected.

4.4. Infrasound Setup

To produce the infrasound, I am using the same equipment as well. The sound is generated in a PureData application called a patch. The figure below shows the patch in PureData, figure 14

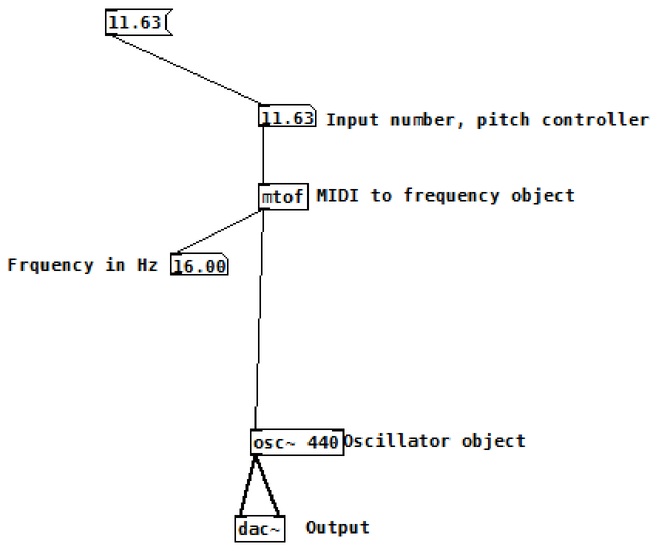


Figure 14 The PureData patch used to generate the sound.

The patch uses a float input number, which needs to be converted into actual frequency done by the 'mtof' object. This patch will output a frequency at 16Hz at maximum amplitude. The volume of the sound will be controlled by separate device, RME Fireface 800 soundcard, see figure 15.

Figure 15, the RME Fireface 800 soundcard used together with the set up.

Figure 16 below, shows how the set up is connected. The PureData patch, run by the PC, sends the sound to the RME Fireface 800 where the the Genelec LSE Series 7071A subwoofer will output and produce the sound.

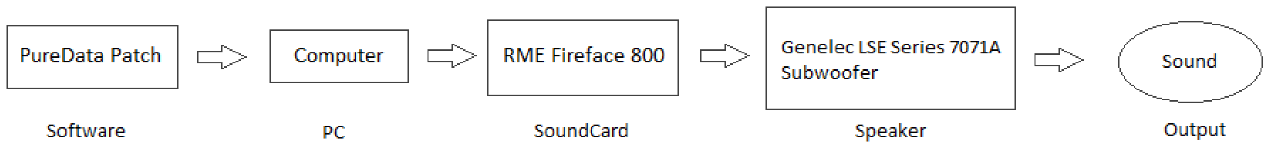


Figure 16, the set up of the sound system, to produce the infrasound.

4.5. Final Test method

The test method for the final test will be similar to the pre-test. Participants will before taking part in the test, be asked to fill out a questionnaire (See Appendix B) about their health conditions and habits. Experience from the pre-test showed that short time where they rest, participants had a very stable pulse and blood pressure, indicating that they were in the optimal resting state possible under the circumstances. For this test people not known to me will also be tested on as well to, widen the array for possible test participants, compared to the pre-test, where it was a priority that people felt as comfortable as possible to get reliable data.

The procedure of the test starts with the participants filling out the first part of the questionnaire, and is presented with the Aim Training game with a time to train with the hardware (the mouse), to let them know what the task will be. Participants will be free to change the speed of the mouse for comfort. Afterwards will be a short resting session, depending on the stability of physiology. Thereafter people will be asked to play the Aim Training game where the results will be recorded, reaction time, targets hit, target missed and misses. Four playthroughs of the game will be required. A playthrough will consist of 100 targets shown targets. I will stop the game when the 100 targets are reached. After each completion of a playthrough, blood pressure and pulse sample will be taken. This will conclude the first part of the test. For the second part of the test, the procedure will be the same, however without the resting session, and with infrasound exposure. In the end they will be asked to fill out the final part of the questionnaire, about their current state, what they felt, if anything, due to what was learned from the self reports from the pre-test.

4.5.1. Hardware

The hardware used for the final test, is Asus laptop with an intel core i7 processor 2gHz, more than enough for a small application such as Aim Trainer. The mouse is a state of the art Razer Mamba G4 wire/wireless laser mouse, gliding on a Razer Goliathus mousepad. Razer gaming hardware is amongst the top of the line hardware producers. The Razer Mamba according to Razer themselves has <1 ms delay time on wireless setting, thus delay from the mouse will not be seen as a factor when analyzing the results.

5. Results

In this section the data gathered from the final test will be listed. The final test included 14 participants (n = 14) 3 females and 11 males. The results will be divided into Test (A) and Test (B).

The questionnaires only showed a few point worth looking to and consider when looking at the data (see appendix C on the CD for the written answers).

Participants	Notable remarks and answers
#1	Only 1-4 hours of playtime per week, on PlayStation 3. Felt uncomfortable after exposure – annoyed by the infrasound.
#2	Felt it was more difficult to regain "control" after missing a target, while exposed to infrasound – also annoyed by the sound.
#3	Felt indifferent from Test A to Test B. A few yawns during test B
#4	Felt dizzy and a disturbing sense of body shaking after exposure.
#5	Yawn shortly into the first game of Test B. Felt sleepy, tired and fatigued and commented that the infrasound made him tired.
#6	Took a lot of deep breaths during test B, had a more difficult time focusing on the game with the sound on, felt a sense of relief when the sound was turned off
#7	Felt slightly fatigued due to performing in the game and felt he had a more difficult time to recuperate after missing a target, also felt annoyed by the sound.
#8	Had coffee just before the test. Felt dizzy after the test. Felt he 'panicked' easier during test B when missing a target
#9	Annoyed, otherwise indifferent
#10	Felt indifferent
#11	Only 1-4 hours of playtime per week. Felt fatigued, motion sickness and uncomfortable. Had a harder time to get focused during test B
#12	Smoker. Felt more stressed and aggressive. Got competitive during play.
#13	Smoker. Felt annoyed, tired and uncomfortable after play.
#14	Sense of drowsiness and were annoyed.

Table 8 lists the self report answers given, and noticeable answers from the questionnaire.

A common observation made during test for each participant, was that no one removed their focus from the screen during play and kept complete focus on the task at hand.

The two tables below, table 9 and 10, shows the averages of the data for each category, table 9 shows the physiological data and table 10 the performance results play Aim Trainer.

Participant	Systolic(A)	Diastolic(A)	HeartRate(A)	GSR(A)	Systolic(B)	Diastolic(B)	HeartRate(B)	GSR(B)
#1	110,25	65,5	66,25	61,18	116,75	65,75	67,75	75,84
#2	110,25	63,25	73,25	65,44	108	71	71	76,11
#3	114,5	84	86,25	46,25	123,25	84,5	88,25	65,79
#4	113,5	78,5	80,5	32,97	112,25	74,25	76,5	38,41
#5	132,25	87,5	66	43,81	133	66,5	66,5	57,27
#6	141,25	82,25	87,25	82,62	167,25	83,25	86,75	98,84
#7	118,5	75	79,25	82,82	119,75	75,5	82,75	88,73
#8	116,5	69	64,5	97,39	112,25	70,25	58,75	112,91
#9	107	63	75,25	92,89	106	63	76,25	107,76
#10	125,75	67	67,5	83,40	112,75	74,75	74,75	97,40
#11	106,75	58	56,75	37,45	102	56	58,5	41,33
#12	115,75	66,5	70,75	19,31	107,5	66,5	74,75	27,78
#13	106,25	59	62,5	27,28	97,25	60,25	64,75	44,05
#14	108,5	59,75	57,5	58,30	106,25	62,75	59	73,24

Table 9, shows the average physiological data gathered from each participant.

Hits represents the number of targets hit out of 100 possible, misses are shots missed total, TM(Targets missed) represents the number of targets not hit and AT(Aiming time) is the average amount of time between each successful target hit.

Participant	Hits(A)	Misses(A)	TM(A)	AT(A)	Hits(B)	Misses(B)	TM(B)	AT(B)
#1	82,75	17,25	17,25	0,768ms	86,5	14,25	13,5	0,702ms
#2	87	13,75	13	0,702ms	88,75	13,75	11,25	0,700ms
#3	85,5	7	14,5	0,677ms	89,5	5,5	10,5	0,639ms
#4	77,75	20	22,25	0,866ms	82,5	22,5	17,5	0,787ms
#5	83,5	21,25	16,5	0,763ms	80,5	16,25	19,5	0,801ms
#6	78,75	10,25	21,25	0,888ms	88	7,5	12	0,751ms
#7	86,75	19	13,25	0,734ms	91	13	9	0,658ms
#8	86,5	16	13,5	0,769ms	88,75	13,75	11,25	0,746ms
#9	78,75	17	16,25	0,914ms	82,5	13,75	17,5	0,818ms
#10	76,5	17,75	23,5	0,941ms	80,75	7,25	19,25	0,846ms
#11	82,5	27,5	17,5	0,821ms	83,25	31,25	16,75	0,807ms
#12	88,25	16,5	11,75	0,729ms	95	9,5	5	0,609ms
#13	88,25	17	11,75	0,703ms	93,25	15,5	6,75	0,632ms
#14	84,25	43,25	15,75	0,781ms	87,75	26,5	12,25	0,705ms

Table 10, shows the average of the performance in the Aim Training game for each participant. Hits is the number of targets hit out of 100, misses is missed shots, TM is targets missed out of 100, AT is Aim Time the amount of time between targets hit.

Table 11, shows the differences in mean from test A to test B, for each participant in each category, both physiology and performance.

Participant	Systolic	Diastolic	HeartRate	GSR	Hits	Misses	Targets Miss	Aim Time
#1	+6,5	+0,25	+1,5	+14,66	+3,75	-3,0	-,3,75	-0,066ms
#2	-2,25	+7,75	-2,25	+10,67	+1,75	0,0	-1,75	-0,002ms
#3	+8,75	+0,5	0,0	+19,54	+4,0	-1,5	-4,0	-0,038ms
#4	-1,25	-4,25	-4,0	+5,44	+4,75	+2,5	-4,75	-0,079ms
#5	+0,75	-21	+0,5	+13,46	-3,0	-5,0	+3,0	+0,038ms
#6	+26	+1,0	-0,5	+16,22	+9,25	-2,75	-9,25	-0,137ms
#7	-4,25	+0,5	+3,5	+5,91	+4,25	-6,0	-4,25	-0,076ms
#8	-4,25	+1,25	-5,75	+15,52	+2,25	-2,25	-2,25	-0,023ms
#9	-1,0	0,0	-1,0	+14,87	+3,75	-3,25	+1,25	-0,096ms
#10	-13,0	+7,75	+7,25	+14,0	+4,25	-10,5	-4,25	-0,095ms
#11	-4,75	-2,0	+1,75	+3,88	+0,75	-14,25	-0,75	-0,014ms
#12	-8,25	0,0	+4,0	+8,47	+6,75	-7,0	-6,75	-0,120ms
#13	-9,0	+1,25	+2,25	+16,77	+5,0	-1,5	-5,0	-0,071ms
#14	-2,25	+3,0	+1,5	+14,94	+3,5	-16,75	-3,5	-0,076ms

Table 11, shows the differences between test A and test B means, for each participant and category.

From the data collected, the collective difference in mean of change from test A to test B is shown in table 12, as well as the standard deviation and calculated T-Test.

Participant	Systolic	Diastolic	HeartRate	GSR	Hits	Misses	Targets Miss	Aim Time
Difference of means	-0,196	-0,286	0,911	12,454	3,643	-5,089	-3,286	-0,061ms
Standard Deviation	9,133	6,523	3,171	4,608	2,714	5,239	2,991	0,046ms
T-Test	0,971	0,934	0,808	0,224	0,034	0,076	0,048	0,055

Table 12, shows the difference in mean from Test A to Test B, as well as standard deviation and T-Test.

The T-test is a two tailed test; due to the possibility of change in both directions also the data is unpaired.

In appendix D, curves of GSR for each participant can be found, below are a few examples, figure 17, 18 and 19.

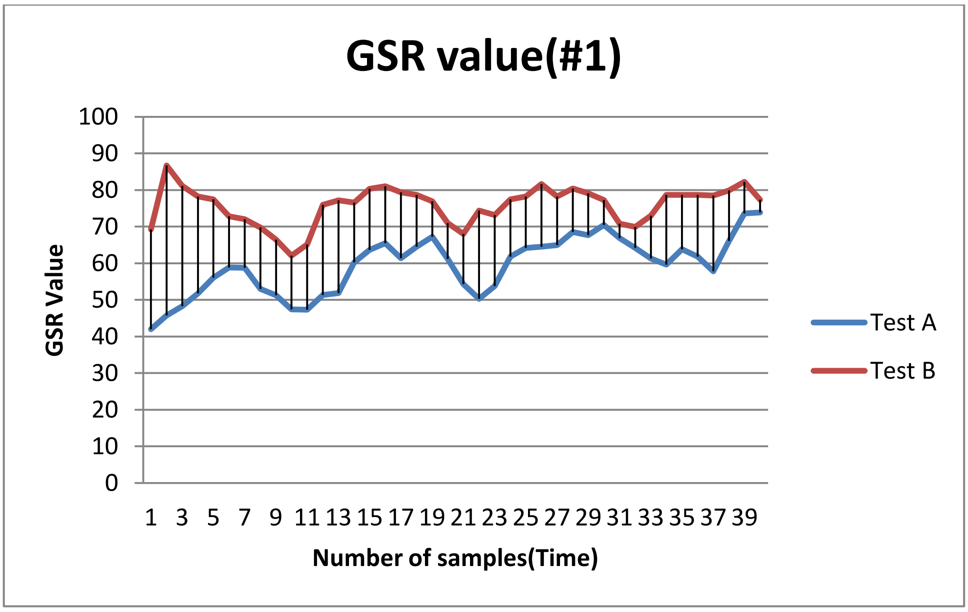


Figure 17, example of the GSR values for participant #1 during test A and B

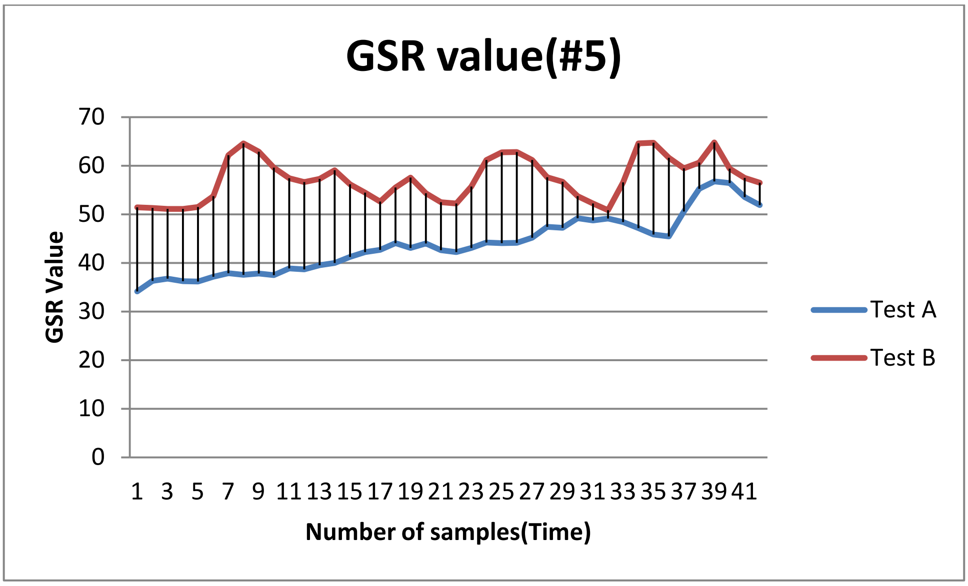


Figure 18, example of the GSR values for participant #5 during test A and B

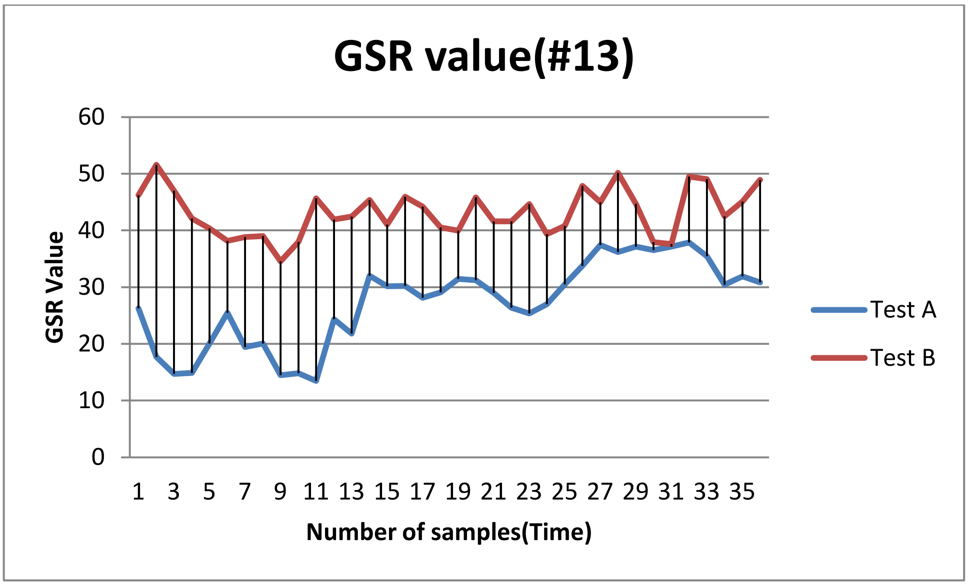


Figure 19, example of the GSR values for participant #13 during test A and B

6. Discussion and Conclusion

In this section the results of the data will be discussed and finding will be concluded upon.

From the pre-test, it was learned that there were no difference between the physiological data. However, for the final test the participants were challenged with an additional stimulus rather than the only infrasound itself, that being the game.

The optimal data for the final test, in regards to performance would be a significant increase in hits, and decrease in misses, TM and AT.

Looking across the data gathered and presented in section 5, Results, it can be seen that the difference in data from test A to test B, in the following categories: systolic, diastolic and heart rate, differs both positively and negatively from participant to participant and are not consistent in any way, see table 13. However, GSR, hits, misses, targets missed and aim time are somewhat consistent, besides from participant #5, who varies in some of the categories and actually performed worse.

Participant	Systolic	Diastolic	HeartRate	GSR	Hits	Misses	Targets Miss	Aim Time
#1	+6,5	+0,25	+1,5	+14,66	+3,75	-3,0	-,3,75	-0,066ms
#2	-2,25	+7,75	-2,25	+10,67	+1,75	0,0	-1,75	-0,002ms
#3	+8,75	+0,5	0,0	+19,54	+4,0	-1,5	-4,0	-0,038ms
#4	-1,25	-4,25	-4,0	+5,44	+4,75	+2,5	-4,75	-0,079ms
#5	+0,75	-21	+0,5	+13,46	-3,0	-5,0	+3,0	+0,038ms
#6	+26	+1,0	-0,5	+16,22	+9,25	-2,75	-9,25	-0,137ms
#7	-4,25	+0,5	+3,5	+5,91	+4,25	-6,0	-4,25	-0,076ms
#8	-4,25	+1,25	-5,75	+15,52	+2,25	-2,25	-2,25	-0,023ms
#9	-1,0	0,0	-1,0	+14,87	+3,75	-3,25	+1,25	-0,096ms
#10	-13,0	+7,75	+7,25	+14,0	+4,25	-10,5	-4,25	-0,095ms
#11	-4,75	-2,0	+1,75	+3,88	+0,75	-14,25	-0,75	-0,014ms
#12	-8,25	0,0	+4,0	+8,47	+6,75	-7,0	-6,75	-0,120ms
#13	-9,0	+1,25	+2,25	+16,77	+5,0	-1,5	-5,0	-0,071ms
#14	-2,25	+3,0	+1,5	+14,94	+3,5	-16,75	-3,5	-0,076ms

Table 13, shows the differences between test A and test B means, for each participant and category.

Table 14, shown below, tells us the final results of the final test. As can be seen there are minor and close to no differences in systolic, diastolic and heart rate. Using the T-test (p=0.05) and stating a null-hypothesis saying that there are no difference between the two tests; the T-test gives us the value about the possibility of that null-hypothesis. As can be seen systolic (0.97), diastolic (0.93) and heart rate (0.81) are well above the margin of the T-test, similar to the pre-test, it can be said that these parameters holds no statistically significance value. As for the GSR, the pre-test showed a T-test value of 0.68, where in the final test the t-test value is 0.224. As the game challenges the participants it can be assumed that their cognitive activity is increased significantly compared to the task in the pre-test which should increase the overall GSR value. However, looking at the results from the pre-test, the difference between the condition A and B the GSR only on average increased by 5.549 where in the final test, there has been an average increase of 12.454 between the two conditions. This indicates that the infrasound together with stimulus of the game affects and increases the GSR value of the participants, but difference between the two tests are not statistically significant.

As for the performance, the participants in general increased their performance from test A to test B. The T-test values for hits and TM are below the p-value, where AT is 0.005 above the limit, and misses is close to the limit by only 0.026 above it.

Participant	Systolic	Diastolic	HeartRate	GSR	Hits	Misses	Targets Miss	Aim Time
Difference of means	-0,196	-0,286	0,911	12,454	3,643	-5,089	-3,286	-0,061ms
Standard Deviation	9,133	6,523	3,171	4,608	2,714	5,239	2,991	0,046ms
T-Test	0,971	0,934	0,808	0,224	0,034	0,076	0,048	0,055

Table 14, shows the difference in mean from Test A to Test B, as well as standard deviation and T-Test.

It cannot be discarded that there is a learning curve issue in this data, since the 'within participants' method is not applied, the reason is as mentioned in the pre-test, because of the possible lingering effects of the infrasound. This would have required that each participant in the test were to be tested two times, hours apart. Within that time their physiology state can change significantly and would be an equally or even greater source of error, due to the difficulty in controlling what the participants are doing, drinking, eating in that time span. However, each participant was given the opportunity to play the game and customize the mouse to fit their comfortable level, to eliminate as much of the learning curve issue as possible.

From the comments and self reports from the questionnaires it can be said that most of the participants felt what previous referred to as psychosomatic symptoms. Fatigue, tiredness, dizziness, difficult focusing, sense of being uncomfortable and motion sickness were reported in the final test. This tells me that the infrasound did have some effect on the conscious parameters, where the unconscious parameters, heart rate and blood pressure were not affected. Even though many of the participants felt psychosomatic effects and reported focus difficulties, their performance according to the numbers improved, and according to the T-test, enough to be statistically significant or at least close to it. This can indicate two things, as previously discussed the learning curve can be a significant factor to this or it indicates that the infrasound affected the participants to perform harder or better. Only by eliminating the learning curve completely it can be said which one of these factors are the true indicator. Looking at the results in appendix D, it can be seen that the GSR values are consistently higher in test B than in test A. This can be due to annoyance from the infrasound but also difference focus and effort put into the performance in test B. In the Analysis, Galvanic Skin Response section 3, it was said by Mandryk & Atkins, 2007:

"Galvanic skin response is linear correlate to arousal and reflects both emotional responses as well as cognitive activity." (38)

This says that the annoyance as well as the level of focus can be factors in the increased values of GSR in the final test. Whether it is annoyance or level of focus that help increase the GSR value, the participants performed better during test B.

The game chosen for the final test can hold some aspects that need to be addressed. The task required in the game is a very simplified version of what you encounter in state of the art games. The reason was to eliminate as many of the aspects of a game that could not be measured in this set up. However, the game might has been too simple to challenge the participants sufficiently. Many of the participants were hitting well above 80% of the targets at any given time, and some close to perfect. Therefore a more challenging game with more room for improvement could have shown more clear results.

To conclude, it can be said that the physiology were not affected by the infrasound or the game, besides from the GSR. The increase in GSR can be due to the psychosomatic effects felt during exposure or due to an increase of focus and cognitive activity, which lead to an improved performance from Test A to Test B. However, it cannot be concluded definitively that the effects from the infrasound is the reason to their improvement, since there is a case of learning curve playing the game. Statistically it can be said that the participants' performance increased during exposure but thinking of the test conduction method chosen, it can be due to the learning curve. Comparing the GSR value from the pre-test and the final test, it can be said that there were an increase in one or more of the areas presented by Mandryk & Atkins, 2007, arousal, emotional response or cognitive activity, which lead to an increase in GSR. This can be interpreted as either an annoyance factor or an increase effort put into the game during exposure, based on the self reports given by the participants.

"Playing a game, can effects of infrasound significantly influence the performance of a player?"

In short to conclude on the above state final problem statement, a player's performance can be increased by a statistically significant margin, but factors like learning curve renders this statement questionable. Therefore this experiment is concluded to be inconclusive.

7. Future Perspective

This section includes what could be done to improve the experiment presented in this study.

Further experimentation of frequency and intensity of infrasound is an obvious area that could have been further investigated. Based on research the frequency of the infrasound has to resonate and be compatible with the subject to have a psychoacoustic effect. This is a very difficult subject to address since it can come down to fractions of frequencies. None the less further experimentation in this field can be done.

The factor of excluding the 'within participants' method and thus learning curve factors, rendered the experiment inconclusive and more carefully and controlled testing should be done to eliminate such factors.

An increased population of participant did not strike as a requirement since data were rather consistent across the participants. However, a larger population will always give a better indication of the results. Furthermore, a game that would challenge the players more, and giving more room for improvement from the baseline measurements could have been used. This might have given more clear results in the end.

Conducting more qualitative interviews after testing, could also have provided with more accurate descriptions of the symptoms felt by the participants.

Bibliography

1. **Haneke, Karen E., et al.** *Infrasound - Brief Review of Toxicological Literature.* s.l. : The National Toxicology Program, provided by Integrated Laboratory Systems Inc., 2001.

2. *Sick Building Syndrome: Acoustic Aspect.* **Burt, Tyrrell.** 5, 1996, Indoor Building Environ, s. 44-59.

3. *The Sick Building Syndrome(SBS).* **Babatsikou, Fotoula P.** 2, 1991, Health Science Journal, Årg. 5, s. 72-73.

4. **Østerby, Anders C.** Videncenter for Arbejdsmiljø. [Online] 25. January 2011. [Citeret: 20. February 2013.] http://www.arbejdsmiljoviden.dk/Aktuelt/Nyheder/2011/01/25012011-koncentrationen-oedelaegges.

5. *Noise Effects on Human Performance: A Meta-Analytic Synthesis.* **Szalma, James L. and Hancock, Peter A.** 2011, Psychological Bulletin, pp. 682-707.

6. *Some experiments on the recognition of speech, with one and with two ears.* **Cherry, Edward Colin.** 1953, Journal of the Acoustical Society of America, Årg. 25, s. 975-979.

7. *Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children.* **Haines, M. M., et al.** 2, 2001, Psychological Medicine, Årg. 31, s. 265-277 doi:10.1017/S0033291701003282.

8. **Leeds, Joshua.** *The Power of Sound.* s.l. : Healing Arts Press, 2001 - ISBN: 978-0892817689.

9. *Effects of Infrasound on Vestibular Funcion.* **Takigawa, H., Sakamoto, H. og Murata, M.** 1991, Journal of Sound and Vivration, s. 455-460.

10. **Wolfe, Jeremy M, et al.** *Sensation & Perception - second edition - ISBN: 0878939539.* Sunderland, Massachusetts U.S.A : Sinauer Associates, Inc., 2009, s. 260-261.

11. **Davies, Alex.** Acoustic Trauma : Bioeffect of Sound. [Online] 26. Frebruary 2011. [Citeret: 6. March 2013.] http://fenomenalll.blogspot.dk/2011/02/acoustic-trauma-bioeffects-of-sound.html - http://schizophonia.com/installation/trauma/trauma_thesis/index.htm.

12. **Cox, Trevor og D. Antonio, Peter.** *Acoustic Absorbers and Diffusers.* s.l. : Taylor & Francis Ltd , 2009- ISBN: 9780415471749.

13. *Factors Influencing Acoustic Performance of Sound Absorptive Materials.* **Seddeq, Hoda S.** 4, 2009, Australien Journal og Basic Applied Sciences, Årg. III, s. 4610-4617.

14. *Effects of Compression on the Sound Absorption of fibrous materials.* **Castagnede, Bernard, et al.** 61, 2000, Applied Acoustics, s. 137-182.

15. *Wood For Sound.* **Wegst, Ulrike G. K.** 93, 2006, American Journal of Botany, Årg. X, s. 1439-1448.

16. **Snyder, Nathan.** Sound Theory. [Online] 30. December 2008. [Citeret: 12. March 2013.] http://owyheesound.com/sound.php.

17. **Agency, Environmental Protection.** Indoor Air Facts No. 4(revised) - Sick Building Syndrome. s.l. : United States - Environmental Protection Agency, 1991.

18. *Early Response of the organism to low-frequency acoustic oscillations.* **Karpova, N.I., et al.** 1970, Noise Vib. Bll.

19. *Some Effects of Infrasonic Noise in Transportation.* **Evans, Margaret J. og Tempest, W.** 22, 1972, Journal of Sound and Vibration, Årg. 1, s. 19-24.

20. *Infrasound hazards for the environment and the ways of protection.* **D. Gužas, R. Viršilas.** 3, 2009, Ultragarsas(Ultrasound) - Šiauliai University. Vilnius str. 141, Šiauliai, Lithuania, Årg. 64, s. 34-37.

21. **Heyrman, Dr. Hugo.** Brainwaves. [Online] Doctorhugo, 10. November 2010. [Citeret: 21. March 2013.] http://www.doctorhugo.org/brainwaves/brainwaves.html.

22. **Learning, Synthesis.** Brain wave states & how to access them. [Online] Synthesis Learning, 11. January 2011. [Citeret: 21. March 2013.] http://synthesislearning.com/article/brwav.htm.

23. **Team, FinerMinds.** Meet Your Brain Waves - Introducting Alpha, Beta, Theta, Delta and Gamma. [Online] Finerminds, 6. August 2012. [Citeret: 21. March 2013.] http://www.finerminds.com/mind-power/brain-waves/.

24. **Nielsen, Oluf Falkenberg og Bpjsen-Møller, Mette Juel.** *Anatomi og Fysiologi.* Copenhagen : munksgaard.dk, 2012.

25. **Layton, Julia.** How Fear Works - Fight or Flight. [Online] HowStuffWorks. [Citeret: 27. March 2013.] http://science.howstuffworks.com/life/fear2.htm.

26. **Ankrom, Sheryl.** The fight or flight theory of panic disorder. [Online] About.com, 6. November 2008. [Citeret: 27. March 2013.] http://panicdisorder.about.com/od/agoraphobia/a/fightflight.htm.

27. *Investigating the effects of music on emotions in games.* **Moffat, David og Kiegler, Katharina.** 2006, s. 37-41.

28. *An Argument for Basic Emotions.* **Ekman, Paul.** s.l. : University of California , 1972.

29. **Ekman, Paul.** Basic Emotions. [forfatter] M. Power T. Dalgleish. *Handbook of Cognitive Emotion.* s.l. : John Wiley & Sons Ltd., 1999, s. 45-60.

30. *What Is Meant By Calling Emotions Basic.* **Ekman, Paul and Cordaro.** 2011, Emotion Review, pp. 364-370.

31. **Fox, Elaine.** *Emotion Science - ISBN; 987-0-230-00518-7.* s.l. : Palgrave Macmillam, 2008.

32. **TopEndSports.** Fitness Testing: Resting Heart Rate Table. [Online] Top End Sports, April 2012. [Citeret: 5. April 2013.] http://www.topendsports.com/testing/heart-rate-resting-chart.htm.

33. **MedlinePlus.** Risks of tobacco. [Online] Medeline Plus: Trused Health Information for You - A service f the U.S National ibrary of Medicin, 23. November 2011. [Citeret: 8. April 2013.] http://www.nlm.nih.gov/medlineplus/ency/article/002032.htm.

34. **LeWine, Howard M.D, Chief Medical Editor.** Increase in resting heart rate is a signal worth watching. [Online] Harvard Health Publications: Harbard Medical School, 21. December 2011. [Citeret: 5. April 2013.] http://www.health.harvard.edu/blog/increase-in-resting-heart-rate-is-a-signal-worth-watching-201112214013.

35. **Boyle, Noel G., MB, BCh, MD, PhD.** Atrial Flutter. [Online] eMedicineHealth, 28. March 2007. [Citeret: 9. April 2013.] http://www.emedicinehealth.com/atrial_flutter/article_em.htm.

36. **Staff, Mayo Clinic.** Low Blood Pressure(hypotension). [Online] Mayo Clinic, 11. May 2011. [Citeret: 9. April 2013.] http://www.mayoclinic.com/health/low-blood-pressure/DS00590/DSECTION=causes.

37. **Hansen, Kim Y. H., et al.** *Psychoacoustics Effects of Infra-sound on Game Experience[Unpublished].* Copenhagen : Aalborg University Copenhagen, 2011.

38. *A fuzzy physiological approach for continuously modeling emotion during interaction with play technologies.* **Mandryk, Regan, L. og Atkins, M. Stella.** Burnaby : Internaional Journal of Human-Computer Studies, 2007, Årg. 65. 329-347.

39. *Correlation Between Heart Rate, Electrodermal Activity and Player Experience in First-Person Shooter Games.* **Yannakakis, Georgios, et al.** 2010, Sandbox '10 Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games , s. 49-54.

40. **Boursein, Wolfram.** *Electrodermal Activity.* s.l. : Springer; 1st edition , 1992. 978-0306442148.

41. **Wang, Che-Wei.** GSR Reader. *cwwang.com.* [Online] 13. April 2008. [Citeret: 30. April 2013.] http://cwwang.com/2008/04/13/gsr-reader/.

42. **Bousein, Wolfram.** *Electrodermal Activity.* s.l. : Springer; 1st edition, 1992. 978-0306442148.

Table of Figures

Table of Tables

Appendix A(See the CD for the written answers)

Appendix B (The final test questionnaire)

1. Health

Do you have any heart diseases or other heart conditions?

__Yes __No

If yes, then you do not need to proceed.

Are you suffering from any illness at the moment?

__Yes __No

If yes, then you do not need to proceed.

2) General information

____Age ____Male ____Female

3) Smoking habits:

Do you smoke?

__Yes __No

If yes, how long since your last smoke _________ minutes

4) Physical activity

How would you rate your activity level? on a scale of 1-7, where 1 is not active and 7 is active on a athletic level.

Poor **Average** **Good** **Athletic Level**

1 -------------- 2 -------------- 3 -------------- 4 -------------- 5 -------------- 6 -------------- 7

Very little **Above Average** **Excellent**

How many hours a week are you active? **(walking, training, sports, bicycling)**

__________Hours

Have you been active within the last hour?

__Yes __No

5) Drinks

Have you been drinking alcoholic drinks today?

__Yes __No

If yes, how long since the last drink? _________hours

Have you been drinking tea, soda or coffee today?

__Yes __No

If yes, how long since the last drink? _________ hours

6) Gamer Profile

How many hours do you spend playing games on an average week?

I do not play ___
1-4 hours ___
5-8 hours ___
9-12 hours ___
13-16 hours ___
16+ hours ___

What kind of games do you play?(RTS, FPS, Racing etc.)?

7) After testing

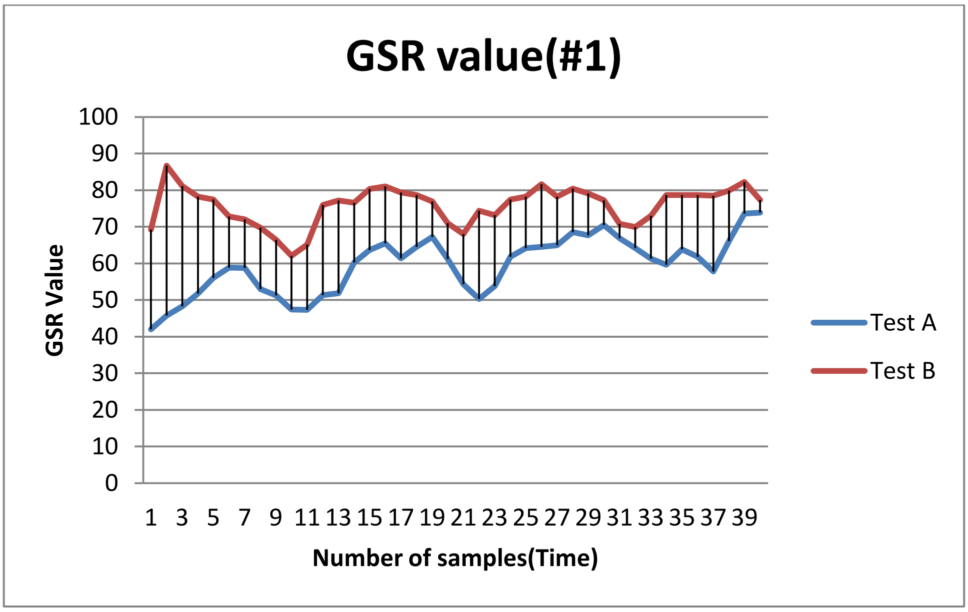
How do you feel? (more stressed, annoyed, uncomfortable, dizziness, fatigued, tired etc.) please elaborate:

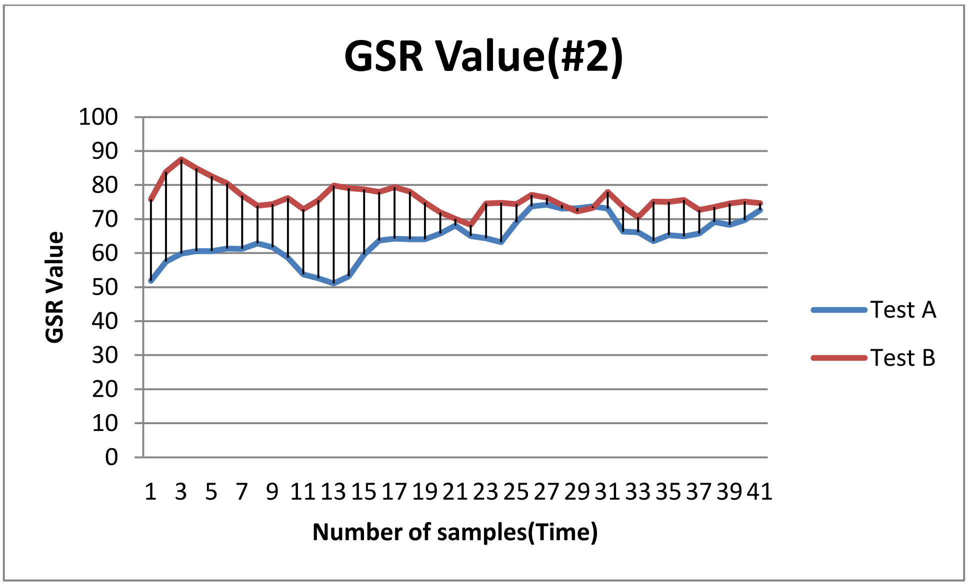
Did the sound affect you and in which way? (Concentration or focus difficulty, annoyance etc.)

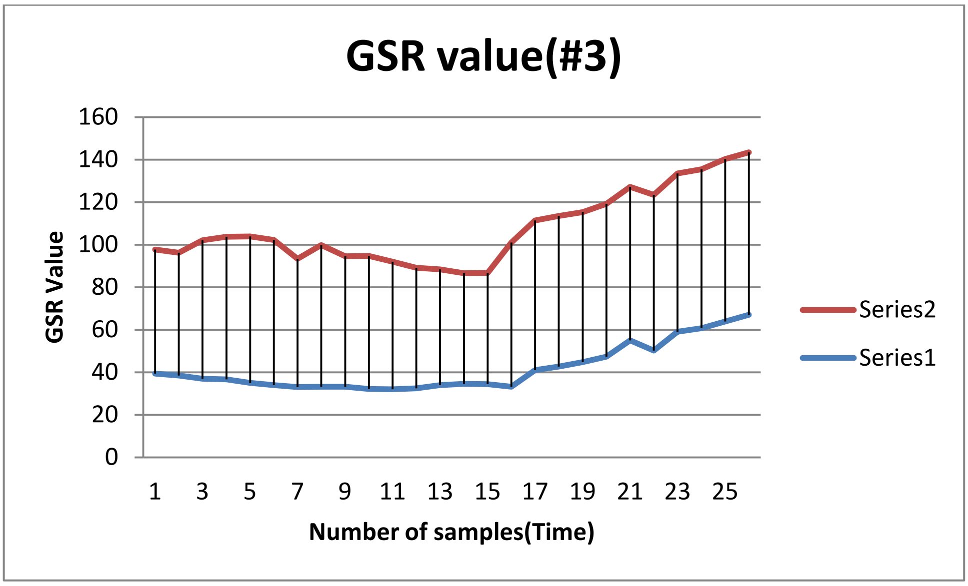
Appendix C (See the CD for the written Answers)

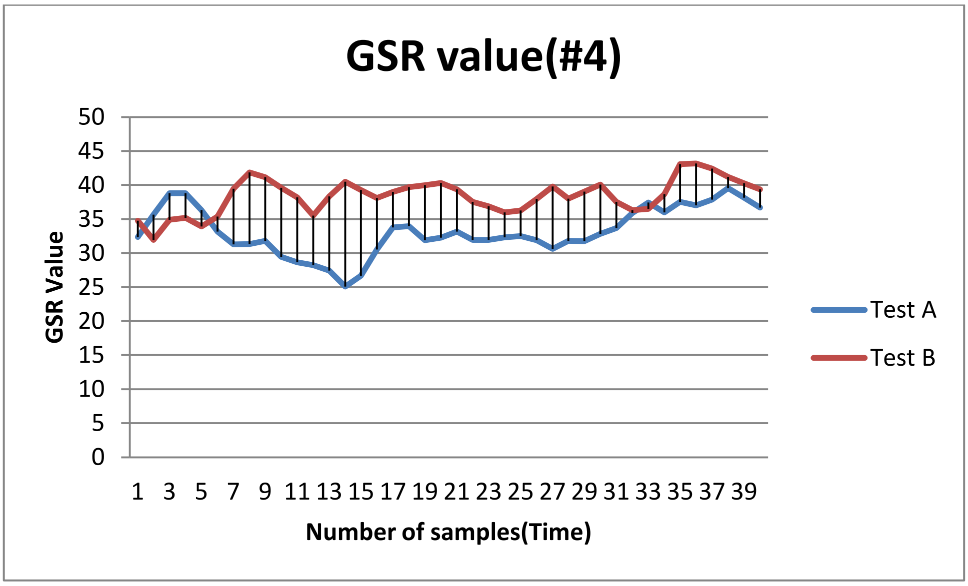
Appendix D(GSR Values from the Final Test, for each participant)

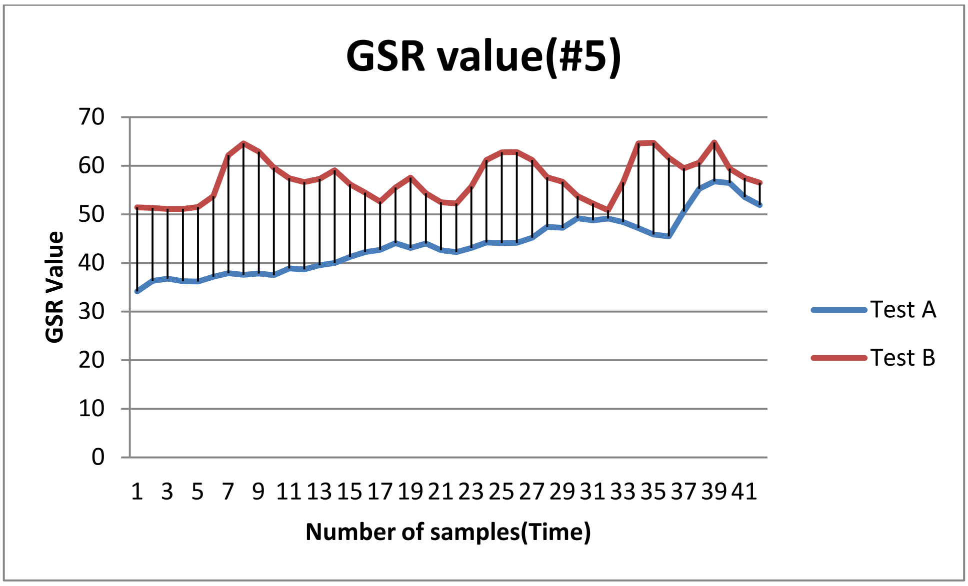
Graphs of GSR values in test A and B for the final test for each participant.

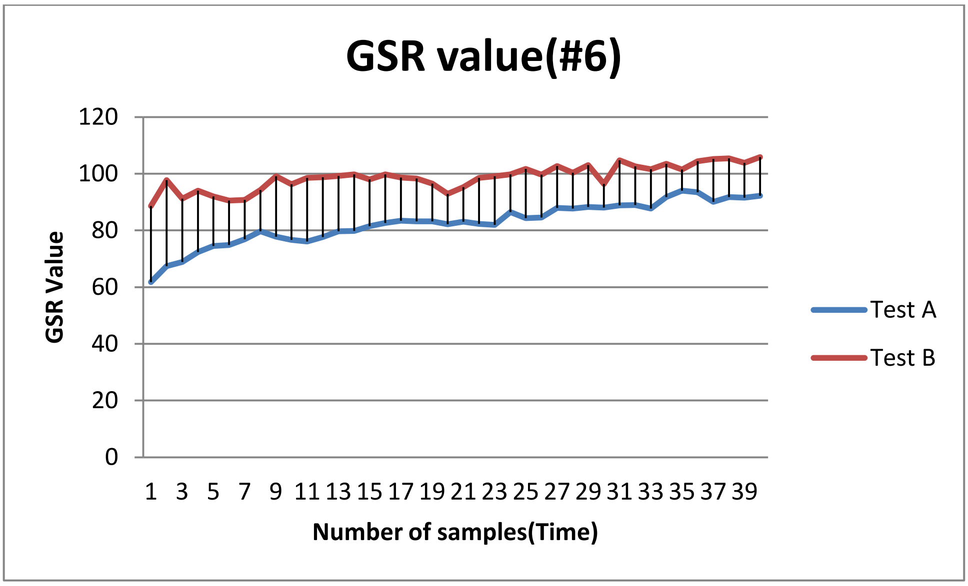


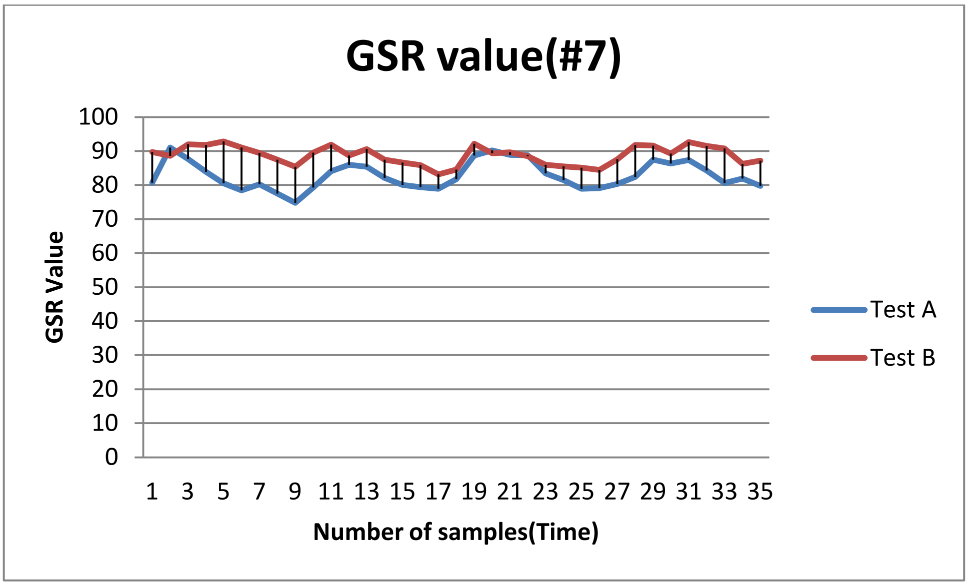


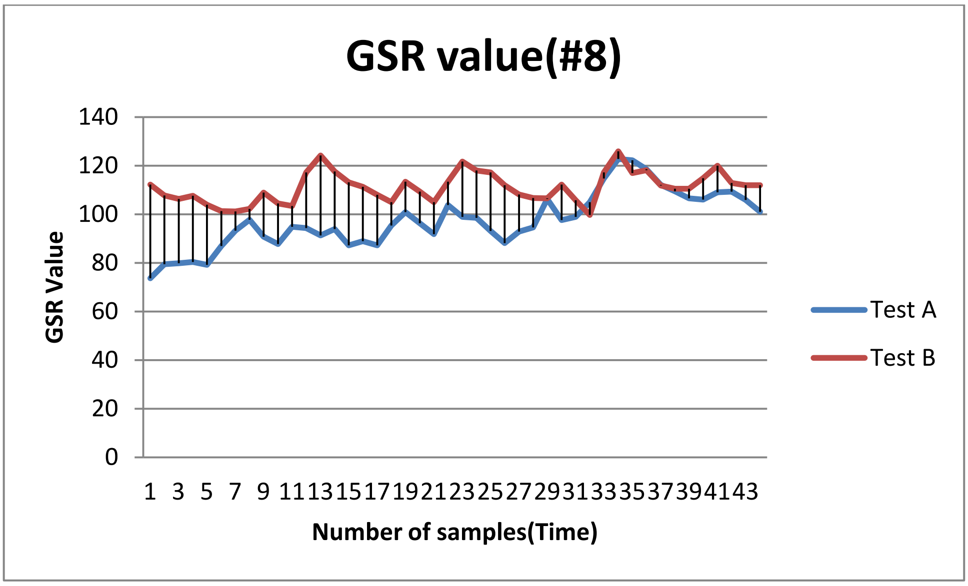

GSR value(#3)
GSR Value
160
140
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Number of samples(Time)
Series2
Series1

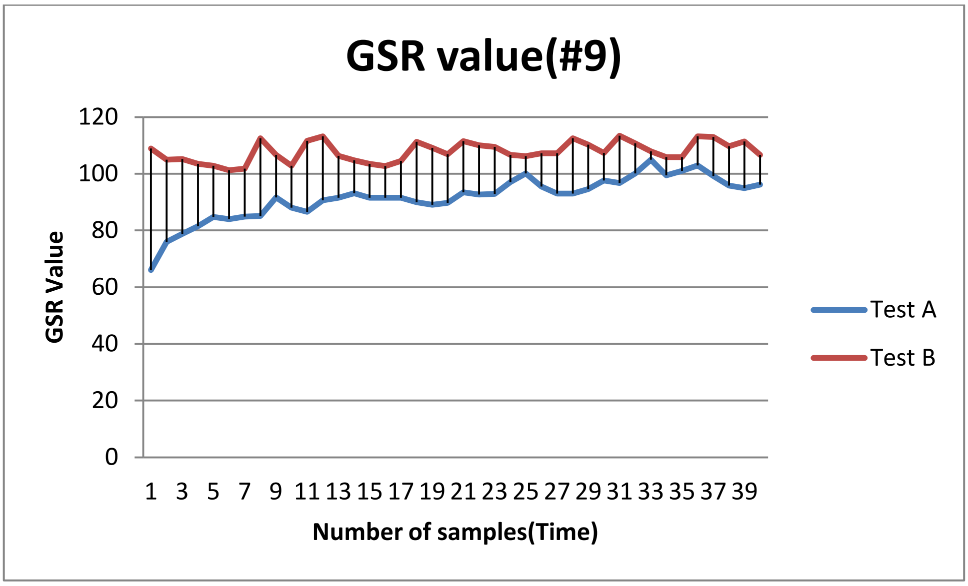

GSR value(#4)
GSR Value
50
45
40
35
30
25
20
15
10
5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Number of samples(Time)
Test A
Test B

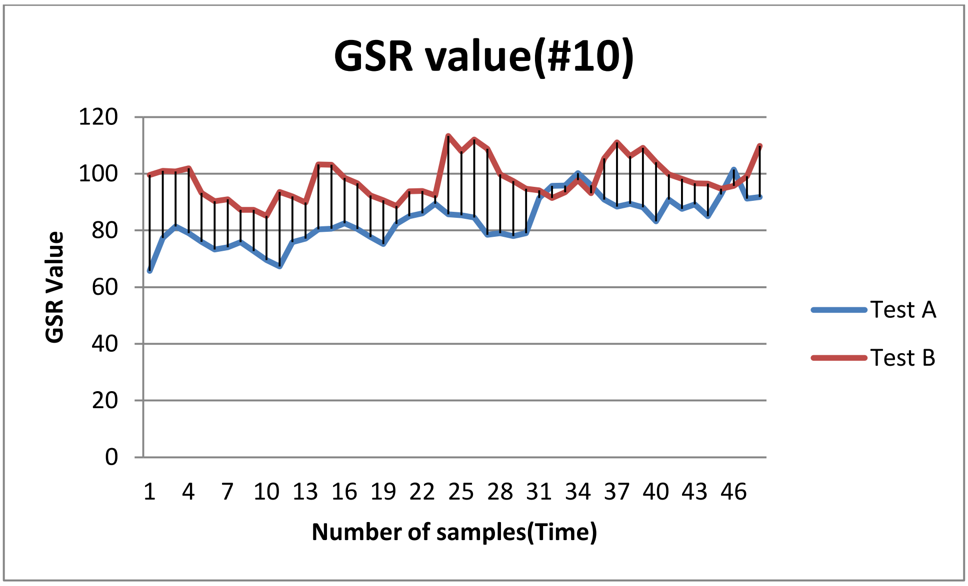

GSR value(#5)
GSR Value
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
Number of samples(Time)
Test A
Test B

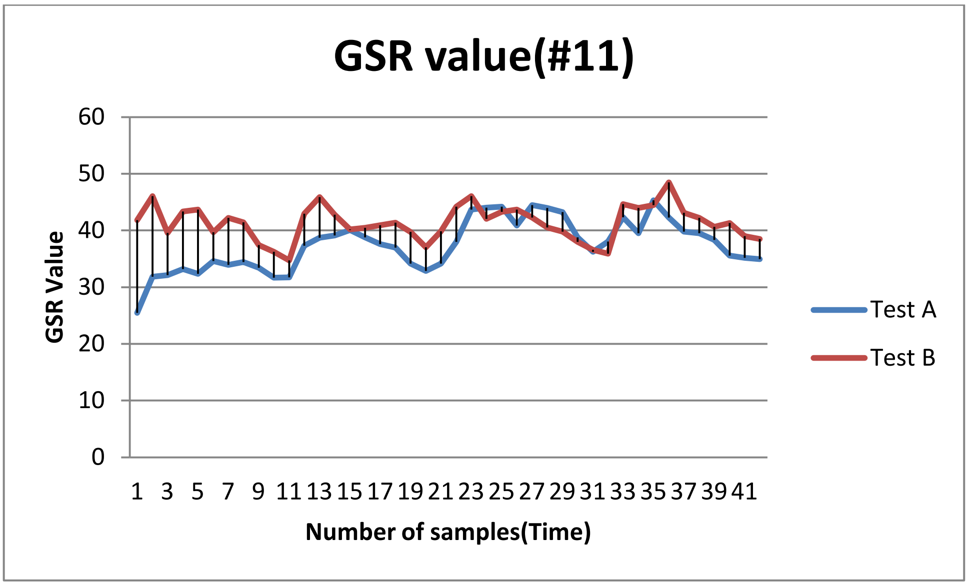

GSR value(#6)
GSR Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Number of samples(Time)
Test A
Test B

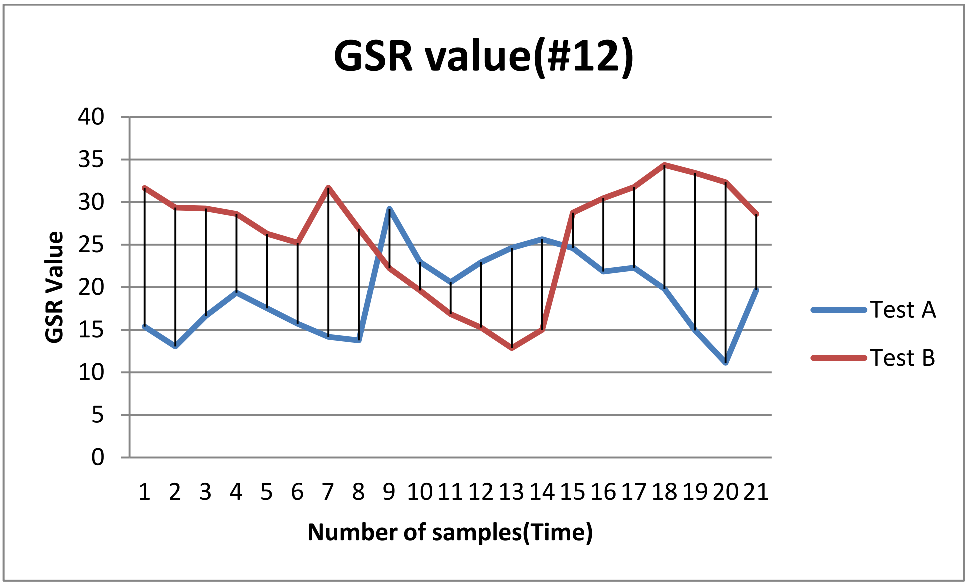

GSR value(#7)
100
90
80
70
60
50
40
30
20
10
0
GSR Value
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
Number of samples(Time)
Test A
Test B

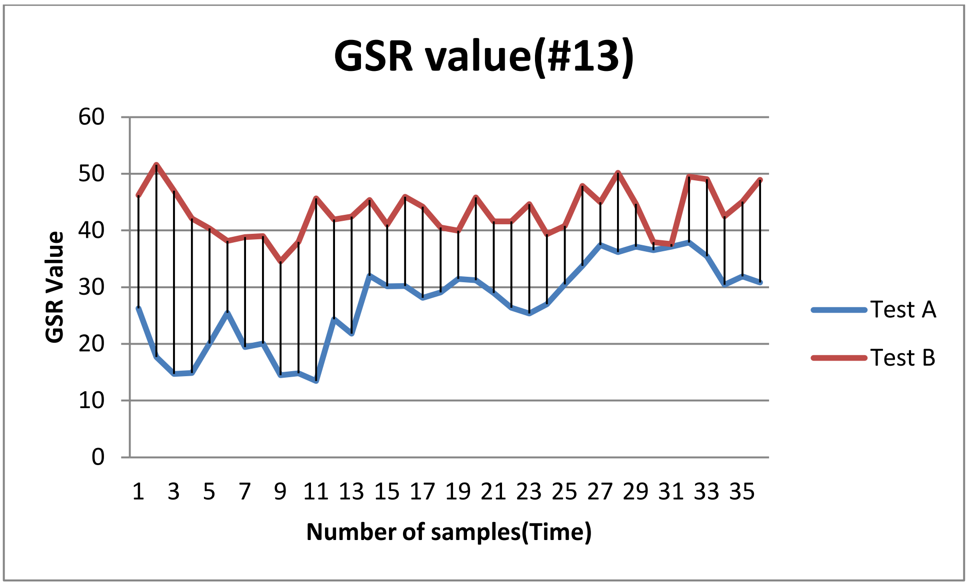

GSR value(#8)
140
120
100
80
60
40
20
0
GSR Value
1 3 5 7 9 1113151719212325272931333537394143
Number of samples(Time)
Test A
Test B

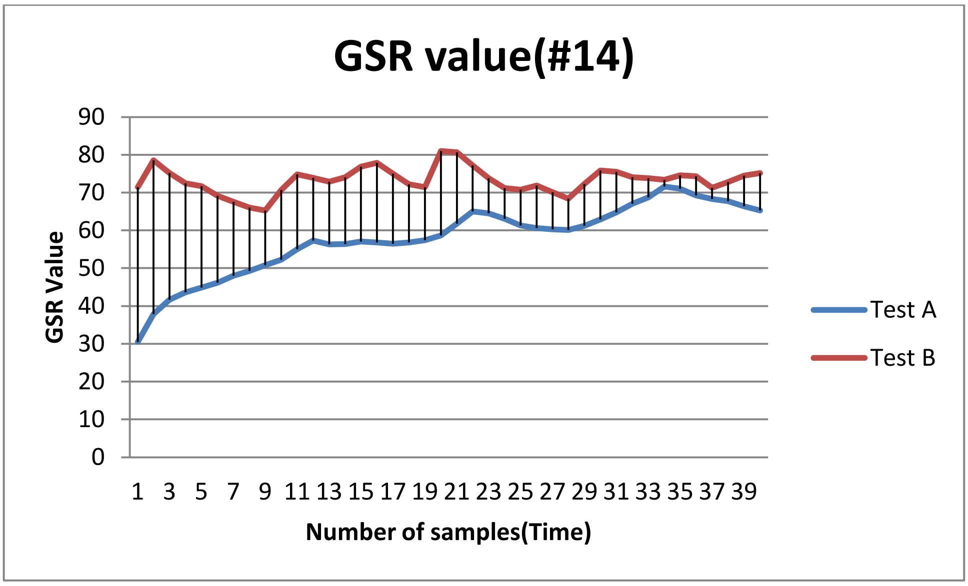

GSR value(#9)
GSR Value
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Number of samples(Time)
Test A
Test B


GSR value(#10)
GSR Value
120
100
80
60
40
20
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46
Number of samples(Time)
Test A
Test B


GSR value(#11)
60
50
40
30
20
10
0
GSR Value
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41
Number of samples(Time)
Test A
Test B


GSR value(#12)
40
35
30
25
20
15
10
5
0
GSR Value
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Number of samples(Time)
Test A
Test B


GSR value(#13)
GSR Value
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
Number of samples(Time)
Test A
Test B


GSR value(#14)
GSR Value
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Number of samples(Time)
Test A
Test B