NTNU – Trondheim
Norwegian University of
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The Sound of Prototyping

Investigating the effect of speed of music on prototyping

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THE NORWEGIAN UNIVERSITY
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MASTER THESIS SPRING 2015
FOR
STUD.TECHN. ERIK SEVERINSEN HANSEN

"The sounds of Prototyping"

The topic of the thesis is to look into the effect of background music on activities such as prototyping, brainstorming etc. with focus on the BPM (speed) of the music vs. level of prototyping/brainstorming activity and outcome.

The hypothesis is that by increasing the BPM of the music we can increase the activity level, and by decreasing the BPM we can decrease the activity level. We also expect an effect on outcome quantity and quality.

The concrete task is to find/develop applicable sensors, develop an experimental setup and run an experiment with a sufficient n.

Formal requirements:

Three weeks after start of the thesis work, an A3 sheet illustrating the work is to be handed in. A template for this presentation is available on the IPM's web site under the menu "Masteroppgave" (http://www.ntnu.no/ipm/masteroppgave). This sheet should be updated one week before the master's thesis is submitted.

Risk assessment of experimental activities shall always be performed. Experimental work defined in the problem description shall be planed and risk assessed up-front and within 3 weeks after receiving the problem text. Any specific experimental activities which are not properly covered by the general risk assessment shall be particularly assessed before performing the experimental work. Risk assessments should be signed by the supervisor and copies shall be included in the appendix of the thesis.

The thesis should include the signed problem text, and be written as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents, etc. During preparation of the text, the candidate should make efforts to create a well arranged and well written report. To ease the evaluation of the thesis, it is important to cross-reference text, tables and figures. For evaluation of the work a thorough discussion of results is appreciated.

The thesis shall be submitted electronically via DAIM, NTNU's system for Digital Archiving and Submission of Master's theses.

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ABSTRACT (ENGLISH)

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Studies on the effect from music on people have been ongoing for thousands of years, and with the technology and knowledge available today it is easier to investigate the underlying reasons for why music affecting us the way it does. Music is said to be a multidimensional art form utilizing the medium of sound, and because of this multidimensional nature studies of music are easily confounded.

In this thesis, an experiment has been constructed to investigate the effect from speed of music on prototyping. Our hypothesis is that music with a higher BPM will result in a higher activity and/or better results during a prototyping session.

The experiment was constructed by analysing available literature and other information to find suitable ways to measure the effect from music, as well as how to develop the music and test setup in order to avoid unnecessary confounding. The chosen means of measurement was quantitative measurements and movement of the test subjects.

During two weeks in June/ July 2015 the experiment performed with summer school children at the science museum Heureka in Finland. With the data gathered, it was not possible to confirm our hypothesis, but because of some elements, such as the age of the children and location of the experiment it cannot be discarded it either. The experiment should therefore be retried at a later and more suitable time, with people in an older age group and at a more controlled location.

Keywords Prototyping, Music, BPM, Speed of music, Activity level

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ABSTRACT (NORWEGIAN)

Forfatter Erik Severinsen Hansen	
Tittel The Sound of Prototyping	
Studieprogram Produktutvikling og Produksjon	
Studieretning Produktutvikling og Materialer	**Kode** PuMa
Veiledere Martin Steinert (NTNU) / Kalevi Ekman (Aalto)	
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Studier omkring effekten musikk har på mennesker har pågått i flere tusen år, og med dagens teknologi og kunnskap er det enklere å undersøke mange av de underliggende effektene fra musikk. Musikk er en multidimensjonal kunstform som benytter seg av mediet lyd, og på grunn av denne multidimensjonale naturen hos musikk er mange av de tidligere studiene plaget av confounding.

I denne masteroppgaven har det blitt konstruert et eksperiment for å undersøke effekten hastighet på musikk har på prototyping. Hypotesen er at musikk med høyere hastighet vil føre til mer aktivitet og/eller bedre resultater i en prototyping-session.

Eksperimentet ble konstruert ved å analysere tilgjengelig forskning og annen informasjon for å finne en passende metode for å undersøkte effekten fra musikk, samt hvordan musikken og aktiviteten i eksperimentet burde konstrueres for å unngå unødvendige feil. Metodene som ble valgt var kvantitative målinger og måling av bevegelse

Over 2 uker i juni/juli 2015 ble eksperimentet testet på barn fra en sommerskole på forskningsmuseet Heureka i Finland. Med dataene samlet fra eksperimentet var det ikke mulig å bekrefte hypotesen, men på bakgrunn av elementer som barnas alder og lokasjonen for eksperimentet er det heller ikke mulig avkrefte den. Eksperimentet burde derfor bli tatt opp på nytt ved et bedre tidspunkt, med personer i en eldre aldersgruppe i et mer kontrollert lokale.

Keywords Prototyping, Musikk, BPM, Musikkhastighet, Aktivitetsnivå

ACKNOWLEDGEMENTS

This thesis was written during the spring and summer of 2015 as an exchange student at Aalto University. Working on this thesis has been an amazing experience with a lot of learning, but it would not have been finished if it was not for all the people who have helped me on the way. I would therefore like to dedicate this chapter to all the people who have been assisting me with this work one way or the other.

First I would like to thank my supervisors, Martin Steinert (NTNU) and Kalevi Ekman (Aalto) for allowing me do my thesis at Aalto University, and for their guidance, feedback and help.

I would like to thank PhD canditate at NTNU, Achim Gerstenberg, for support and help with the experiments and analysis, for assisting with ideas, and for giving feedback on my work.

To all of the fantastic people at Aalto Design Factory, thank you for including me and making sure I got DF'd. Especially thanks to Saurabh for guiding me around at ADF, and to Essi for assisting with my workshops.

A big thank you is directed to Heureka for giving me the possibility to run my workshop on their visitors, and to Rauno for helping me around on their premises. Without their help, it might not have been possible to aqcuire participants needed for the workshops.

Last but not least, I would like to thank all the participants who took the time to participate in the workshops as well as my family and girlfriend for support throughout this period.

Erik Severinsen Hansen Helsinki, 10.08.2015

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ABBREVIATIONS

ADF – Aalto Design Factory

BAT – Department of Civil and Transport Engineering (NTNU)

BPM – Beats per minute

dB – Decibel

EEG – Electroencephalography

fMRI – Functional magnetic resonance imaging

GPS – Global Positioning System

IPM – Department of Engineering Design and Materials (NTNU)

MEG – Magnetoencephalography

MEMS – Microelectromechanical system

NTNU – Norwegian University of Science and Technology

TMS – Transcranial magnetic stimulation

1. INTRODUCTION

1.1 BACKGROUND

Up through history music has been claimed to affect people in various different ways. Music is supposed to change your mood [1], help with recovery [2], and improve your performance [3]. Whether these claims are true or not has been up to many discussions, and it often seems that as soon an experiment is completed with one result, someone else does the exact same experiment with a completely different result.

One of the most famous discussions regarding this topic is the so-called Mozart effect. In 1993, Rauscher confirmed that Mozart's sonata for two pianos in D major, K488, could improve a person's spatial task performance [4]. This led to Mozart being the solution to make everyone smarter, and some even claimed that listening to Mozart during pregnancy would increase the IQ of the baby. However, Rauschers study was not performed on babies, and later studies suggest that improving spatial task performance have nothing to do with Mozart's music in particular, but rather if the music is enjoyable and liked [5].

Even though the topic is widely discussed, there seems to be an agreement that there is an effect from music, we just do not know exactly how and why. With better technology and more knowledge, we are now in a time where solving many of the riddles around music might be possible. One interesting debate is whether music is able to activate people or not, and that is what we will take a closer look at in this thesis.

1.2 SCOPE AND OBJECTIVE

In this thesis, we will investigate if music can be utilized as a stimulus to change the activity level of a person doing creative work such as brainstorming or prototyping. We will specifically focus on the speed (BPM) of music, and the hypotheses are as follows:

H0: *There is no difference in activity level between music with high or low BPM*

H1: *Music with a higher BPM will result in more activity compared to music with a lower BPM.*

The aim of this thesis is to investigate this hypothesis by developing and running an experiment with a sufficient amount of participants (N). Developing such an experiment will include finding or developing applicable sensors, methods of measurement, music and activities that are suitable by utilizing knowledge in the field of study.

1.3 Structure of the Thesis

The thesis is divided into nine chapters. The first chapter describes the initial test conducted in relation to this thesis. The following two chapters, three and four, introduces theory and studies behind the topics of music and creativity, before chapter five take a closer look on possible ways of measuring activity. In chapter six, the information gathered is used to create a setup to test the hypothesis, and chapter seven introduces the experiment and its results. The last two chapters are dedicated to observations during the experiment and conclusion of the thesis.

2. THE INITIAL TEST

2.1 BACKGROUND

On March 19th, BAT at NTNU arranged a one-day seminar for PhDs with the theme "Failing your way to success", and during this seminar two PhD's from IPM (Carlo Kriesi and Achim Gerstenberg) held an egg drop workshop. The activity in this workshop was quite suitable for testing the topic of this thesis, and therefore, together with Achim a first draft for an experiment testing the effect of speed of music was made and tested. It should be noted that this test was done barely two weeks after the start of the thesis, and before the literature review was done. Hence, the experiment was used to get a kick start for the thesis, and to test one possible way of incorporating music and measuring its effect.

The egg drop challenge is a challenge where the participants are to make an egg survive a fall from as high as possible [6]. The specific rules on how the challenge is performed can vary somewhat, but during the BAT- workshop the participants were given a specific set of building materials and 25 minutes to complete the challenge. The materials can be seen in figure 2.1 and were as follows:

- 8 Pipe cleaners
- 8 Rubber bands
- 8 Popsicle sticks
- 1 10x20 cm poster board
- 1 10x15cm flat foam
- 1 sheet of tissue paper
- 30cm scotch tape

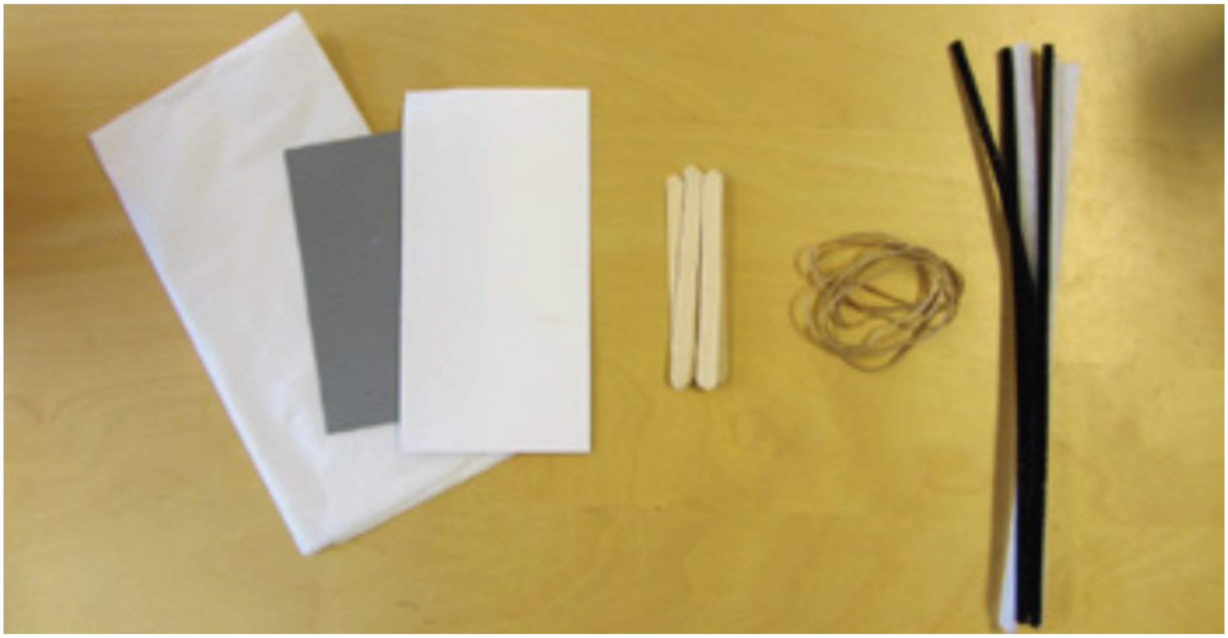

Figure 2.1: Materials for the BAT workshop [7]

2.2 SETUP

To test the effect of music on the given activity we first had to determine what kind of music should be used. We ended up with using a remix of the song "*Tonight*" by Axwell made by Martysounds [8], which can be characterized as house music with an original speed of 125 BPM. This song was edited using Adobe Audition [9] to make one version with 120 BPM and one with 80 BPM, further, the song was rendered in order to avoid big differences in the pitch when the speed was adjusted. These two versions was then put together in four parts (slow-fast-slow-fast). Each part was supposed to be 6:15 min making a 25 min soundtrack, but after the workshop was done, it was discovered that the timing was a bit off and the soundtrack was in fact 26 min as shown in table 1.

Table 1: Timing of speed change

Speed	Duration (sec)
Slow	375
Fast	375
Slow	362
Fast	448
Total	**1560**

Secondly, we had to measure the activity in the workshop and this was done by measuring movement. The movement was measured using two different accelerometer setups, one setup using Lightblue Beans [10] and the other using an Arduino Uno [11] with attachments as shown in figure 2.2. Both the Lightblue Bean and the Arduino Uno are microcontroller boards commonly used for prototyping.

The difference between these two setups, regarding our measurements, is that the Lightblue Bean has an on board accelerometer, while there was an external accelerometer added in the Arduino setup. Specifications for the setups, and the code used in the Lightblue Beans can be found in Appendix A – Arduino Code **.**

Figure 2.2: Bean setup (left) and Arduino Uno setup (right)

25 PhD's from BAT (18 male and 7 female, age 24 to 39 years old) attended the egg drop workshop and were divided into 11 teams of two and one team of three members, 12 teams in total. Due to a shortage of available sensors, 10 Beans and 4 Uno boards, only 14 of the available PhD's were tested. Team 1 to 10 were handed one bean each, and Team 1, 2, 11 and 12 were handed one box each as shown in table 2. During the workshop, six teams were standing and the other six were sitting.

The test subjects was told to put the beans in their front pockets, and the sensor box was worn around the waist like a belt. At a cue, the beans and boxes were turned on before everyone jumped 10 times simultaneously and then stood still for 10 seconds to get a good starting point in the measurement as seen in figure 2.3. After the 10 seconds of standing still the music was started, and the workshop began.

Table 2: Overview of teams and sensors for BAT workshop

	# of Members	Lightblue Bean	Sensor Box	Standing / Sitting
Team 1	3	Yes	Yes	Standing
Team 2	2	Yes	Yes	Sitting
Team 3	2	Yes	No	Standing
Team 4	2	Yes	No	Sitting
Team 5	2	Yes	No	Standing
Team 6	2	Yes	No	Sitting
Team 7	2	Yes	No	Standing
Team 8	2	Yes	No	Sitting
Team 9	2	Yes	No	Standing
Team 10	2	Yes	No	Sitting
Team 11	2	No	Yes	Standing
Team 12	2	No	Yes	Sitting

After the workshop, the text files made by the sensors was imported to Excel for formatting before they were exported to OriginPro [12] for graphical analysis as shown in the results.

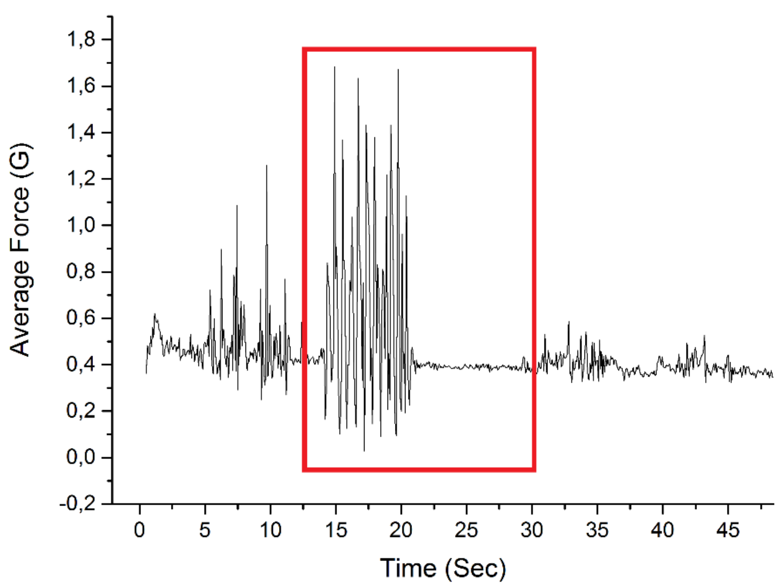

Figure 2.3: 10 Jumps and standing still, starting the measurement

2.3 RESULTS

The data was analysed graphically both with X, Y, Z coordinates separate and with the average values $\left(Average = \frac{X+Y+Z}{3}\right)$, and in figure 2.4 the difference between the two graphs for bean 2 can be seen. By looking at the shape of the graphs and the peaks it is easy to see that the two graphs represent the same data, and therefore the average value was used for further analysis.

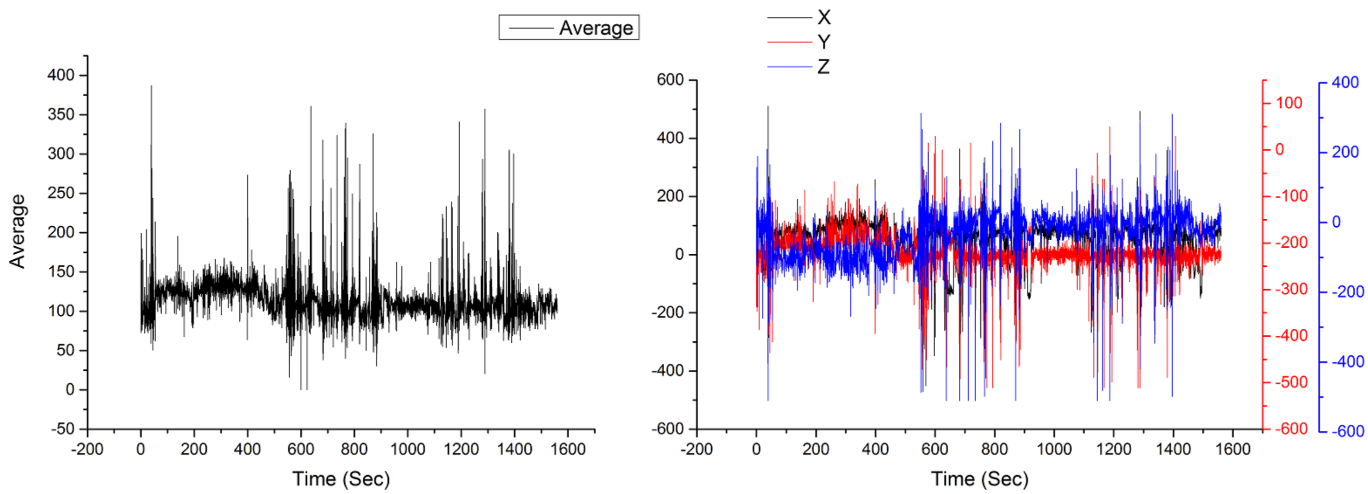

Figure 2.4: Results from LightBlue Bean 2 with average values (left) and all coordinates (right)

Looking through the rest of the data, there seems to be two things that are recognizable. The average accelerations seems to increase during the timespan of the workshop, and the measured activity varies in sections as seen in figure 2.5. The music starts of slow (80 bpm) and changes to fast (120 bpm) after approximately **375** seconds. Then it changes again to slow at **750** seconds and fast at **1112** seconds, the music ended after **1560** seconds.

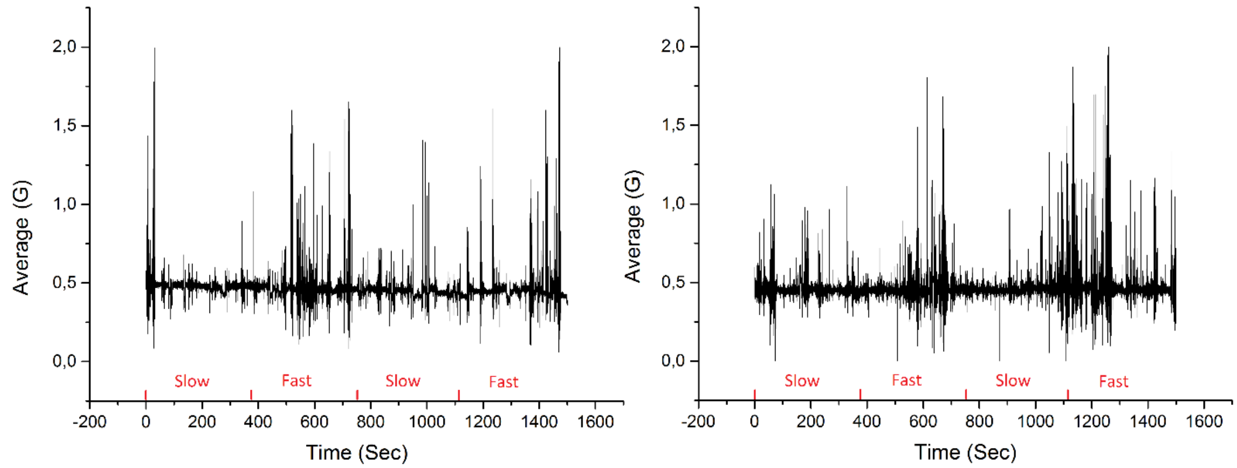

Figure 2.5: Average values from group 7 (left) and group 4 (right)

In figure 2.6 we can see a comparison between the measurements from a Bean and Uno used by group 2. The output from the Uno is in G – force while the output from the Bean is G-force divided by a factor of $3.91 * 10^{-3}$, which means that 100 Bean units = *0.39 G* and 150 Bean units = *0.59 G.*

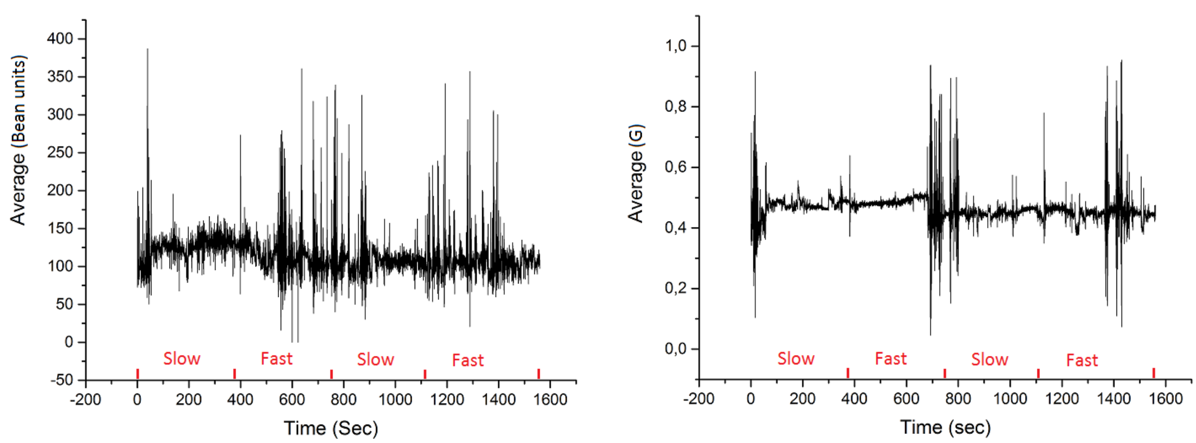

Figure 2.6: Comparison of Bean 2 (left) and Uno 4 (right) used by group 2

2.4 Discussion

From this test, it was not possible to find any correlation between the movement data collected from the accelerometers and the speed of the music. This shows that the solution with using accelerometers might not be the best one, at least not accelerometers alone.

There are some factors from this test that should be considered for improvement. First, just placing the beans in pockets is not an optimal solution as the beans can move around and the orientation of the beans will change over time, which can affect the data. This might not necessarily be a big problem as we are only measuring an average amount of activity in all directions but it should be considered. Secondly, more moving does not necessarily mean more doing. People taking a small break will probably move more as they are walking around instead of standing/sitting next to the table where they are working, at least it will seem so when we are measuring movement at the centre of gravity instead of looking at arm and torso movements. Third, the creativity of each prototype made was not taken into account, only the functionality.

From the results, we noticed that the activity in general increased during the workshop. This is most likely due to people discussing and planning in the beginning before they start building and testing and is most probably not related to the speed of the background music. It can also be seen in the video taken of the workshop that the participants spent a long time at their tables before they started the testing. On the positive side, the beat from the music was clear throughout the room and it did not seem to bother the test subjects, which means that the music most likely did not have a negative effect on the work being done.

To improve this experiment we will need to dig deeper into how music works, and we need to find some better way of measuring the activity. In the next three chapters we will look into these issues starting with understanding music.

3. MUSIC

In this chapter we will take a closer look on some research and theory in the field of music. We will define some important parts in the structure of music and look into how they affect people in order to avoid unnecessary errors in the experiments conducted for this thesis.

3.1 BACKGROUND

Studies on the effects of music on people has been ongoing for thousands of years. In ancient Greece it was believed that music could affect people's thoughts and actions [13], and Aristotle among others noted that different modes and rhythms affected people in different ways [14]. Over the last decades, the available methods and equipment utilized in this field of research have improved drastically, but even though extensive research has been done, a lot of aspects are not yet fully understood.

Music can be described as an art form that utilizes the medium of sound and the main elements is said to be rhythm, melody and harmony [15]. Another way of describing music is to say that it is the art of organized sound. It is multidimensional in nature and the major dimensions of musical sound are time, pitch and texture [1]. Within the time dimension, you find elements such as tempo, rhythm and duration. The pitch dimension inhibits elements such as tonality, melody and harmony, and the texture dimension consists of timbre and orchestration.

In this thesis we will focus on tempo as we will investigate if speed, or BPM, of music has any effect on the activity level in creative activity. However, this does not mean that we can look away from the other elements, as earlier research has shown that results can easily be confounded [16].

In 1972 Fox and Embrey experienced that lively and beaty music for short periods of time could increase the performance of workers at a conveyor belt [17]. Later, in 1982 Milliman found out that speeding up the background music in a supermarket made the customers move through the store at higher speeds (and spending less money) than if the music was slow [18]. He later did a similar test on restaurant patrons, with similar results. Playing fast music in the restaurant made the customers finish their meal and leave earlier than if the music was playing at a slower pace [19]. The problem with Millimans research however, was that he used different music at different speeds, and this can potentially result in confounding tempo with pitch and textural elements [16].

In modern research, with better sensory equipment available and more knowledge, it is now easier to test specific effects from different sounds or elements of music. One example of this research can be found in the Brain and Music Team at the University of Helsinki, where they are utilizing EEG, MEG, TMS and fMRI to among other things figure out how music works in childhood development and rehabilitation [20].

3.2 What is fast and what is slow music?

The speed (or tempo) of music is usually measured as BPM, and is often recognized by listening to the drums in a music piece. The beat can also be recognized as the rhythm a listener usually will tap his or her feet to when listening to music.

One problem that can occur while doing tests regarding the BPM of music, is mistaking the beat level with division or multiple levels of the beat shown in figure 3.1. For example if one is using music with a BPM of 120 it can be mistaken for a BPM of 60 if the drums are playing on the multiple level of the beat. Avoiding this is essential for the experiments in this thesis and can be done either by consciously using beats that are not divisions or multiples of each other, or by choosing music with a prominent beat.

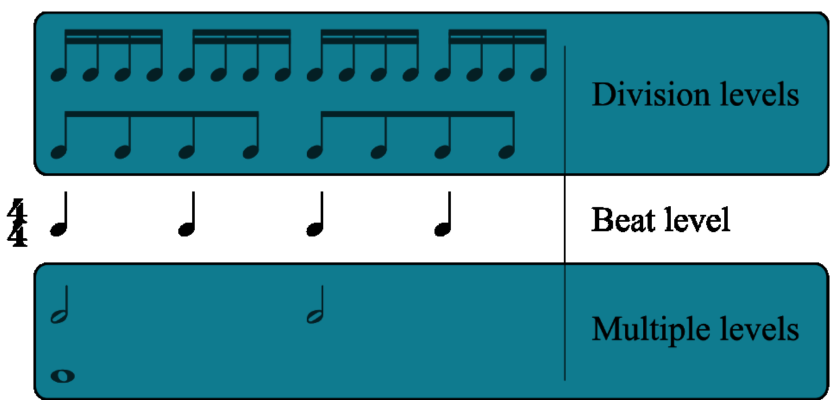

Figure 3.1: Metric levels - beat level shown in middle with division levels above and multiple levels below [21]

Another issue to address regarding BPM of the music is how to define what is fast, and what is slow music. As people are different, the preferences of what they look at as fast or slow music varies. What a person defines as fast and slow can even vary with different genres, and therefore, setting a specific number on fast and slow music is not straightforward. However, some previous researches have attempted, with different methods, and varying results.

In 1982, based on results from questionnaires Ronald Milliman classified music with a tempo of 73 BPM or fewer as slow, and 94 BPM or more as fast [18]. This classification was used in at least two of his studies [18] [19] with good results, but in a later study, it has been discussed whether these results may have been confounded as a result of Milliman utilizing different music for different speeds [16].

This study was conducted in 1994 by James Kellaris and Robert Kent, and trying to avoid confounding tempo with pitch and textural variables they produced unfamiliar, original compositions in three different tempo levels. The tempo levels were based on results from earlier research in psychology [22] and consumer aesthetics [23] and looked as follows:

- 60 BPM was considered *slow*
- 120 BPM was considered *moderate*
- 180 BPM was considered *fast*

By looking away from research, and over to orchestras around the world, we find yet another way of determining the speed of the music. Most common is the Italian terms describing different ranges of tempo, and the most interesting ones regarding this thesis is as follows:

- *Lento* (slow): 45 – 60 BPM.
- *Andante* (walking tempo): 76 – 108 BPM
- *Allegro* (fast): 120 – 168 BPM
- *Presto* (very fast): 168 – 200 BPM

Looking at these descriptions of what is fast and what is slow music, it is easy to see that there are big differences. Most likely, this is a result of different kinds of music being tested, and this must be kept in mind when choosing music for the tests in this thesis.

3.3 Volume

It is important that the music is not too loud during the experiments, nor can it be too quiet. We need to find a volume range where the music does not disturb the subjects during the experiments at the same time as it is possible to observe the beat.

In a research from 2012 [24], looking into the effects of ambient noise on creative cognition, it was discovered that a moderate level of noise (70 dB) enhanced the performance on creative tasks compared to a low (50 dB) or high (85 dB) level. This gives us a good guideline for a possible volume level, but since we are utilizing music instead of noise in this thesis, we need to take into consideration that music can vary in pitch and texture over time. Therefore, the volume level should be tested before the experiments begin.

3.4 Optimizing the music

Once we have decided the speed of the music, we need to figure out what kind of music to use. Different genres of music can have big variations in the way it is performed, and what elements it consists of. The optimal solution would be to utilize music that affects everyone in the same way, but since music is a complex stimulus, there is little chance that such music actually exist. However, from research in the field, we do have knowledge about the effects from different elements in music, and therefore we are able to make some educated guesses to avoid unnecessary and unwanted effects and confounding.

3.4.1 Vocals

Although there is little research to be found on the difference between listening to music with or without vocals, as well as the difference between male and female vocals, we can assume that music without vocals is more "neutral" than music with vocals. Earlier research into the effects of the speed of music have in general utilized instrumental music [1] [18] [19], and the reason is the belief that music with fewer elements will decrease the possibility of confounding. Therefore, instrumental music will be used in the experiments in this thesis.

3.4.2 Melody and beat

The music needs to be simple and easy to understand. Thus, there should be no sudden changes or surprising elements in the music that can catch your attention or distract you. Examples of surprising elements could be sudden changes in speed, rhythm or pitch that you would usually not expect from the music you are listening to.

It has been shown that music with simple and strongly emphasized rhythmic structures (such as techno) is easier to understand than for example rap [25]. Hence, by utilizing electronic music with a prominent beat we can decrease the problem of listeners being confused about the actual tempo in the music. Using electronic music is also positive in the sense that it is often easier to modify without deviating too much from the original. For example, it is easier to keep the same pitch of the music while speeding it up or down.

An extreme case that could be interesting to investigate would be to use music with percussion only, and no melody. This way we would be able to play the beat without the risk of test subjects being affected by other elements of music. However, if this is to be applied in this thesis it is necessary with further testing. Otherwise, it should be a case for further research.

4. CREATIVITY

In this chapter, we will take a look at creativity, and most importantly what it means to have a bias towards action. We will look into two creative activities, namely brainstorming and prototyping, and we will take a quick look into possibilities for measuring creativity and how this can be applied for this thesis.

4.1 BACKGROUND

Creativity is, in the same way as music, something that is not easily explained with words. If you ask ten different people what creativity is, you will most probably end up with 10 different answers. In the literature, one way of describing creativity is to say that it involves the production of novel, useful products [26]. Another is to say that creativity is propulsion. It moves a field form some point to another [27].

For this thesis, an exact definition of the term creativity is not needed as we will not work with the term itself. Instead we will be looking at what could be called creative activities (such as brainstorming and prototyping), but most importantly we want to know if music can be used to create a bias toward action.

4.2 BIAS TOWARD ACTION

To have a bias toward action means to spend less time discussing and more time doing. It is a core principle, or mindset, of design thinking [28], and it is also an important attribute that characterizes some of the most innovative companies in the world [29].

The general idea is that a more action-oriented behaviour inspires new thinking and can help with hard decision-making. To sustain this kind of mind-set one has to be willing to try things out and experiment, and one needs to overcome the fear of failing. Usually there is a lot more learning in doing an experiment, no matter if it succeeds or fails, than spending time discussing the issue. As it turns out it is often cheaper to do a quick experiment [29].

Learning by doing is a term that coincides well with having an action-based bias.

4.3 BRAINSTORMING

Brainstorming is a way to stimulate creative thinking, and it can be performed individually or in a group. In the D.School Bootcamp Bootleg [30] it is described as follows:

"The intention of a brainstorming is to leverage the collective thinking of the group, by engaging with each other, listening, and building on others ideas".

When conducting a brainstorming session the participant(s) will ideate around a topic, often trying to find solutions to a problem. This kind of work can be mentally exhausting in the long run, and it is therefore important to invest the energy in a short period of time (e.g. 15 -30 min).

There is not one correct way of performing a brainstorming session, and different people will be used to different setups. If we are to utilize such an activity to gather information it is therefore important to set up easy-to-understand boundaries, and to have a clear and simple topic or problem statement. It is also important that the topic, or problem statement, is given in a way that it favours practical solutions.

4.3.1 Brainwriting

Brainwriting is an alternative method to brainstorming that is also used to generate large amounts of ideas. The biggest difference between the two lies in the way the ideas are gathered. In brainstorming the participants usually say out loud all of the ideas that pop into their heads for a facilitator to collect and sort, while in brainwriting the participants write down every idea themselves.

The general idea is still the same, but by writing down ideas directly it can be easier to monitor the session, both for the facilitator and the participants themselves. Hence, brainwriting might be a suitable option for this thesis.

4.4 PROTOTYPING

To prototype is to materialize ideas, and in the same way as brainstorming, this is also something that can be solved in many different ways. A prototype can range from a wall of post-it notes or a picture to a shop floor made out of cardboard boxes and all the way to for example a fully functional concept car. The difference between these prototypes is the resolution, where a wall of post-it notes is a low-resolution prototype, and a functional concept car is a high-resolution prototype.

Prototyping is done in order to learn what we cannot do when the idea is only in our minds, for example to test functionality and effect. By making low-resolution prototypes early in a development stage you will often learn more in shorter time than if you spend time discussing the problem or idea.

In the BAT workshop, ch.0, we utilized a prototyping workshop called the egg-drop challenge. This kind of workshop can be held in order to push people to be creative, and/or to get a kick-start for a project. For the BAT workshop we only focused on the movement of the participants, and not the amount or quality of the prototypes. With a better setup this is also a possibility, and it can provide interesting data for the thesis.

4.5 Measuring creativity

There are many tests available for measuring creativity. Examples of such tests are the Creative Product Semantic Scale [31], Torrance Tests of Creative Thinking [32] and The Creative Product Inventory [33]. The focus of the different tests vary from defining creative products to creative people, but how effective or correct they are have been up to discussion several times.

The main problem with these tests is that one test alone is not able to cover all the factors that yield creative achievement. Factors such as knowledge of a field, technical skill, mental health or opportunity are usually not integrated in the tests, and therefore they are best thought of as measures of creative potential [34].

However, measuring the creative potential of solutions given in an eventual brainstorming or prototyping session could be an interesting measurement to include in order to get information about the quality of the session.

One way to do this would be to include such a creativity test made for products or ideas, another solution is to utilize the method proposed by Mehta, Zhu and Cheema when they researched the effects of ambient noise on creative cognition [24].

To assess the creativity of ideas gathered in a brainstorming they first gathered all the unique ideas from the session. Then they recruited 12 independent “judges” (from the same population as the participants) and made them grade each unique idea on a 7-point scale. When every idea was graded, they averaged the points for every idea and was then able to grade each group.

5. MEASURING ACTIVITY

Successfully measuring the activity of the group did not turn out to be as easy as earlier presumed. In this chapter, we will take a closer look at some possibilities for measuring activity utilizing sensors, systems or other means of measurements to investigate how applicable they are to the experiment being developed.

5.1 MOVEMENT

Movement was the main activity measured in the first test but the setup was not very refined, and this might well be the reason for the quality of the results. There are several possibilities for measuring movement today, such as camera vision, GPS, accelerometers etc. Some of these give more detailed results than others, and some solutions combine several of the different sensors to improve the measurements.

Measuring movement and activity has become more and more popular over the last decades with pedometers, GPS-watches, phone apps and activity bracelets. It is widely being used as an asset in sports in both the private and the professional market. Pulse watches with GPS can be used to control time and distance for the everyday runner, while systems like ZXY sport tracking [35] measures movement, acceleration and position of a football player on the field and can be a good resource for improving a team. Movement sensors can also be found in other areas such as phones and security systems.

Since sensing of movement is so widely used, it is easy to get hold of sensors with a good quality. However, we still need to decide what kind “movement” that is interesting for this thesis, and how to measure it in the best possible way. Is it for example necessary to measure the movement of every part of the body, or can we get enough information from looking at the body as a whole? To answer this we will take a closer look at two possibilities, accelerometers and video monitoring.

5.1.1 Accelerometers

How an accelerometer works can be described by thinking of a housing with a mass attached to a spring on the inside. If you accelerate the housing the spring will stretch because of the delayed movement of the mass and you can measure the acceleration as seen in figure 5.1

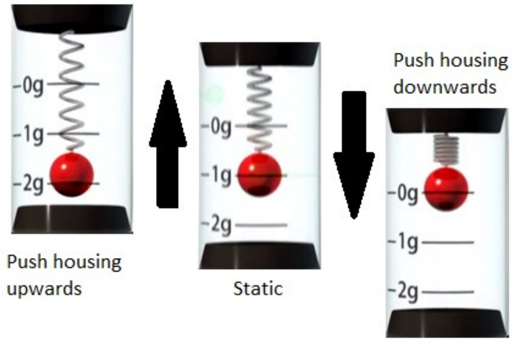

Figure 5.1: The effect of moving a mechanical accelerometer up and down

The accelerometer mounted on the Lightblue Bean is a BOSCH sensortech BMA250 accerelerometer. This is a low-g, triaxial sensor which utilizes a microelectromechanical structure (MEMS) working on the differential capacitance principle, and it is able to measure tilt, motion and shock.

The principle of this kind of accelerometer sensor is the same as shown in the figure above, but it works in a bit different way. This sensor has a set of independent fixed plates, and moveable central plates. The moveable central plates works as the mass and it has fingers placed in the middle between two fixed plates. When an acceleration occurs, the mass will move and the finger will get closer to one of the fixed plates as seen in figure 5.2. This will change the capacitance between the moving finger and the fixed plate, hence, we can measure the acting force.

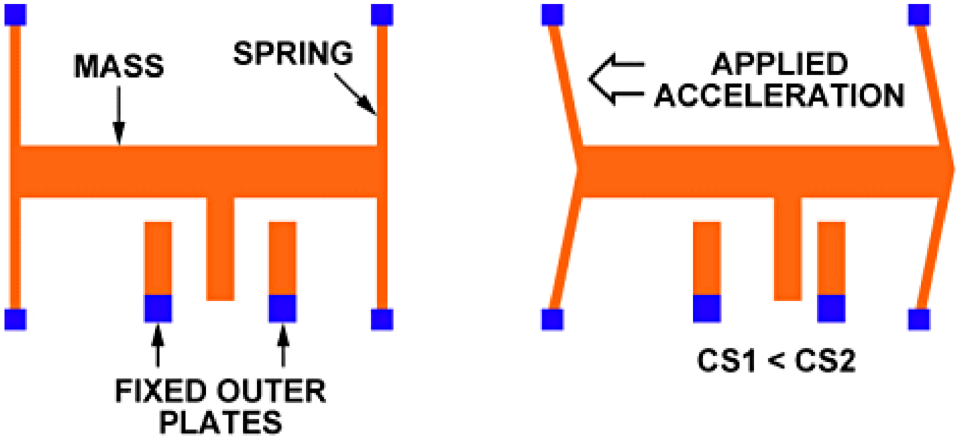

Figure 5.2: The structure of a MEMS accelerometer [36]

In general, this way of measuring can easily be scaled up and down by including or removing sensors, but it is probably best used with a single sensor mounted at the centre of mass of the test person.

5.1.2 Video

Video monitoring or computer vision is a great way to measure movement. It does not need a lot of equipment, but basic knowledge of programming is necessary. Off-the-shelf technology available for this type of monitoring has also come a long way the last years, especially thanks to the Microsoft Kinect camera [37].

The Kinect utilizes a colour camera and IR depth sensors and is able to sense finger movements. For this thesis, the most interesting feature is probably the skeletal tracking, which can recognize and track the actions of people. The downside is that one sensor can only track two people at the time as shown in figure 5.3.

If computer vision is deemed unnecessary, it will still be profitable to utilize a camera to record the experiment. This way, we are able to go through the sessions afterwards to double check results, and if needed, to collect more information from the sessions.

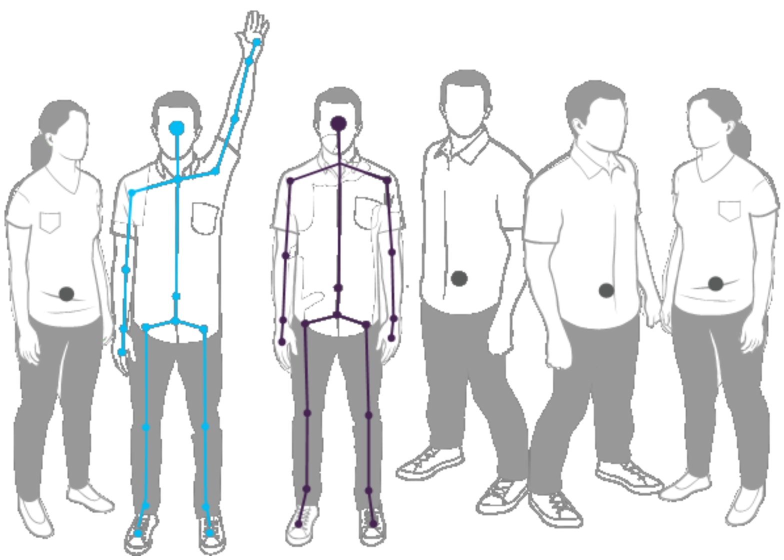

Figure 5.3: The Kinect can recognize six people and track two [38]

5.2 Physiological measurements

Another possibility for measuring activity is to look at physiological measurements, such as pulse, EEG, blood pressure or breathing. Previous research have investigated how these effects are affected by music and will be the basis to decide whether these measurements are feasible for this thesis.

5.2.1 Pulse

The general idea of measuring pulse is that music with a high BPM will increase the activity level, and the increased activity level will result in an increased pulse.

Measuring pulse can be done both manually and with a heart rate monitor. For manual measurements it is most common to measure the radial (wrist) or the carotid (neck) pulse. To measure the pulse you simply put two fingers on one of these places (wrist /neck), locate the pulse and count the beats. For automatic measurements, you can use a heart rate monitor that measures electrical activity produced by the heart. Usually this is done by placing an electrode on the chest that detects the electrical signal, and then transmits the signal to a monitor (e.g. a watch). Both of these methods are shown in figure 5.4.

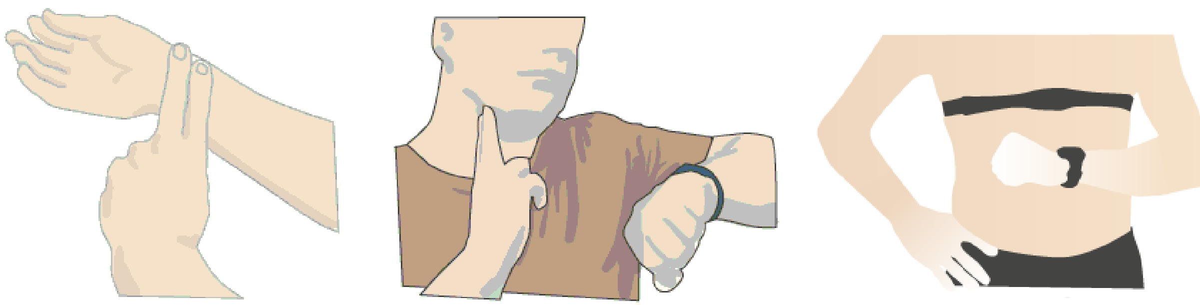

Figure 5.4: Manual and automatic heart rate monitoring [39]

5.2.2 Blood pressure

Blood pressure is another method to measure activity. As the activity level of a person increases the heart will pump more blood through the body and the blood pressure will increase. Measuring blood pressure us usually done with cuff-based methods where you wrap an inflatable cuff around your arm. This cuff is pumped up to a certain pressure to stop the blood flow, and then deflated until you can hear the pulse beat using a stethoscope. The pressure in the cuff at the first pulse beat is equal to your systolic pressure, and by deflating the cuff further the pulse beat sound will disappear and you have found the diastolic pressure. This can also be done automatically without the stethoscope with an automatic cuff.

The problem with this method is that we are not able to measure the blood pressure continuously, at best you can get a measurement every 1-2 minutes. However, there are other ways of measuring blood pressure that are continuous, such as the tonometric technique [40]. This technique utilizes an array of pressure sensors mounted non-invasively on the skin over an artery, and is therefore a possible solution for this thesis.

5.2.3 Brain activity

One method that has been utilized by several institutions in hope of solving the puzzle of music is measuring brain activity. This is usually done with help of EEG, which measures the electric activity in the brain through electrodes connected to the scalp.

The clinical EEG systems are generally quite complex and very expensive, but in the recent years cheaper off-the-shelf EEG systems have become available and research claims that these might be good enough for certain types of measurements, for example reading activity recognition [41]. Examples of such systems can be seen in figure 5.5.

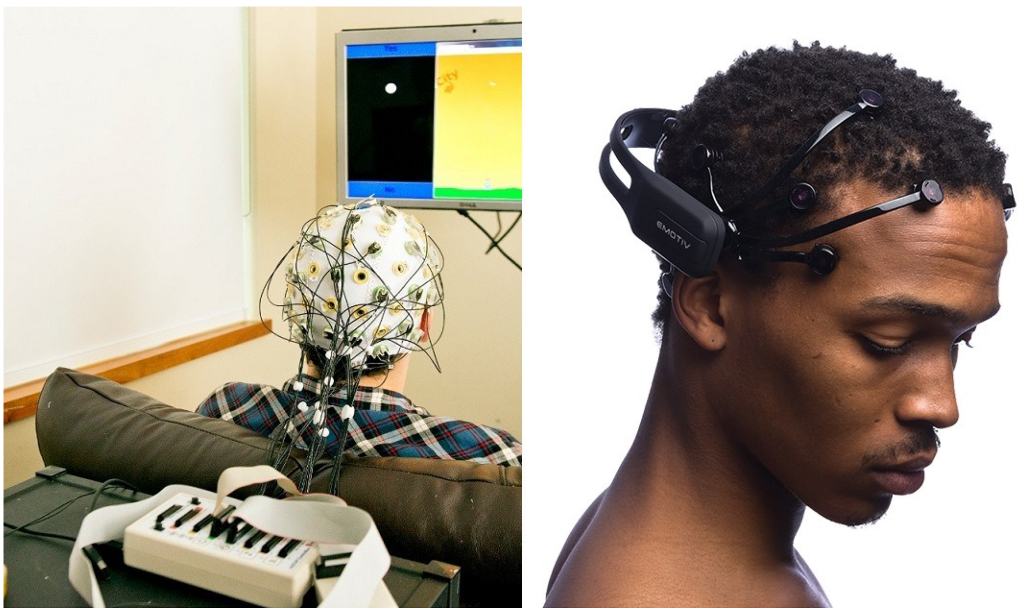

Figure 5.5: Clinical EEG (Mary Levin, U. of Wash.) VS. Off-the-shelf EEG (Emotiv) [42]

For the purpose of this thesis, an EEG can be utilized to measure the test subjects brain activity while conducting the experiment. In the same way as with blood pressure or pulse, we would expect that increased activity would result in increased brain activity. The problem, however, is that the music itself will most probably affect the readings together with the general activity, and the EEG should therefore be combined with other means of measurement if we decide to utilize it.

5.3 QUANTITATIVE MEASUREMENTS

The last way of activity measuring to be presented in this thesis is quantitative measurements. By quantitative measurements we are essentially talking about counting the amount of solutions, and/or tries during a brainstorming or prototyping session. Depending on the type of activity we choose for the experiment we can also include time measurements.

This is probably the easiest way of measuring activity presented so far, but also one that is prone to be very different from person to person. A person familiar to the idea of design thinking can for example be expected to test more often than someone who is used to more theoretical work. Hence, the initial mind-set of the person conducting the experiment can influence this measurement more than for example heart beat.

When looking at the amount of solutions, it can also be necessary to look at the quality of the solutions. This can be solved either by looking at the creative quality as discussed in chapter 4.5, or by looking at how good the solution solves and eventual task. For example, in the egg drop challenge described in chapter 2.1, the quality can be measured by the height an egg can be dropped from without breaking.

5.4 Discussion

All of the means of measurement presented above have their strengths and weaknesses, and we might therefore need to combine a set of methods to get decent measurements. It is important that the chosen means of measurement is simple and robust, but first we need to decide which methods are actually feasible.

We have already tested measuring movement using the accelerometer on the Lightblue bean in the BAT-workshop. The sensors worked as expected, but we failed to generate a good method to analyse that data. Utilizing a Kinect camera gives us the possibility to get more detailed information without strapping up a test person in sensors, but the question is if the more detailed measurement as well as a higher cost is necessary.

One question that came up while analysing the data from the BAT-workshop was if measuring movement actually gave us the information we want. More moving does not necessarily mean more doing, and more doing is what we want regarding an increased bias-towards-action (ch.4.2).

However, measuring the movement can still give us some interesting viewpoints and since we already have the sensors, it will be easy to implement them in the final experiment. The only essential upgrades needed is some sort of strap to attach the bean around the waist of the test person, as well as a good method to analyse the data. Also, since the sensor is attached to the waist it will most likely not interfere with any work being done in the experiment. Therefore, it will not affect the other measurements, and it is not a big problem if the data is eventually deemed unnecessary.

If we look at the physiological measurements we face the same problem as we do with movement, that they in general do not measure if we have an increased bias-toward-action. Additionally, there is a slight possibility that they will also be affected by the music itself [2], instead of showing an increased activity level.

The EEG systems are also quite expensive, around $6000.00 [43], and since we already have a cheap movement sensor in the lightblue bean it is rather unnecessary to include more sensors that does not measure exactly what we are looking for. Again, the measurements could give us some additional viewpoints, but because of the cost in time and money, these measurements will not be included in the experiment in this thesis.

Last, we have the quantitative measurements. With these we are actually able to measure an increased bias-toward-action, but we still have the problem that people with different mind-sets can affect the results greatly. There are two ways of avoiding this problem:

1. Run the experiment with people gathered from the same population to get people with similar mind-sets
2. Run the experiment with a large number of people to minimize the effect of people being different.

Depending on the activity that is used for the experiment, we can easily gather a large amount of data from quantitative measurements. Therefore, it is also important to be able to double-check the measurements and the easiest way to do this is by recording the session. One or more cameras should be placed to get good recordings of everything that happens throughout the experiment. A camera with a wide lens that also records audio is to prefer, e.g. action cameras.

With quantitative measurements as well as improved movement sensors, we should be able to gather all the information needed to answer the hypothesis in this thesis. The next step will be to develop the general set-up of the experiment by finding a suitable activity and music.

6. DEVELOPING THE TEST SETUP

In this chapter we will use the information gathered in the previous chapters to create the experimental setup that we will use to test the hypothesis for this thesis.

6.1 ACTIVITY

The activity chosen for the experiment is a prototyping workshop called "the candle transport". In this workshop, the participants are given a specific set of materials, and told to use these materials to transport a burning candle across a water-filled canal powered by wind generated by a fan as fast as possible. The time is noted at every successful attempt, and failed attempts are noted with an "X" on the scoreboard. The participants have 25 minutes to complete the challenge.

The materials given pr. team / participant can be seen in figure 6.1 and are as follows:

- 1 A4 paper
- 1 20x20cm cardboard
- 1 roll of tape
- 1 pair of scissors
- 1 knife
- 2 small sponges
- 1 roll of aluminum foil
- 4 thin wooden sticks
- 2 straws
- 2 tea lights

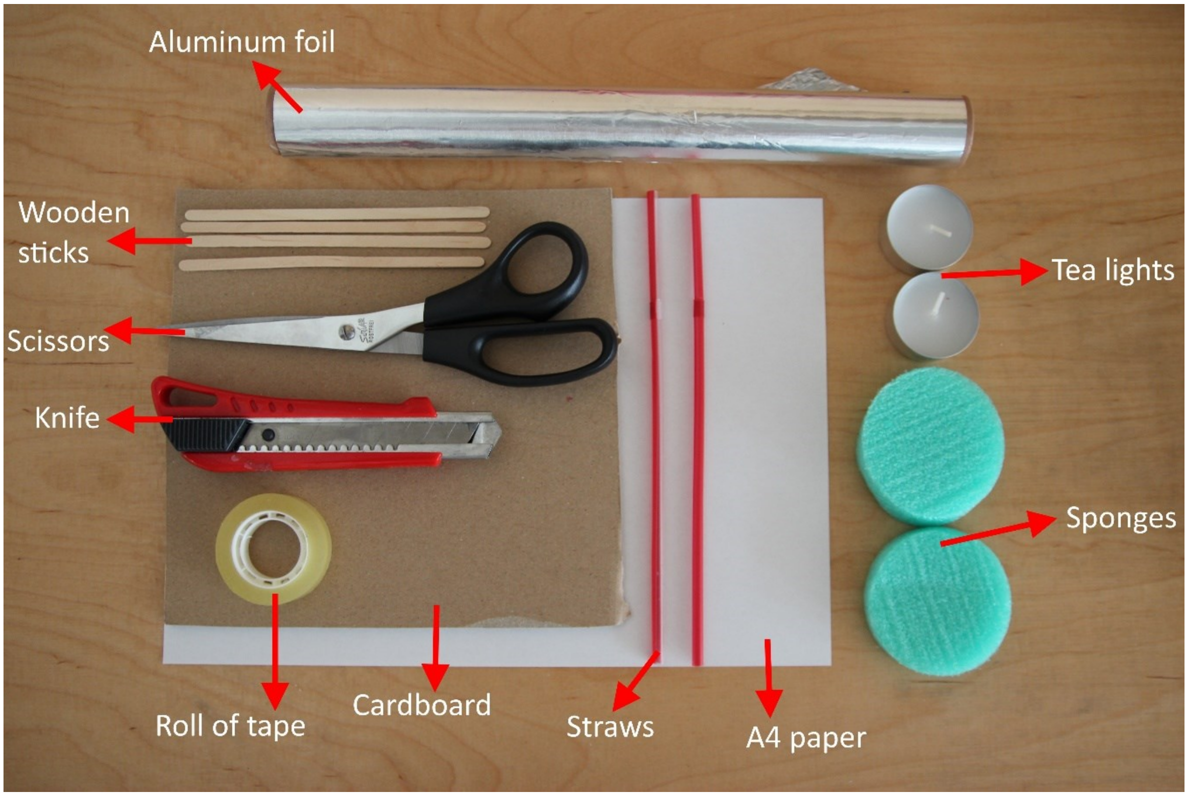

Figure 6.1: Materials for the candle transport workshop

6.2 Measurements

In the previous chapter we decided to focus on quantitative measurements, and with this workshop we are able to measure the following:

- The amount of prototypes built/tested (both with the candle and in total)
- The time when the first test is committed (both with candle and in general)
- The amount of successful and failed attempts
- The quality of the prototypes, i.e. the time it needs to cross the canal in a successful attempt.

We also decided to make some improvements to the Lightblue Beans and include them as movement sensors, as well as include a video camera to record the workshop.

6.2.1 Improved Lightblue bean setup

From the results in 2.3 it was clear that the Lightblue bean setup had to be improved if it was to be used in further tests. The main problem was the placement of the bean and just placing the bean in a pocket was not sufficient.

To solve this issue we attached each bean with the battery pack to a small piece of cardboard. This cardboard was then attached to a tie-down strap that made it possible to wear the bean around the waist like a belt. This way we can make sure that the bean does not move around too much during a session and we will get measurements close to the test subjects' center of mass. The improved Lighblue Bean setup can be seen in figure 6.2.

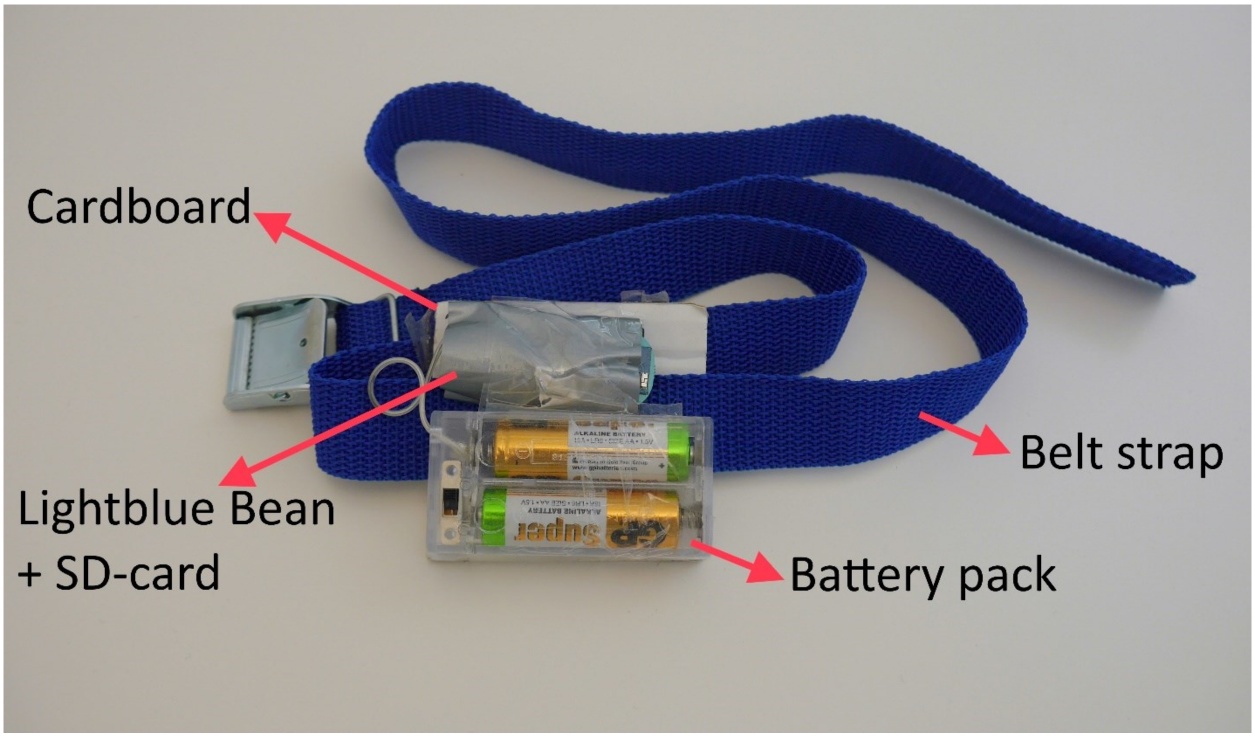

Figure 6.2: Improved Lightblue Bean setup

6.3 THE TEST SOUNDTRACK

From the criteria set in 3.3 and discussions with professors, students and a composer a track called *Skyline* by *Labtracks* was chosen. The genre of the track is Indie Dance and it has an original speed of 125 BPM.

6.3.1 Choosing the speed (BPM)

We have already seen in 3.2 that earlier research have come up with suggestions on what is fast, and what is slow music. However, since there is so little background on the topic a small experiment was conducted to see if we can back up the earlier research.

For this experiment, the Martysounds remix from chapter 2.2, referred to as track 1, and a Robin Schulz remix of the track "*I am frost*" by The Village [44] , referred to as track 2, was chosen. Both of the tracks can be put in the electronic music genre, and the main difference between the tracks is that in track 1 the bass emphasizes every beat, while in track 2 it emphasizes every second beat.

Using Adobe Audition, the speed of the tracks was modified ranging from 70 to 140 BPM, and the tracks were rendered to avoid difference in pitch. Ten test subjects listened to the different speeds at random and were told to describe the tracks they listened to as slow, medium or fast. By scoring the descriptions (slow = 1, medium = 2, fast = 3) an average score was generated for each speed in both of the tracks and the results can be seen in table 3.

Table 3: Average scores for track 1 and track 2

Speed	Track 1	Track 2
70 BPM	1,1	1
80 BPM	1,4	1,1
90 BPM	1,1	1,4
100 BPM	1,5	1,9
110 BPM	1,8	1,9
120 BPM	2,4	2,3
130 BPM	3	2,8
140 BPM	2,9	3

From the results, we can see that the transition from slow to medium occur between 90 and 100 BPM and the transition from medium to fast occur between 120 and 130 BPM. This does not coincide with the earlier research cited in chapter 3.2, but rather the notation used in orchestral music.

As discussed earlier, different types of music will affect people in different ways, hence, the results from this experiment might be the correct answer for this genre of music. Therefore, we have chosen to characterize speeds from 90 BPM and lower as slow, and speeds from 125 BPM and higher as fast.

6.3.2 Putting the music together

When the track for the workshop was chosen we needed to modify the speed and length of the track to make it fit with the workshop. As with track 1 and 2, Adobe Audition was chosen for this purpose. Instead of just playing the track on repeat for 25 minutes we edited and extended the track. By doing this we could erase some of the calmer parts of the track and make sure that there is a prominent beat throughout the entire 25 minutes it lasts. The speed of the track was changed to 85 BPM for the slow version and 127 BPM for the fast version

6.3.3 During the session

The way the music was played in the initial test complicated the movement analysis by giving more variables pr. session (see ch.2.4). Therefore, we have chosen to play either fast or slow music throughout the entire workshop in the final experiment. The drawback with this method is that different people will be tested with different speeds, but if we get a big enough sample of people, this error can be minimized.

As discussed in chapter 3.3 it is important that the volume of the music is constant throughout the workshop and at a level that is noticeable by everyone, but not distracting. This will be achieved by measuring the volume with a decibel meter app, and adjust it to approximately 70dB.

6.4 TEST RUN

With help from students attending a summer course at ADF a test run was made for the workshop. A total of ten students attended, four in the first session with slow music, and six in the last session with fast music. During this test run we looked into what kind of complications that might arise during the workshop, and if there was necessary with improvements. The setup can be seen in figure 6.3.

Figure 6.3: Test setup at Design Factory

The experience from the test run was that the students were having fun during the workshop, and they did not seem to be bothered by the music playing in the background. However, while introducing the task the word “boat” was mentioned, and this might have affected the students as all of them spent a lot of time making something resembling a boat. In the main workshop this should be avoided, and the introduction should be standardized and rehearsed. An example could be as follows:

“*In front of you, you have a 3m canal filled with water. Your task is to transport a live candle as fast as possible across the canal without blowing out, utilizing the fan as propulsion and the materials handed to you. You have 25 minutes to build and improve your prototype.”*

7. Candle Transport Challenge at Heureka

7.1 Background

Due to lack of test subjects available, the workshop was moved from Aalto Design Factory to Heureka. Heureka is a Science Centre made to introduce the public to science and technology in an engaging and interactive way, and is located in Tikkurila, Vantaa. Every summer Heureka facilitates a set of one week long summer camps for kids in the age group 7 – 15 years old, and these were asked to participate in the workshop.

7.2 Setup

Because of the change of location, and age of the participants we had to make some minor changes in the building kit. The updated building kit can be seen in figure 7.1 and consist of the following:

- 1 A4 paper
- 1 20x20cm cardboard
- 1 roll of tape
- 1 pair of scissors
- 1 roll of aluminum foil
- 2 small sponges
- 2 straws
- 4 thin wooden sticks
- 1 tea light

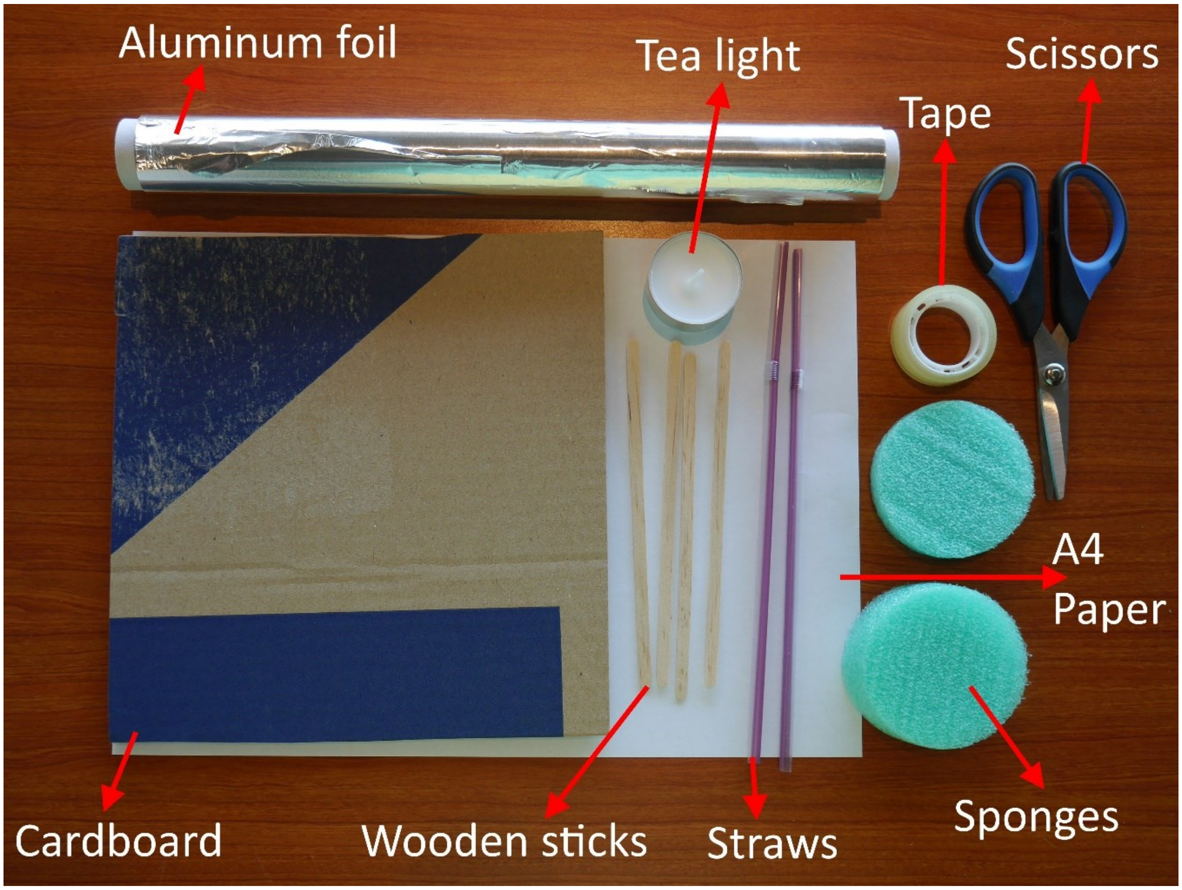

Figure 7.1: Building kit given at the Heureka summer camp workshop

We ran one workshop per day, three days a week for two weeks, but since participating in the workshop was voluntary we did not manage to get all of the kids to participate. A total of 26 children participated in the workshop, 12 in the slow sessions and 14 in the fast sessions. The age group of the children participating was 10 – 15 years. The test setup is seen in figure 7.2.

One extra session was run with eight of the youngest participants in the summer camp (7 – 9 years), but because of the way they solved the challenge we have chosen to discard this session from the results. In general, it seemed as they did not completely understand what went wrong when their tests failed, and there was minimal improvement on their prototypes between the tests. None of these participants managed to find a way to solve the challenge.

Figure 7.2: Test setup at Heureka

There were two participants per table working on their own with the challenge, and some of them were strapped up with movement sensors. To get a starting point for the movement sensor, the participants jumped simultaneously ten times before standing completely still until the workshop started. The music was used as the start signal, and when the 25 minutes of building/testing time was over the participants was allowed to test their prototype one final time.

The water tank setup can be seen in figure 7.3, and the distance between the start and finish line was 2 meters.

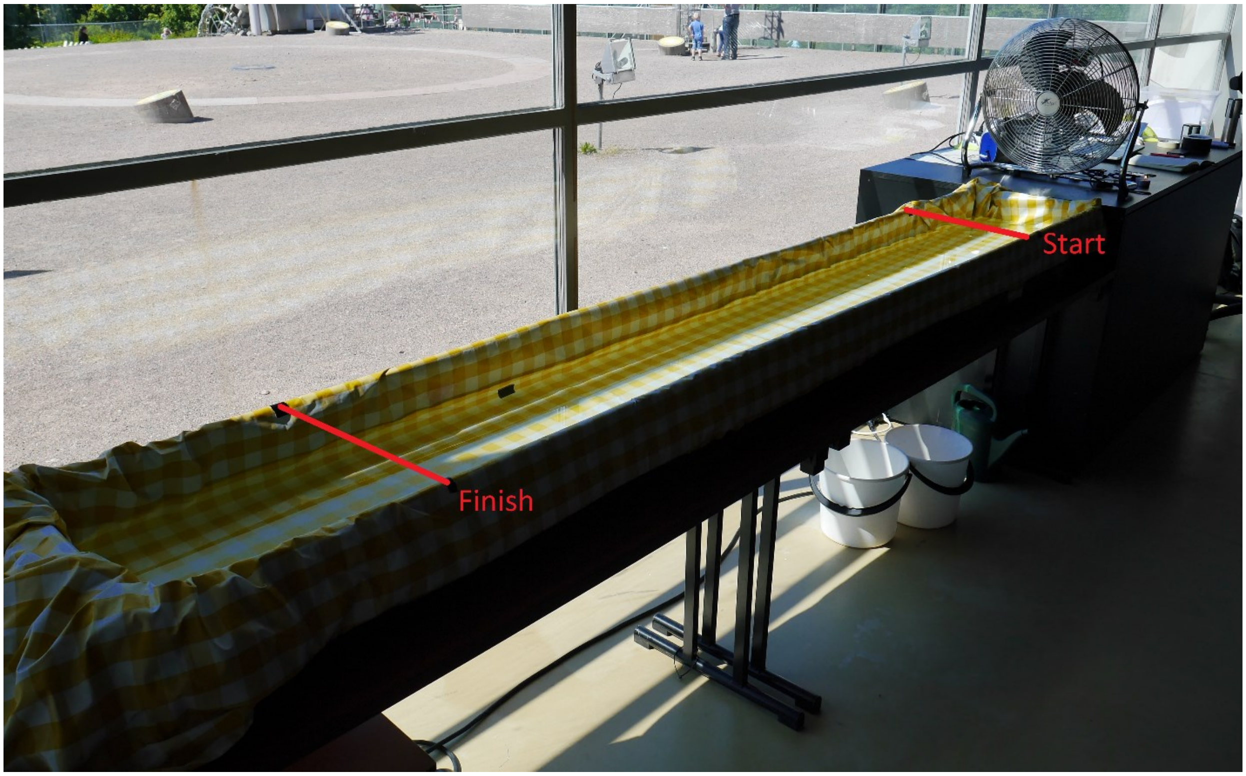

Figure 7.3: Start and finish line for the candle transport

7.3 RESULTS

To investigate if the difference between the results from the fast and slow workshops are significant, the T-test have been used. The T-test is a statistical test commonly used to investigate if two groups of data are significantly different when the data set is small.

A program called IBM SPSS Statistics [45] was used to analyse the data. This program also includes a Levene's test, which is used to assess the difference between the variances of two groups. Thus, if there is no significant difference between the variances, the t-test where equal variances are assumed can be utilized.

Significant difference will be achieved when the P-value is less than the significance level. In this thesis, the significance level is set to 5%, which means that the P-value must be less than 0.05 for the data sets to be significantly different.

7.3.1 Total amount of tests, fails and successes

In table 4 the statistical analysis of the amount of tests, fails and successes from the workshop, as well as the difference between the means are presented. A green colour code signals that the mean is in favour of the hypothesis H1, and a red colour code signals that the mean is against it. The actual means are presented in table 5, for a full representation of the data see Appendix B – Test results. In Table 4, **F** stands for the F-value from the Levene's test, **t** is the t-value from the T-test, **df** is the degrees of freedom and **P** is the probability of getting the results given that H0 is true.

Table 4: T-test for the amount of tests, fails and successes

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	**P**	**t**	**df**	**P (2-tailed)**	**Mean Difference**
Total tests	Equal variances assumed	0.807	0.378	0.668	24	0.511	0.583
	Equal variances not assumed			0.653	20.241	0.521	0.583
Test runs w/ light	Equal variances assumed	0.004	0.949	-1.837	24	0.079	-0.785
	Equal variances not assumed			-1.807	21.157	0.085	-0.785
Fails	Equal variances assumed	0.942	0.341	-0.826	24	0.417	-0.452
	Equal variances not assumed			-0.798	17.997	0.435	-0.452
Successes	Equal variances assumed	0.966	0.335	-0.769	24	0.450	-0.333
	Equal variances not assumed			-0.767	23.236	0.451	-0.333

In table 4 the P-value for the Levene's Test is above 0.05 for all of the categories, hence, there is no significant difference in the results and we can assume equal variances. The P-values from the 2-tailed T-test are also all above the significance level of P = 0.05 and there is therefore no significant difference between the fast and slow sessions regarding the amount of tests, fails and successes.

Additionally the mean difference varies from being for and against H1, implicating that there is no connection between the speed of music and these measurements.

Table 5: Average values for the total amount of tests, fails and successes

	N	Total tests:	Test runs (w/light):	Fails:	Successes:
Fast	14	5.50	2.21	1.71	0.50
Slow	12	4.92	3.00	2.17	0.83

7.3.2 Time measurements

In table 6 the statistical analysis of the time measurements is presented, where the same colour coding as in 7.3.1 is applied. The means are presented in table 7, for a full representation of the data see Appendix B – Test results.

Table 6: T-test for time measurements

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	**P**	**t**	**df**	**P (2-tailed)**	**Mean Difference**
Time at first test	Equal variances assumed	9.466	0.005	-0.453	24	0.654	-.777
	Equal variances not assumed			-0.433	15.865	0.671	-.777
Time at first test w/light	Equal variances assumed	0.529	0.474	1.788	24	0.086	3.905
	Equal variances not assumed			1.820	23.906	0.081	3.905
Best time across canal	Equal variances assumed	0.003	0.956	1.007	7	0.348	1.864
	Equal variances not assumed			1.029	6.958	0.338	1.864

Table 6 shows that the P-values for the Levene's Test are above the significance level, except for the measurement of time at first test, P = 0.005. The T-test also gives a P-value above the significance level, both for equal variances assumed and equal variances not assumed, and there is therefore no difference in the results between the fast and slow sessions for the time measurements.

For the time measurements, the mean difference also varies between being for and against H1 in the same way as for the measurements in 7.3.1.

Table 7: Average values for time measurements

	N	Time at first test:	Time at first test w/light:	Best Time across canal:
Fast	14	6.06	17.39	10.35
Slow	12	6.84	13.49	8.49

7.3.3 Movement

In figure 7.4 and figure 7.5 a total average from all of the beans in the fast and slow sessions are presented. Both of the graphs are quite similar, with the difference of the average of the average being 0.42 G in the fast sessions, and 0.44 G in the slow sessions. The fact that the graphs are similar corresponds well to the results from the quantitative measurements.

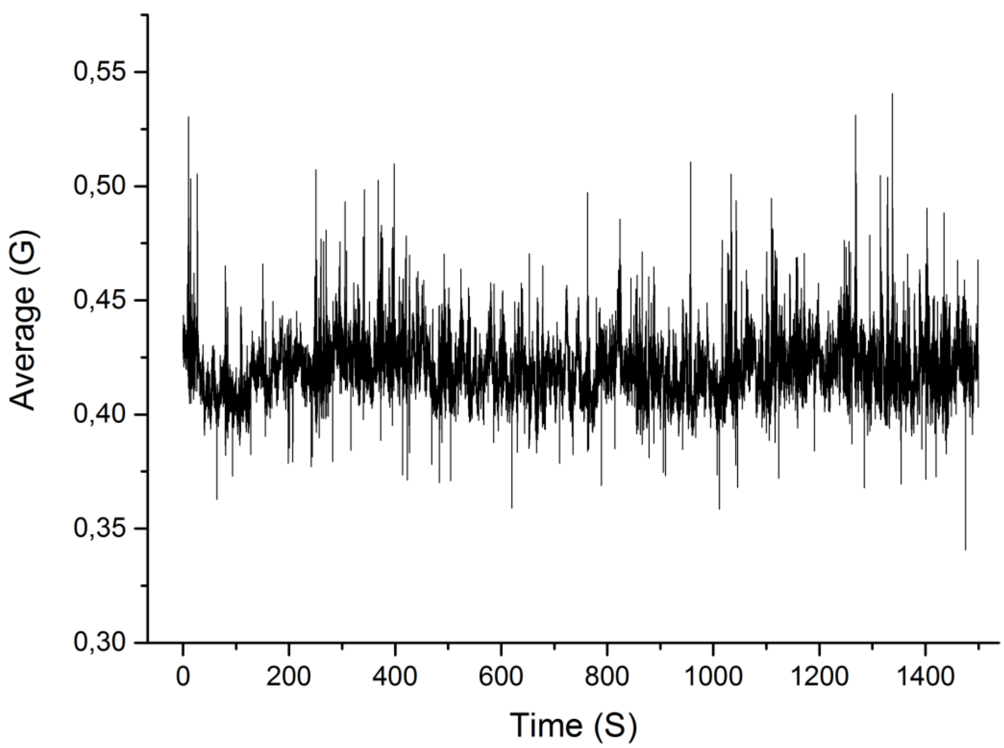

Figure 7.4: Total average from the fast sessions

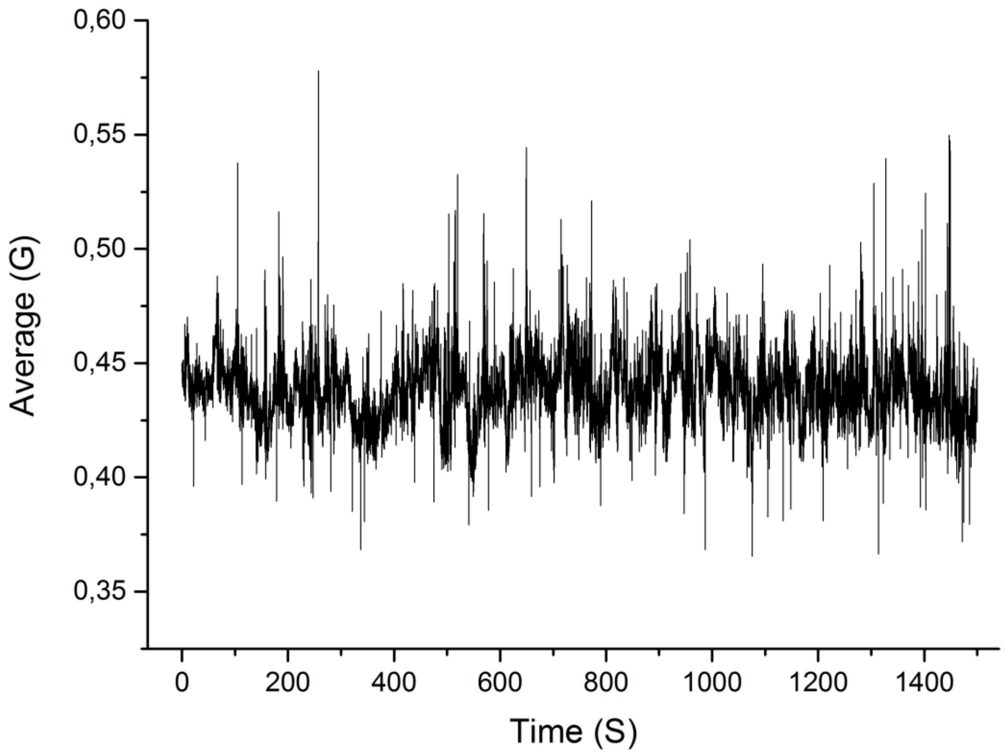

Figure 7.5: Total average for the slow sessions

7.4 Discussion

With the results gathered from our experiment we were not able to confirm our hypothesis of faster music making people more active, but this does not necessarily mean that the hypothesis does not hold. The amount of test persons (N = 26) was not nearly as big as hoped for, and it is not enough to get a clear answer. Additionally, the subjects were not in the wanted age range, i.e. university students, which would make it easier to gather participants with similar backgrounds. This was unfortunately not possible to achieve because of the time frame of the experiment.

Our initial thought was that the age would not affect the results too much, as long as enough test subjects was gathered. However, since we did not get that many participants it gave us more problems than first expected. The main problem of having test subjects in the age range 10-16 is that these in general have a varied mind-set and often quite different backgrounds. The way they complete the challenge can therefore be a result of the test subjects just being very different, instead of showing an effect from the music. If older people would have been used, it is easier to gather subjects with a common background, and therefore give a better foundation for saying something about the actual effect.

Another issue with the conducted experiment was the location. The area used for the experiment was a part of the main hall in Heureka with a big window where you could see the people looking at the exhibitions outside. The ambient noise level in the area would therefore change with the amount of people visiting Heureka, and the people outside could be a possible distraction. Since we only had one speaker standing in front by the water tank, the perceived volume was also different between the participants.

The movement data was mostly gathered because we already had the Lighblue Beans available, and the data itself did not add too much value to the research. Measuring movement from the center of mass might be more informative if we are measuring the difference between standing and sitting. As all of the participants in this workshop was standing, the movement data shows us when the participant moves to the tank to test, which can also be observed from the video footage.

An improvement could be to measure movement elsewhere, for example arm movement. One possible solution for this is to use computer vision as discussed in chapter 5.1.2, but this will increase the cost and more advanced programming is necessary.

Because most of the participants was not fluent in the English language, a trainee from Design Factory gave the instructions and answered questions in Finnish. As a result of this, not all of the conversations made during the experiments at Heureka was understood by the author, and some interesting information might therefore have been missed.

As discussed in chapter 3 it is not easy to measure the effects from music, and many of the issues discussed above are possible sources of error in the experiment. We would therefore recommend to seize the activity with the current experiment and set up a new experiment at a time were gathering test subjects in the correct age segment is easier, and in a more controlled environment. An extra possibility is to investigate if there is a difference between subjects being able to see what the others are doing or not.

8. OTHER OBSERVATIONS

Even though we did not manage to confirm our hypothesis, there are some other observations worth noticing.

More or less all of the participants conducted several tests without mounting and/or lighting the candle. This was somewhat expected since people often want to test if an “unfinished” prototype floats etc. The interesting observation was that when they for example had confirmed that their prototype was floating (some also tested with the fan), they went back to continue building instead of also trying with the candle. In some occasions, when the participant had done this a couple of times, we deliberately asked if the participant wanted to test with a candle, but they still seemed to have some minor changes to correct.

The result of this was often that the first test with a candle was performed late in the workshop. It also resulted in failed tests when the candle was added because the candle was not protected enough and/or it added weight to the prototype, which made it behave differently than expected.

The reason for this behaviour was not investigated closely, but one probability is that the participants are afraid of failing. The fact that the experiment was performed in a way that allowed everyone to see what the others were doing might also have increased the effect. To investigate this effect we would propose to either perform the same workshop while not letting the participants see what the others are doing, or to prime the participants to think that failing is ok before the workshop starts, and then see if there is any observable difference in the results.

Another element that could be interesting to look further into, is whether the possibility to see what the others are working on or not will affect the general design of the prototype. We did not take the design of the prototypes into consideration in this experiment, but it is worth mentioning that we did observe a slight difference between the children participating at Heureka compared to the test runs completed with students at Aalto Design Factory. The general observation was that the prototypes made by the older students more often resembled something that could be thought of as a boat.

This might be a result of a difference in the general mind-set of the participants, or it might be because the older students have more knowledge about “what works” and therefore spend more time to make the prototype look like a boat. It is also worth mentioning that only one participant had the thought of utilizing the candle to give propulsion to the prototype. This participant was in the discarded group at Heureka and was eight years old.

Additionally, it could be interesting to investigate the importance of the design. Is it possible to find a general solution design that works better than others, and does it affect the result in terms of how many tests are being made, and how fast the prototype can traverse the canal. If such a design exists, we would assume that the results would be more affected by the chosen design, rather than the amount of prototypes.

The fact that there can be a big difference in the mind-set and knowledge of people in different age groups may also implicate that the possible effect from music might also be different. If a later experiment succeeds in getting good data, and our hypothesis is confirmed, it would be interesting to investigate what happens if the same music is used over a long period of time. Will it make the eventual effect wear off, or will the effect stay the same as the subjects gets used to the music?

9. Conclusion

In this study, it was found that the speed of music did not affect the results in any noticeable way and the hypothesis could not be proven. However, the conducted experiment ended up with having several sources of error that we were not able to avoid due to the unfortunate timing of the experiment (mid summer). Most importantly, it was not possible to gather test subjects with the same background and the testing area contained many distracting elements.

It was first believed that having a high number of participants could minimize the error of participants being different, but because of the complexity of music is seems that it is essential that the participants are as similar as possible. The experiment should therefore be conducted at a more controlled location with people in the wanted age segment and with the same background to get better data, and results that are more accurate.

During the experiments, some additional observations were made. The participants seemed to avoid running timed tests on their prototypes as if they were afraid of failing, which can be an effect from the fact that all of the participants could see what the others were doing.

Some prototype designs seemed to work better than others, and the originally chosen design by the participant can therefore affect the result. The big variation in designs during the study can be a result from the earlier mentioned problem of the attending participants having diverse backgrounds.

If this study is to be continued at a later point of time, it is advised that these observations are taken into consideration, by implementing them into the research, or to make them subject for further study.

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APPENDIX A – ARDUINO CODE

```
#include <SD.h>

const int chipSelect = 2;

const int sleeptime = 100;

unsigned long time = 0;


uint8_t temp;

void setup()

{

Serial.begin();

Bean.setLed(255, 0, 0);

// Check if the card is present and can be initialized

if (!SD.begin(chipSelect)) {

Serial.println("SD fail");

return;

}

}

void loop()

{

// Get the ambient temperature with a range of -40C to 87.5C

//temp = Bean.getTemperature();

Bean.setLed(0, 0, 0);

time = time + sleeptime;

AccelerationReading acceleration = Bean.getAcceleration();


String stringToPrint = String();

  stringToPrint = stringToPrint + "timestamp: " + time + "\tX: " + acceleration.xAxis + "\tY: " +
acceleration.yAxis + "\tZ: " + acceleration.zAxis;


// Open the data file
```

```
File dataFile = SD.open("datalog.txt", FILE_WRITE);
// If the file is available, write to it:
if (dataFile) {
dataFile.println(stringToPrint);
//dataFile.println(String(temp));
dataFile.close();
}
// If the file isn't open, send an error message over serial
else {
Serial.println("error opening datalog.txt");
Bean.setLed(255, 0, 0);
}
// Sleep for a minute before we read the temperature again
Bean.sleep(sleeptime);


}
```

APPENDIX B – TEST RESULTS

The tables in this appendix shows the exact results and their averages from the experiment conducted at Heureka.

Fast sessions:

Nr.	Total tests:	Test runs (w/light):	Fails:	Successes:
1	7	4	0	4
2	10	3	2	1
3	8	3	3	0
4	4	2	2	0
5	5	3	3	0
6	3	1	0	1
7	5	1	1	0
8	5	1	1	0
9	4	1	1	0
10	3	2	2	0
11	6	2	2	0
12	6	2	1	1
13	6	3	3	0
14	5	3	3	0
Average	**5,5**	**2,214285714**	**1,71428571**	**0,5**

Nr.	Time at first test:	Time at first test w/light:	Best Time across canal:
1	7	15,17	7,63
2	5,58	9,5	12,97
3	0,25	18,18	-
4	6,33	16,2	-
5	6,3	7,5	-
6	5,83	8,67	8,97
7	8,5	25	-
8	8,97	25	-
9	8,97	25	-
10	4,67	14,67	-
11	11,27	23,58	-
12	4,32	21	11,84
13	4,95	15,5	-
14	1,87	18,5	-
Average	**6,057857143**	**17,39071429**	**10,3525**

Slow sessions:

Nr.	Total tests:	Test runs w/light:	Fails:	Successes:
1	6	2	2	0
2	2	2	2	0
3	6	4	3	1
4	11	2	0	2
5	3	3	3	0
6	2	2	2	0
7	7	6	6	0
8	4	3	1	2
9	6	4	4	0
10	5	2	2	0
11	4	3	0	3
12	3	3	1	2
Average	**4,91666667**	**3**	**2,16666667**	**0,833333333**

Nr.	Time at first test:	Time at first test w/light:	Best Time across canal:
1	1,33	8,57	-
2	8,83	8,83	-
3	9,83	9,83	13,47
4	0,23	17	7,97
5	13	13	-
6	16,33	16,33	-
7	0,13	8	-
8	13,83	14	8,47
9	4,72	16,43	-
10	1,83	21,33	-
11	3,97	20,5	6,25
12	8	8	6,28
Average	**6,835833333**	**13,485**	**8,488**

NTNU	Risikovurdering	utarbeidet av	Nummer	Dato
		HMS-avd.	HMSRV2603	04.02.2011
		godkjent av	side	Erstatter
HMS/KS		Rektor	1 av 3	9.2.2010

Enhet: IPM
Veileder: Martin Steinert
Deltakere ved risikovurderingen (m/ funksjon): Masterstudent Erik S. Hansen

Dato: 25/03-14

ID nr	Aktivitet fra kartleggings-skjemaet	Mulig uønsket hendelse/ belastning	Vurdering av sannsyn-lighet (1-5)	Vurdering av konsekvens: Menneske (A-E)	Ytre miljø (A-E)	Øk/ materiell (A-E)	Om-dømme (A-E)	Risiko-verdi	Kommentarer/status Forslag til tiltak
1	Prototyping	Injury from use of heavy machinery / tools	2	D	A	C	C	2D	I have completed the HSE-course. Remember to follow guidelines set for the workshop, use the correct protective gear and ask for help when in doubt.
		Injury from use of light machiney / tools	3	A	A	A	A	3A	Follow guidelines set for the tool and use recommended protective gear
		Damage on machinery / tools	2	A	A	D	C	2D	Follow guidelines set for the workshop, use correct protective gear and ask for help when in doubt
2	Working at Design Factory	Fire	2	B	D	C	B	2D	Know where fire extinguishing equipment is placed, know the guidelines for the facility and be aware of the Finnish emergency numbers
		Long workdays sitting still	4	B	A	A	A	4B	Remember to change positions and to get up and move around once in a while

Sannsynlighet
1. Svært liten
2. Liten
3. Middels
4. Stor
5. Svært stor

Konsekvens
A. Svært liten
B. Liten
C. Moderat
D. Alvorlig
E. Svært alvorlig

Risikoverdi (beregnes hver for seg):
Menneske = Sannsynlighet x Konsekvens Menneske
Ytre miljø = Sannsynlighet x Konsekvens Ytre miljø
Økonomi/materiell = Sannsynlighet x Konsekvens Øk/matriell
Omdømme = Sannsynlighet x Konsekvens Omdømme

Sannsynlighet vurderes etter følgende kriterier:

Svært liten 1	Liten 2	Middels 3	Stor 4	Svært stor 5
1 gang pr 50 år eller sjeldnere	1 gang pr 10 år eller sjeldnere	1 gang pr år eller sjeldnere	1 gang pr måned eller sjeldnere	Skjer ukentlig

Konsekvens vurderes etter følgende kriterier:

Gradering	Menneske	Ytre miljø Vann, jord og luft	Øk/materiell	Omdømme
E **Svært Alvorlig**	Død	Svært langvarig og ikke reversibel skade	Drifts- eller aktivitetsstans >1 år.	Troverdighet og respekt betydelig og varig svekket
D **Alvorlig**	Alvorlig personskade. Mulig uførhet.	Langvarig skade. Lang restitusjonstid	Driftsstans > ½ år Aktivitetsstans i opp til 1 år	Troverdighet og respekt betydelig svekket
C **Moderat**	Alvorlig personskade.	Mindre skade og lang restitusjonstid	Drifts- eller aktivitetsstans < 1 mnd	Troverdighet og respekt svekket
B **Liten**	Skade som krever medisinsk behandling	Mindre skade og kort restitusjonstid	Drifts- eller aktivitetsstans < 1uke	Negativ påvirkning på troverdighet og respekt
A **Svært liten**	Skade som krever førstehjelp	Ubetydelig skade og kort restitusjonstid	Drifts- eller aktivitetsstans < 1dag	Liten påvirkning på troverdighet og respekt

Risikoverdi = Sannsynlighet x Konsekvens

Beregn risikoverdi for Menneske. Enheten vurderer selv om de i tillegg vil beregne risikoverdi for Ytre miljø, Økonomi/materiell og Omdømme. I så fall beregnes disse hver for seg.

KONSEKVENS						
	Svært alvorlig	E1	E2	E3	E4	E5
	Alvorlig	D1	D2	D3	D4	D5
	Moderat	C1	C2	C3	C4	C5
	Liten	B1	B2	B3	B4	B5
	Svært liten	A1	A2	A3	A4	A5
		Svært liten	Liten	Middels	Stor	Svært stor
		SANNSYNLIGHET				

Prinsipp over akseptkriterium. Forklaring av fargene som er brukt i risikomatrisen.

Farge	Beskrivelse
Rød	Uakseptabel risiko. Tiltak skal gjennomføres for å redusere risikoen.
Gul	Vurderingsområde. Tiltak skal vurderes.
Grønn	Akseptabel risiko. Tiltak kan vurderes ut fra andre hensyn.