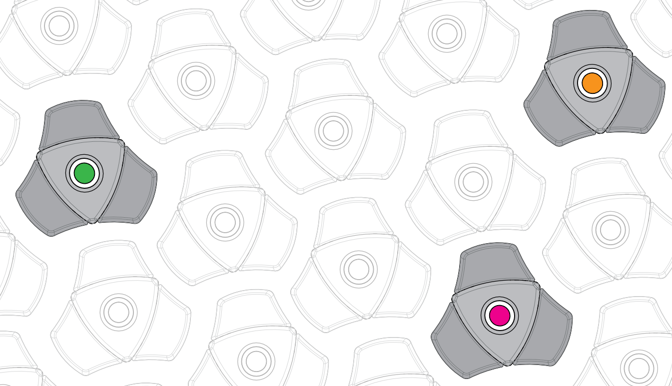

Stimulating adolescents' physical well-being by gamification

The design of a product-service combination called: Move on

TU Delft

Stimulating adolescents’ physical well-being by gamification
The design of a product-service combination called: Move on

MSc Integrated Product Design - graduation thesis

Faculty of Industrial Design Engineering
Delft University of Technology

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EXECUTIVE SUMMARY

This thesis describes the design of the product-service combination called Move on. Move on is designed to stimulate adolescents to be more physically active. This stimulation is done by gamification, which therefore can be considered as serious gaming product.

This thesis starts with a literature analysis of the decreasing level of childrens' physical well-being.
Added to this analysis, is a literature research on the increased digitalization among children to see if there is a connection between their increased screen-time and the decreasing level of fitness. A relation between digitalization and emotional behavior, and digitalization and social relationships, has also been taken into account.
It seems that there is no clear proof of the coherency between the increasing digitalization and decreasing physical activity. Which was a positive result, since the advantages of the digitalization could be taken into account when designing a product for children.

After finding out that the adolescents, of all children, spend the most time stuck to their screens, the target group for the ideation phase was determined.
A target group analysis and a market analysis eventually lead, together with the previous insights, to a full program of requirements and therefore the end of the design brief.

The design brief created the base for the next phase: the synthesis phase. Within the synthesis phase of the product development, some concept directions were found. These concept directions lead to some iteration steps which eventually resulted in the embodiment phase of the Move on.

The embodiment phase describes the final concept with regard to its materials, production method, and price estimation.
An important part of the Move on, is that it is able to recognize the user motion. This motion will be converted to a reward, which the user can use in their favorite game.
Since this motion recognition plays a big role in the product, a basic machine learning validation is executed. Data from walking and running sessions is used to actually predict if the user is walking or running. This validation succeeded with a hit rate value of 96 percent.

The end of the thesis will describe recommended steps fur future development of the product, together with a project and a personal evaluation.

TABLE OF CONTENTS

1
PROJECT APPROACH

This graduation project focusses on designing a product that stimulates the physical well-being of adolescents.

The envisioned product can be considered a cyber-physical system relying on wearable sensors. To achieve a higher level of stimulation, a gamification element will be introduced.

Figure:1 describes the determined approach to use within this thesis. The project is divided into 4 phases: The analysis phase, the synthesis phase, the embodiment phase, and the evaluation phase.
The figure also shows the determined output of each phase. This output will serve as a base for the next phase to start with.

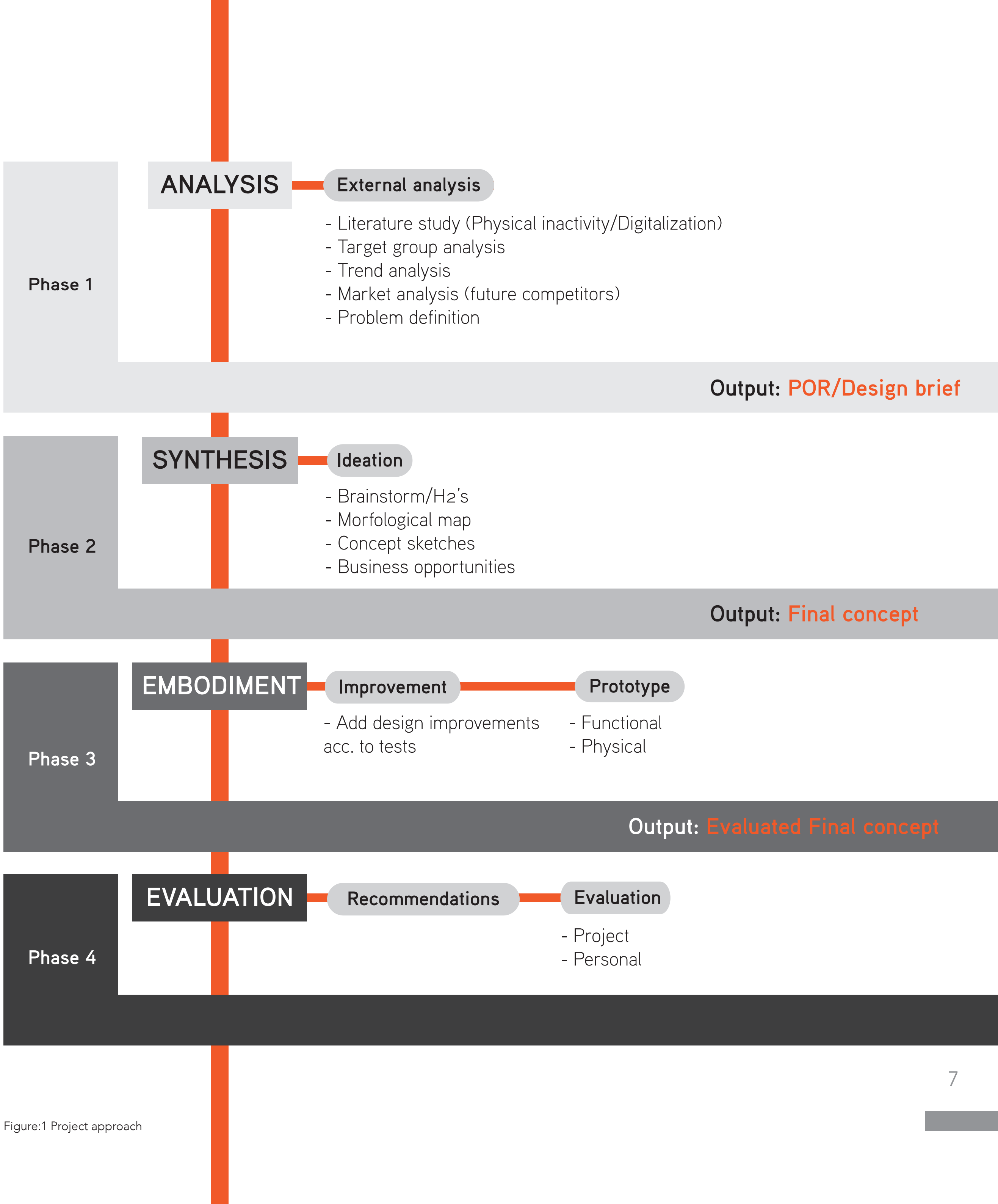


Figure:1 Project approach

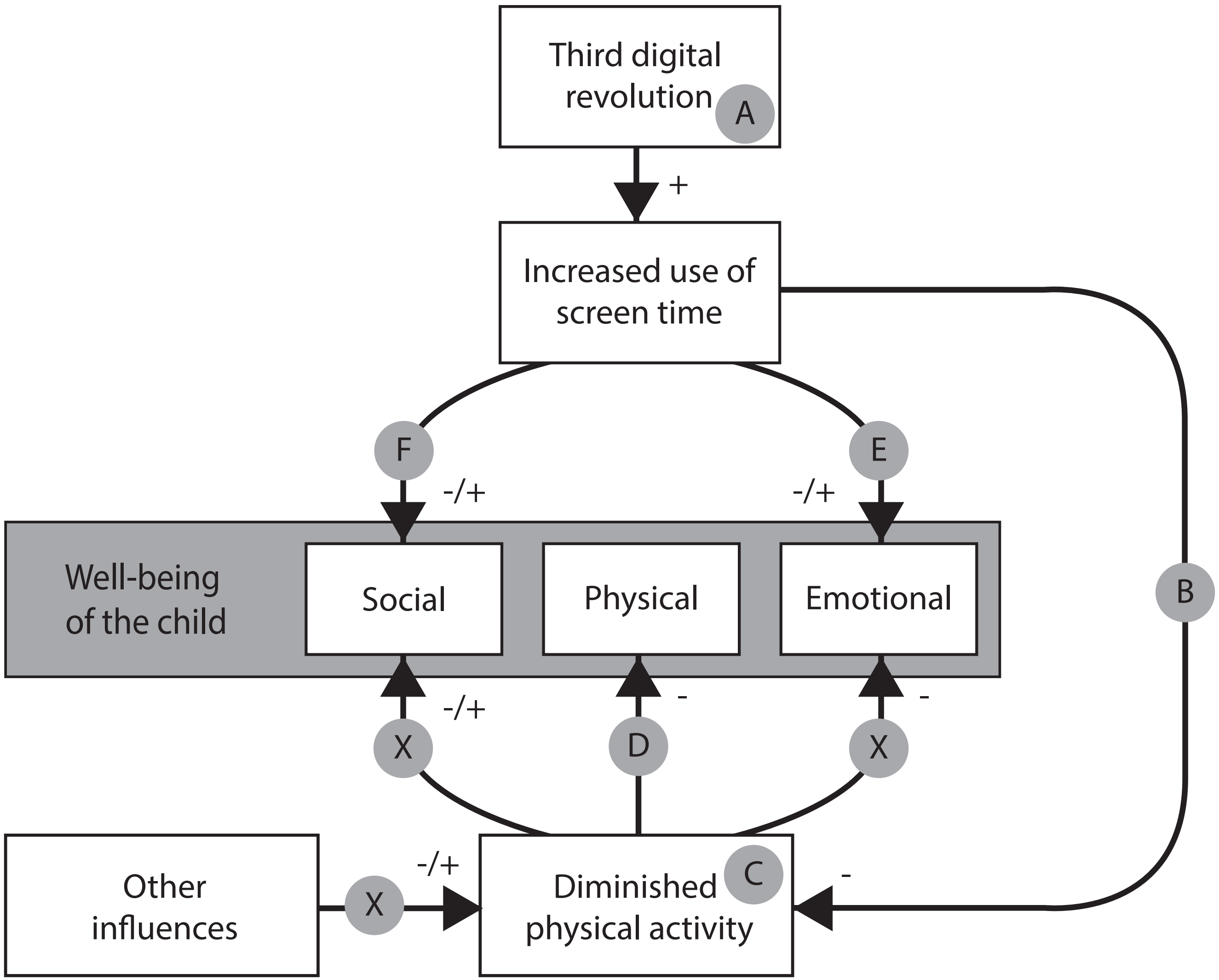


Figure:2 Reasoning modelv3

2 LITERATURE STUDY

2.1 INTRODUCTION

Within the research part of this thesis, some new insights should be obtained in order to design a product that suits the market and identify a target group.
The main hyposthesis to be answered within this research is: *The influence of the increasing digitalisation will have a negative effect on childrens' physical activity and therefore well-being.*

The reasoning model, Figure:2, describes the expected relationship between the different subjects. Each of the connections (A-G) will be described in this thesis. The connections indicated with an 'X' are research topics that are not within the scope of this thesis. Also the predicted influence within the connections is described. A '-' will indicate a negative influence, a '+' will indicate a positive influence and '-/+' indicates that the influence is uncertain or both positive and negative.
In order to answer the main hypothesis, several sub-questions will be answered. The answers for these sub-questions will be provided by the connections of the reasoning model above.

A. Has the level of daily physical activity among children dropped in the last couple of years?
B. What are the consequences of digitalisation on the well-being of children?

2.2 PHYSICAL ACTIVITY (C)

To answer sub-question A: *Has the level of daily physical activity among children dropped in the last couple of years?*, a clear understanding of the term physical activity will be provided and followed by a specification of the physical activity among children.

2.2.1 Definition

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. The lack of physical activity, also known as physical inactivity, has been identified as the fourth leading risk factor for global mortality (6% of deaths globally). (WHO, 2018b)
The intensity of physical activity refers to the rate at which the activity is being performed, e.g. 'How hard a person works to do the activity'. This intensity of different forms of physical activity varies between people. It also depends on previous individual exercise experience and the level of fitness. The level of intensity is categorized into moderate intensity (walking, gardening, carrying loads (<20kg)) and vigorous intensity (running, swimming and carrying loads (>20kg)). The intensity can be expressed in Metabolic equivalents (METs) (whereas 3-6 METs refers to moderate intensity and >6METs refers to vigorous intensity)(Figure:3).

Moderate-intensity Physical Activity (Approximately 3-6 METs) Requires a moderate amount of effort and noticeably accelerates the heart rate.	Vigorous-intensity Physical Activity (Approximately >6 METs) Requires a large amount of effort and causes rapid breathing and a substantial increase in heart rate.
Examples of moderate-intensity exercise include:	Examples of vigorous-intensity exercise include:
• Brisk walking	• Running
• Dancing	• Walking / climbing briskly up a hill
• Gardening	• Fast cycling
• Housework and domestic chores	• Aerobics
• Traditional hunting and gathering	• Fast swimming
• Active involvement in games and sports with children / walking domestic animals	• Competitive sports and games (e.g. Traditional Games, Football, Volleyball, Hockey, Basketball)
• General building tasks (e.g. roofing, thatching, painting)	• Heavy shovelling or digging ditches
• Carrying / moving moderate loads (<20kg)	• Carrying / moving heavy loads (>20kg)

Figure:3 Intensity diagram

For the past couple of centuries, the level of peoples' daily physical activity is decreasing. One of the likely causes of this high increase of inactivity is a result of not pursuing the recommended moderate-intensity physical activity of 150 minutes a week (adults between 18 and 64 years old), according to numbers of the World Health Organisation (WHO). Globally around 31% of adults aged 15 and over are not meeting the minimum recommendations for moderate-intensity physical activity (men 28% and woman 34%)(WHO, 2018). Wherein in 2009 the global physical inactivity was 17%. (Kohl et al., 2012) This physical 'inactivity' is one of the main reasons for the increasing number of people suffering from obesity (WHO, 2018). The WHO estimates that 1.9 billion adults are overweight, of which 600 million suffer from obesity. People are generally considered obese when their body mass index (BMI), a measurement obtained by dividing a person's weight by the square of the person's height, is over 30 kg/m2, with the range 25–30 kg/m2 defined as overweight ("Wikipedia", 2018c). Besides obesity the inactivity is accompanied with a high risk of chronic diseases. Diseases as breast cancer, coronary heart disease, colon cancer, stroke, diabetes, and osteoporosis (Colditz, Nguyen, & Dart, 2017).
Over the last 60 years, epidemiological research had been conducted(Rod K. Dishman, Gregory W. Heath, 2013)(Varela et al., 2018). Rod K. et Al describe the upcoming of the physical activity epidemic, which leads to a serious global health problem, which cause approximately 3.2 million deaths each year (WHO, 2018b).

2.2.2 Children

According to the WHO and Morrison (2015), the problem of physical inactivity starts in childhood. If we specifically look at children (5-17 years old), the recommended moderate-intensity physical activity (3-6 METs) is about 60 minutes per day(WHO, 2018a).

In chapter 3 the research among experts describes that stimulating the physical activity of children in their early years is a critical foundation for a active and healthy live as an adult (Mishra, 2015). That is also the reason why children need to be more physically active than adults. In comparison, the recommended moderate-intensity physical activity(3-6 METs) for adults (18-65 years old) is around 20 minutes per day. This number is significantly lower than recommendations for children.

Figure:4 shows a worldwide indication on prevalence of physical inactivity, as a result of insufficient physical activity, among school going children in 2010. Figure:5 shows also this prevalence indicator for adults (18+). The average prevalence of physical inactivity among children is 80.7%, in comparison to 23.3% for adults. This indicates the fact that a lot of children are physically inactive. At least more than adults being physically inactive.

Sandercock et Al. 2015, performed research among children with regard to their level of fitness, coherent to their level of physical activity. From 1998 till 2008 he investigated both girls and boys and he found out that the level of fitness among children is decreasing with 0.95% each year. He stated that only 25% of the children (6-17 years old) manages to spend at least the recommended 60 physical activity minutes per day.

According to Mishra (2015), who studied the reasons why people not exercise, this inactivity epidemic is linked to several cultural and societal developments, such as a lack of support by their role models (parents) and the increasingly amount of sedentary time children dedicate to screen time (watching TV and playing video games). Chapter 3 will dive deeper into potential physical inactivity causes.

The conducted research shows that children suffer the most from physical inactivity and can therefore be pointed out as the category with the highest impact on changing the worldwide physical well-being.

According to the researchers, the level of physical activity among children has dropped. The level of fitness among children is decreasing with a shocking 0.95% (around 220.000 children) per year.

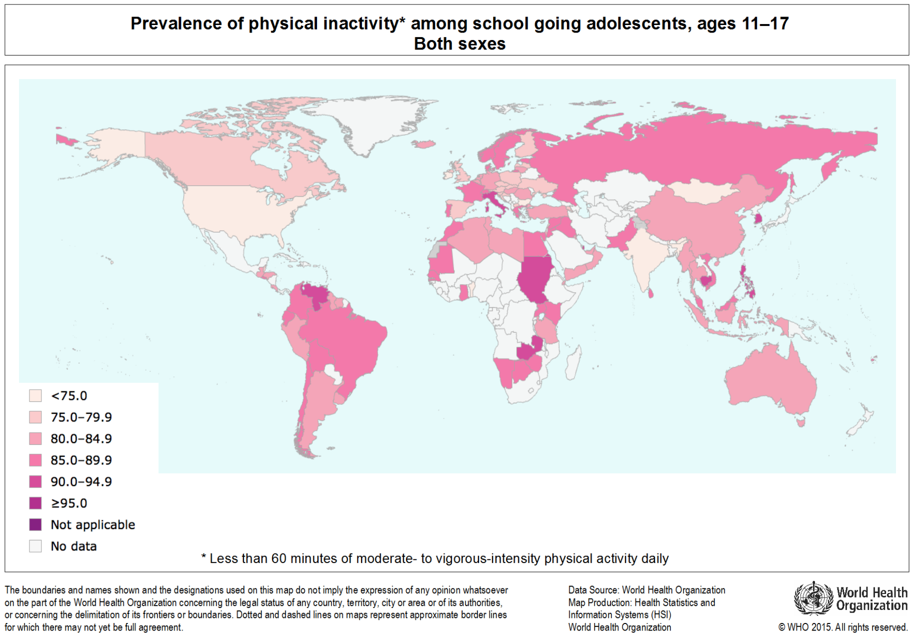


Figure:4 Global InsufficientActivity index BothSexes 11-17 2010

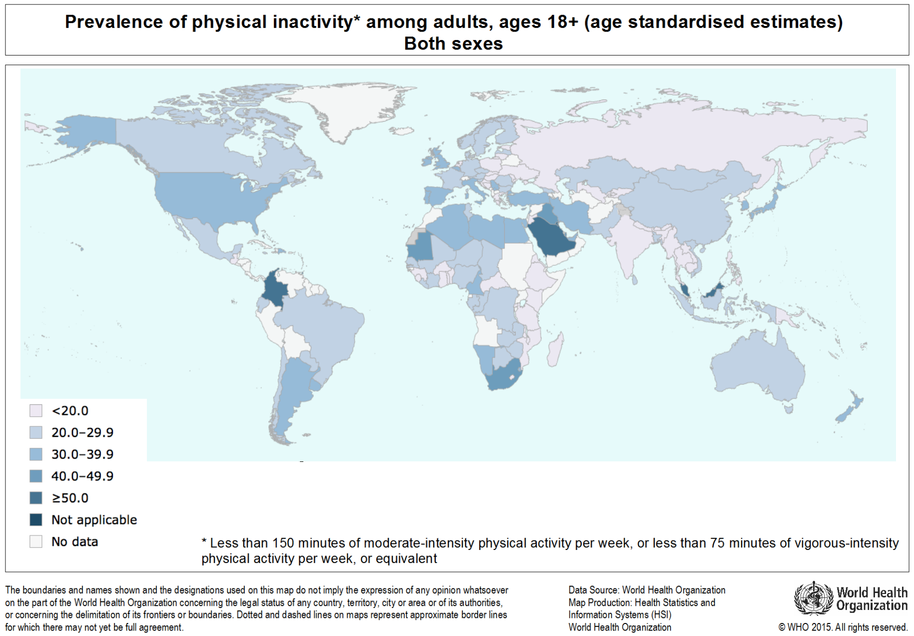


Figure:5 Global InsufficientActivity Adults BothSexes 18+ 2010

2.3 DIGITALISATION AMONG CHILDREN

Within this chapter, sub-question B: *What are the consequences of digitalisation among children?,* will be answered. A brief summary of the so-called 'digital revolution' will be described. Further on, the cohesion between digitalisation and children will be brought to light.

2.3.1 History (A)

The digital revolution, also known as the third industrial revolution, refers to the advancement of technology from analogue electronic and mechanical devices to the digital technology available today. (Technopedia, 2018) This new revolution implicated the beginning of the so-called information age'. The first digital revolution started with the development of the transistor in 1947. From then on, digital computers and digital record keeping became the norm for almost everyone. According to Gershenfeld, Gershenfeld, & Gershenfeld, 2017, the first two stages of digital revolution can be described as the computing revolution and the communication revolution, which had a tremendous influence on society. Beside the effect that we are still experiencing the enormous amount of possibilities created by the first two revolutions, the third digital revolution also found its way to contemporary society. Since the 1980s, the fabrication revolution started due to new additive manufacturing processes. This digital fabrication will allow individuals to design and produce tangible objects on demand, wherever and whenever they need them(Gershenfeld, 2012).

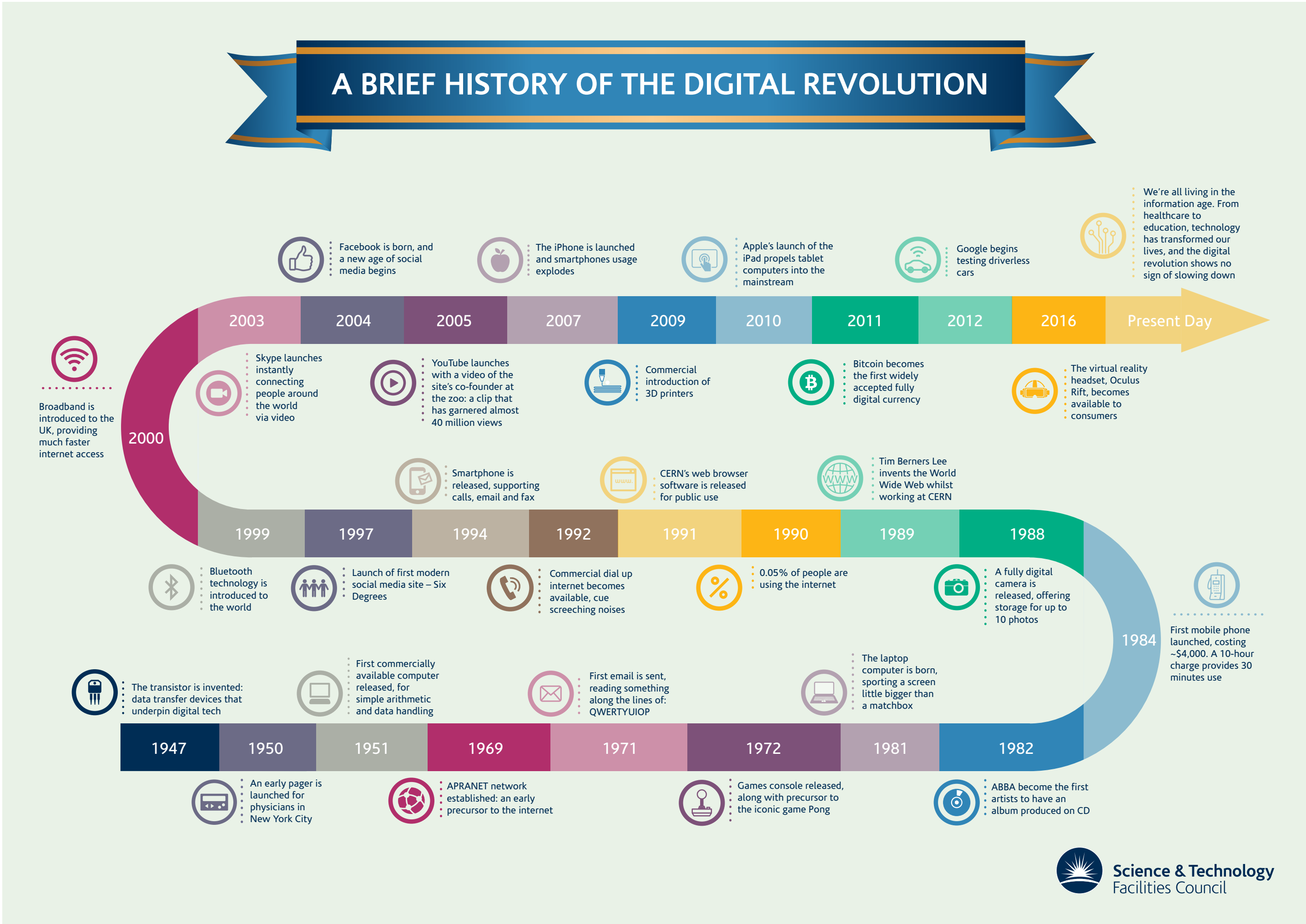


Figure:6 Digital Revolution Infographic

Figure:7 Child playing on tablet.

2.3.2 Consequence (s) of digitalisation (B)

Due to the engaging digital revolution, children interact with electronic screens more often.
Already a lot of research has been conducted with regard to potential impact of computer/smartphone/tablet use on health. Straker et al., 2008 describes the research on discomfort and disorders among young children being addressed for working on a desktop, tablet and paper conditions.
The new user interface of tablet and smartphone devices makes it very intuitive to interact with the graphical touchscreen for even very young children (0-4 years old).
Studies showed that in urban areas of the US, 97% of the 4-years olds had used a mobile device and almost two-thirds had their own tablet (Howie, Coenen, Campbell, Ranelli, & Straker, 2017).
Common Sense Media Research addressed in 2014 that half (52%) of the children worldwide have access to a mobile device at home.
This widely spreading use of tablets and smartphones among children has many potential benefits and risks for both mental and physical health. Within the next topics the consequences of digitalisation will be shown with regard to the emotional behaviour, social behaviour and physical behaviour.

"97% of the 4-years olds had used a mobile device and almost two-thirds owned their own tablet"

2.3.3 Emotional behaviour (E)

Moderate use (1-3 hours a day) of digital technologies such as watching television, playing games or spending time on the mobile phone, should have a positive effect on mental well-being up to a certain point. Generally it can be stated that if the moderate time of use is exceeded, this will have a negative impact on the emotional behaviour of children. Taking into account that this effect can differ per child, some may see these advantages diminish or dissapear after 2 hours and some will maintain these advantages even after 4+hours a day. Some cross-sectional studies have found a positive association between both internet and mobile phone use and self-reported feelings of depression (Bezinović, Roviš, Rončević, & Bilajac, 2015; Ikeda & Nakamura, 2014; Kardefelt-Winther, 2017; Kim et al., 2010). Even at the large scale study, where 6000 children aged 12-18, found a small positive association between screen time and depressive symptoms and delinquency (Ferguson, 2017). Also, other research found out that television viewing was associated with a small increase of emotional problems over time, if viewing exceeded 3 hours per day. (A. K. Przybylski, 2014)

Other large scale studies, with over 120.000 15-year-old children, showed (Andrew K. Przybylski & Weinstein, 2017) that the impact of a variety of digitally-mediated activities on the other hand, had negligible impacts on the childs' mental well-being. A longitudinal study specifically focussing on playing video games also found no negative impact on either conduct problems or emotional symptoms (Parkes, Sweeting, Wight, & Henderson, 2013).

In general it can be stated that the use of digital technologies for 1-3 hours a day should provide a positive effect on the mental well-being of the child.

2.3.4 Social relationships (F)

Conducted research among 1300 adolecents shows that the quality of a parent-child relationship remains more or less the same, even if the time spent on digital technology is increased (Lee, 2009). Also the greater engagement in online communication seems to strengthen the band between friends even better according to various studies (Ellison, Steinfield, & Lampe, 2007; Valkenburg & Peter, 2007). These studies addres that it is easier to talk about the childs personal or sensitive topics online than it is in real life. Talking about each others feelings and therefore understanding each other better will improve the quality of the friendship.
Other hypotheses also address the improvement of social skills online, specifically for those who lack in social skills in real life. Those children find it easier to self-disclose online compared to offline. This effect seems to be more common among boys than girls(Valkenburg & Peter, 2007).

It seems that digital technologies actually do have a positive impact on a child's friendship and social networks. This improved quality of existing friendship and social network will therefore also lead to a better emotional well-being.

2.3.5 Physical activity (D)

A lot of research has been done with regard to the coherency between physical activity and digital technologies. Some researchers found that the impact of digital technology creates a reduction of a childs' physical activity (Kautiainen, Koivusilta, Lintonen, Virtanen, & Rimpelä, 2005). Iannotti at. Al (2009) also found that the increase in screen time was associated with among other things, the reduction of physical activity among 2000 Canadian and US School-Aged children. However the effects on physical activity were very small in both studies.

Other studies, on the other hand, show that there is no significant coherency between physical activity and digital technologies. Kautiainen et al., 2005; L. Straker, Smith, Hands, Olds, & Abbott, 2013 showed that different screen-time activities relate differently to physical activity. The research on Finnish adolescents, for instance, shows that only some forms of digital technology is associated with higher obesity rates. Playing digital games had no effect and watching television only led to very small increases.

Other studies stated that the time spent on mobile phones even increases the childs' physical inactivity (Lepp, Barkley, Sanders, Rebold, & Gates, 2013) The research of Devís-Devís, Peiró-Velert, Beltrán-Carrillo, & Tomás, 2012, disproves this conclusion due to walking around while playing on the phone or engaging in other activities.

Overall it can be stated that there is no clear proof of the coherency between physical (in)activity and digital technologies. Explanations for the reduced physical activity seems to depend on multiple factors than only screen time activities. Of course it differs per child if their screen time is related to their reduced physical activity. Children who already spend a lot of time on screens are more likely to spend even more time which will have a negative effect on their physical activity.

Figure:8 Social children with phone.jpg

2.4 CONCLUSION

Within this research part of the thesis, the main question to be answered was: Does the influence of the increasing digitalisation have a negative effect on childrens' physical activity?
According to the individual answers to sub-question 1 and 2 ("Has the level of daily physical activity among children dropped in the last couple of years?" and "What are the consequences of digitalisation among children?") it can be stated that there is no clear answer for this question at the moment. In some cases the digitalisation have a negative effect on physical activity, but in other cases digitalisation could have a positive effect on physical activity.
Research shows that there is definitely a drop in the childs' physical activity over the past years, but there are no clear results that digitalisation could be the main cause of this trend. The drop in physical activity can be seen as a consequence of many factors, such as the lack of support by their role models.

DESIGN CONSIDERATIONS

- Moderate use of 1-3 hours per day on screen
- Recommended moderate-intensity physical activity of 60 minutes per day
- Watching television is not preferred
- Provide online communication to enhance social relationship
- Talking about feelings will improve friendship

3
DEFINING TARGET GROUP

3.1 INTRODUCTION

In order to investigate the boundaries of the project and to find out the correct age and desired target group, a panel of experts were addressed. The main question to be answered within this chapter can be formulated as: What specific age or group of children spend the most time on their cell phones or behind a screen and can what can we learn about getting these children more physically active?

Every expert has their own specialisation concerning physical activity healthcare for children. The group of experts exists of physiotherapists. Almost all of them are specialised in children.
- Lucinda van Dijk (child physiotherapist)
- Wanda Krispijn (child physiotherapist)
- Esther Hulspas (child physiotherapist)
- Rianne Stollenga (child physiotherapist)
- Jorina de Vrij-Dogterom (physiotherapist)
- Linda Massar-van Haeringen (child physiotherapist)
- Nikki Vermeij (child physiotherapist)
- Moniek Abee (child physiotherapist)

The individual interviews can be found in appendix A.

3.2 QUESTIONS

In order to answer the main question, several sub questions were formulated and asked to the group of experts:
(1) According to you, what target group or specific age ranges spends the most time on their cell phones and therefore does not achieve the recommended physical activity per day?
(2) Besides digitalisation, what else could be the cause of severe overweight among children?
(3) What specific movements, concerning daily motoric skills, can be addressed as conducive for a childs' development?
(4) Is there a recommendation to be made for the minimum and maximum time per day spent on physical activity by a child?

3.2.1 Target group (1)

According to the experts, almost all ages (among children) suffer from spending too much time on their cell phone. Even with babies who are only 2 years old. Although many experts affirm this large variety of children, some also point out even more specific target groups.
Esther mentioned that only the risk groups can be found a lot on their cell phones. Risk groups like children with autism/PPDNOS for example, have a lack of social interaction and therefore seek distraction in gaming/ playing on their phone. Also children who have behavioural problems, physical problems or motor retardation problems end up in this specific group, according to van Dijk.
By far the most experts say that children within their puberty, also called adolescents (roughly 12-17 years old), within the final years of the elementary school and in their first 3 years of high school, spend the most time on their phone.

3.2.2 Other causes of severe overweight (2)

The experts mentioned a large variety of severe overweight causes:
- Cultural differences
A lot of experts are dealing with children from foreign cultures, like Moroccan or Turkish. Eating plays a big role within these cultures. Also the fact of being a bit more overweight suggest prosperity and a 'higher' status in the neighbourhood. Families do not often realise or care about the health risks that are upcoming.
- Parents as role models
A lot of children do not receive any support from their parents in achieving a healthy life. They simply do not set a good example. Often, children are being brought to school by car, instead of cycling or walking. Also, when at home, parents are stuck to their phones or television. This has a contradictory effect on the stimulation of their physical activity.
- Lack of money
Money could also be of great influence on severe overweight of children. Because some parents do not have that much money to spend, they can not afford to buy a bicycle or to pay the sport club dues.
- Eating habits
This topic has some coherency with the previous topic. When parents do not have enough money, often they buy the cheap unhealthy food, instead of the more expensive fresh healthy food.

One expert reffered to the promotion session of Prof. dr. L. Van Rossum (2017), an expert on obesity and overweight. She mentioned other, less of an influence, causes like children's intestinal flora, lack of sleep, stress, hormones, medicines, and genetic disadvantage.

3.2.3 Recommendations for movements stimulating development (3)

The recommendations according to the movement of children can be divided into fine motor skills and gross motor skills. Wherein fine motor skills are assumed to be the small movements, like hand-eye coordination and gross motor skills are assumed to be the bigger movements, like running.
The experts specifically recommended to create a certain challenge to be fulfilled and stimulate the moving experience. The focus should lie on the gross motor skills like strength exercises as climbing, walking the stairs and dragging things along.
Balance is also key to a child's development, with balance exercises as skating, hopping, jumping.
Other experts addressed that children develop while discovering, the more a child discovers, the greater the development of gross motor skills will be. Playing outside is a key example to stimulate a large variety of motion development in both gross and fine motor skills.

3.2.4 Hours per day spent on physical activity(4)

The best advice the experts gave is that children, in any way, should have fun during exercising.
Some suggest to spend a minimum of 1,5 hours a day (beside walking/cycling to school). Others suggest that a minimum of 1 hour a day of moderate intensity should be enough. The Nederlandse Norm Gezond Bewegen also suggests exercising 1 hour each day and at least 2 times per week focus on increasing the child's physical fitness. (Sportzorg, 2018)

This Norm also indicates that children should not spend more than 2 hours a day on 'spent sitting', beside the time spend sitting down at school.

It is remarkable to see that many experts suggest that in order to decrease the overweight of the child, the entire family should change their way of living. This will obviously encourage the child to eat healthy and be physically more active.

3.3 CONCLUSION

The conducted research leads to some serious answers to the main question:
What specific age or group of children spend the most time on their cell phones or behind a screen and can what can we learn about getting these children more physically active?

Due to the outcomes of the expert questionnaires, together with the literature study at page 8, the actual target group can be specified as children within their puberty (having the age of 12-17 years old). Next to this, several causes were formulated regarding severe overweight such as cultural behaviour, parents as a role model, money and eating habits.
The gross motoric skills should be enhanced in order to develop the motion of a child, whereas playing outside can be seen as an excellent example.
Children should spend a minimum of 1 hour each day and at least 2 times per week focus on increasing the child's physical fitness.

DESIGN CONSIDERATIONS

- Design for children between 12 and 17 years old, the so called adolescents
- Causes to take along while designing
  - Cultural differences
  - Parents as role models
  - Lack of money
  - Eating habits
- Change the way of living for the family to enhance stimulation
- Create a challenge to be fulfilled for stimulation
- Focus on gross motor skills (strength exercises, climbing, walking, skating)
- Balance is key for child's development
- Discovering is development
- Stimulate outdoor play
- Fun factor should be determinant
- 1 hour a day focussing on increasing childs fitness, for 2 times a week

4
TARGET GROUP

Within this topic, specific information will be provided concerning the target group. This target group will be used as a main focus point for the invisioned product. First some general information will be provided on what the actual target group looks like and what they are up to. Next, some characteristics will be provided and how to reach them followed by a list of guidelines for the design.

Figure:9 Generation Z

4.1 INTRODUCTION OF GEN Z

According to chapter 2 and 3, the focus for this project should be on children between 12 and 17 years old, the so called adolescents. This specific group of people can be categorized within a certain generation. Of course we know the Millennials or Generation Y(people born between 1977 and 1994), which is currently the biggest group of people living on earth. But these adolescents fit to a new, relatively unknown generation: Generation Z, also known as the Throwback generation or Digital Natives or pragmatic realists. People from this generation are born between 1995 and 2012 (Villa & Dorsey, 2017) so approximately between 6 and 23 years old. According to W.J. Schoer (2018), this generation already counts 23 million people and their numbers will grow dramatically over the next few years. Digital natives are very comfortable with technologies and grew up in the current environment of mobile communications. Due to this hyper-connectivity they have access to any information at any moment (Seemiller & Grace, 2017). Being digitally savvy is not al that defines this generation. Generation Z believe that they have the power to change the world. For instance, they embrace the strive for equal human rights, no matter what colour, race, ethnic group, (or) sexual orientation. Also due to the widespread public shootings and on going violence and terrorism, they believe that they live in a world where they do not feel safe anymore (Seemiller & Grace, 2017).

4.2 INTERESTS

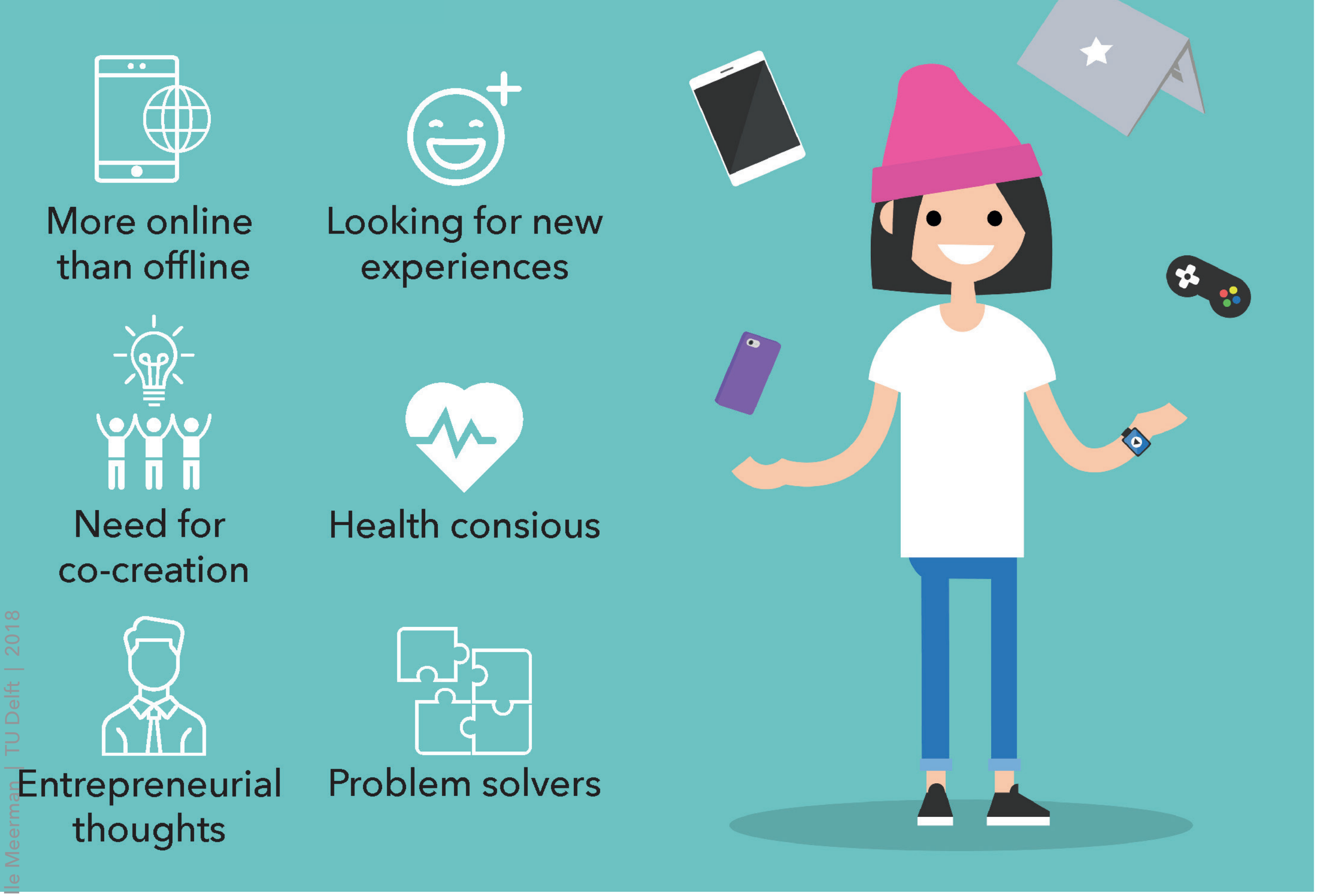


Figure:10 Interests

More online than offline
The words 'digital natives' speaks for itself. Gen Z spend on average more time online than they spend offline. Overall, almost 94% of this generation is online (Khlif, 2018) and this is considered for computer, smartphone, tablet and game device.

Looking for new experiences
Due to a fair bit of curiosity and an open minded attitude, gen Z is more willing to try new activities or technologies than any other generation before them (Khlif, 2018).

Need for co-creation
Gen Z is eager to create and develop. The best way to enhance these features are to co-create. For instance, gen Z will respond extremely positive towards ads that let them decide or vote for something to happen. Gen Z likes to be 'part of the job'. By doing so, they feel respected and understood (Busch, 2016).

Health conscious
Gen Z grew up with the engaging understanding of good nutrition. They know quite well how much fruit and veg a person should eat and are aware of the enormous amount of sugar used in modern day food. Gen Z is aware eating healthy stands for a healthy live (Oxford-Royale, 2018).

Entrepreneurial thoughts
Due to self-awareness, self-reliance, gen Z is very innovative, uber-productive, goal oriented and realistic. These topics fit perfectly to the thoughts of young entrepreneurs (Merriman, 2015). In fact 62% would actually like to start their own companies rather than work for an established business.

Problem solvers
One of the advantages of being online most of the time is the boundless access that they have to the internet everywhere at any time. This allows the generation to easily counter any problems that come ahead. (Merriman, 2015) YouTube, for instance, is used a lot for instruction video's or visual explanation of theories. Due to the high amount of information gen Z also mastered in filtering content. (Jurg, 2017)

4.3 FIND HAPPINESS

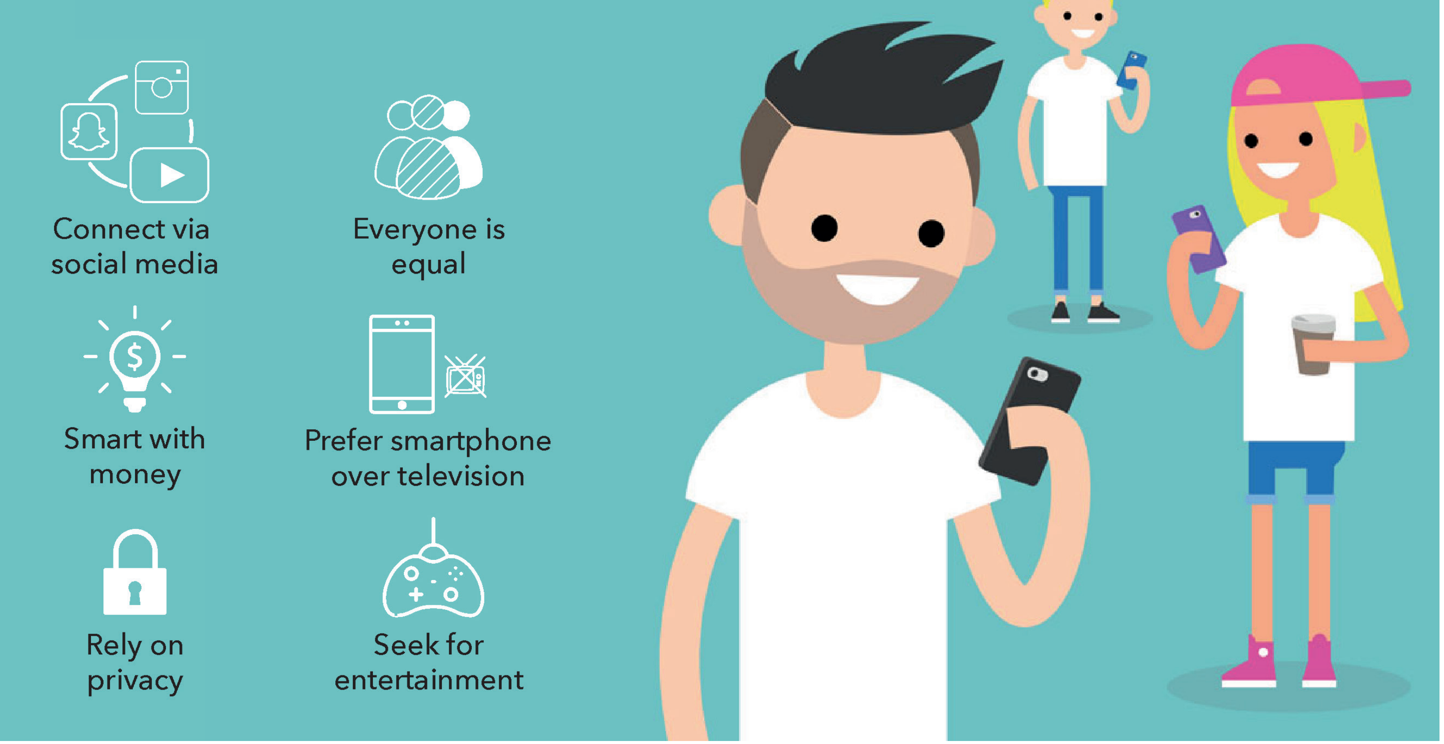


Figure:11 Find happiness

Connect via social media

Previous generations like Gen Y or Gen X, grew up playing at the 'cul-de-sac' (the dead end of a street) with some friends. They kept their social interactions at this particular place. Koulopoulos (2016) referred to his son: "Dad, this computer is my 'cul-de-sac'". This relates to the fact that Gen Z is actually being social while using the smartphone, they are connecting with friends whether this is via social media or via a mobile game.

Everyone is equal

In general, Gen Z does not differentiate based on ethnics or cultures. Gen Z is the generation whose parents met people from all over the world through cheap flights and the internet. As a result, they are more likely to be mixed race and hold more than one nationality than their predecessors (Oxford, 2018).

Smart with money

Gen Z can be considered as a generation with a thoughtful way of spending/earning money. 23% of them believes that a personal debt should be avoided at all costs. (Villa & Dorsey, 2017) This number is significally higher than previous generations. They are taking full responsibility for their financial situation. Also 35% of them is already thinking about saving money for their retirement when turning 20.

Prefer smartphone over television

Gen Z spends 10 % less time watching TV than Millennials and 1 out of 5 does not even watch television at all. If they watch TV, they prefer to watch streaming services like Netflix. The absolute most desired device by gen Z is the smartphone (average of 26 full hours per week). The tablet or laptop would come in second, with 15,4 hours a week (Critical Vision, 2017).

Rely on privacy

In comparison to other generations, gen Z cares more about their privacy online. They grew up with a keen understanding of the line between public and private online settings and the high amount of hacking crimes (the I-cloud for instance). Therefore they also have little interest in Facebook and prefer Instagram, which restricts the post to their closest friends. "They love their audience, but value their anonymity" (Oxford, 2018)

Seek for entertainment

Gen Z is always looking for new ways to trigger them. They crave authentic, fun, raw, scrappy content from popular social media creators and celebrities as a way of entertainment (Khlif, 2018).

4.4 HOW TO ENGAGE

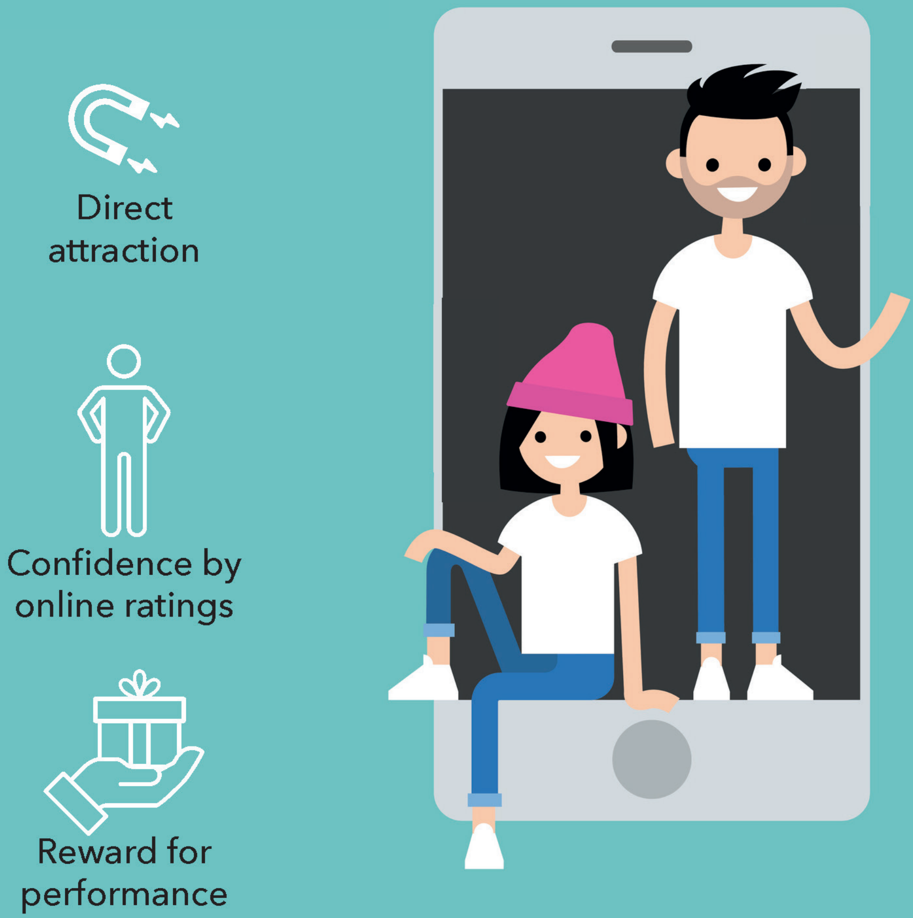


Figure:12 How to engage

Direct attraction

Due to the fact that gen Z is faced with a constant input of information, they have a very short attention span (8 Seconds to be precise). This is also why they prefer Instagram/Snapchat over Facebook. To engage gen Z the approach needs to be direct and to the point in order to keep them satisfied. (Bussink, 2017)

Confidence by online ratings

Gen Z attach great importance to the online community. If they want to buy a new product, ratings and reviews on the internet are being consulted. Also gen Z will gain confidence when they have a lot of followers on Instagram for instance (Merriman, 2015).

Reward for performance

Gen Z will only be more interested if they receive any kind of a reward for their performance. They are easily triggered to challenges if the reward is beneficial enough. Just like in videogames, as you receive new features, levels, or accessories for completed challenges (Khlif, 2018).

DESIGN CONSIDERATIONS

- Create an online environment
- Integrate new experience into design
- Integrate co-creation into design
- Availability to connect via social media
- Smartphone oriented
- Entertainment thrill
- To the point approach, design has to speak for itself
- Create reward for performance or completed challenges

5
MARKET ANALYSIS

Within the market analysis, an overview of several potential competitors will be shown. These competitors can be divided into three main topics; physical environment products, digital environment products and combined environment products. Beside these topics a deep dive into some new technologies focussing on reality has been conducted. The so-called AR/VR/MR products. Eventually these products only served as an inspiration and did not lead to any concept directions, therefore these products can be seen in appendix C.

The market analysis has been conducted without any limitations regarding a specific target group. All of the topic products can be used by both children and adults. Nevertheless, within each topic a summary of products especially designed for children will be shown. Since there were almost no specific products for adolescents (12-17), these products are selected for children of all ages (1-18).

5.1 INTRODUCTION

Physical environment products can be described as products where hardware components are key and can be assisted with software components to provide stimulation of physical activity. Within the industry, hardware components can be seen as physical equipment directly involved in performing any function, or the physical parts of a computer and related devices"(Farlex, 2018; Techterms, 2018a). Within physical environment products, software components, described as computer programs such as applications, scripts, and instructions, only provide an assisted role to support hardware components (Techterms, 2018b).

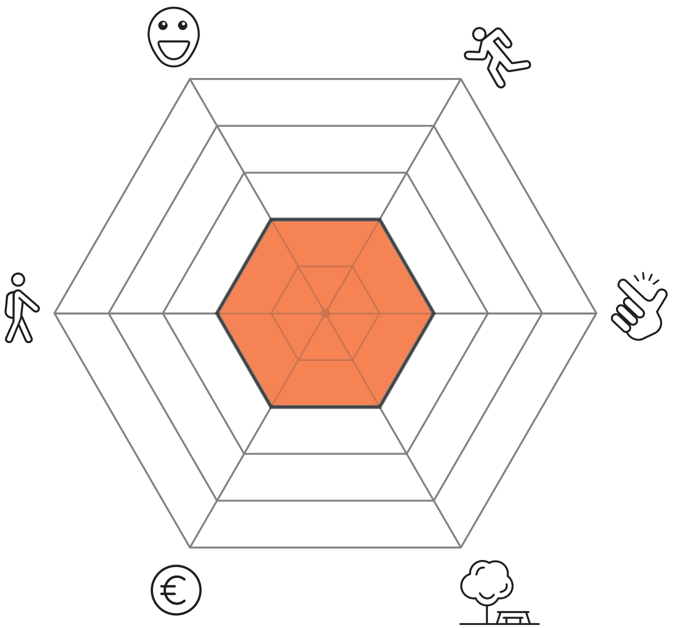
Within *digital environment products* on the other hand, the software programs have a leading role that is assisted with a hardware component to provide physical activity stimulation. These products can also be seen as information processing products. Hardware components described within digital environment products can be considered as smartphones, tablets, computers or other electronic devices.

The last topic describes *combined environment products*. These products can be considered as products where hardware components will serve as accessories for software components and will provide both a more or less equal role in stimulating physical activity.

5.2 RATING SYSTEM

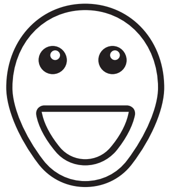
The aim for this analysis was to look specifically for products/competitors which have a distinctive goal of stimulating the (daily) physical activity. Within each topic, a summary of products especially designed for children will be shown.

In order to distinguish some existing differences between the competitors of the market analysis, a rating guide has been made. Within this rating guide 6 key features will be analysed using a hexagon diagram (shown below). The bigger the orange cloud within the diagram, the higher the overall score. For this analysis every feature will have the same value.



The level of stimulating physical activity

Within this feature, the actual input from the product to stimulate physical activity is mentioned. Examples like a coach, or specific challenges will receive a higher score than products that only show progress or not even that.



Addiction potential

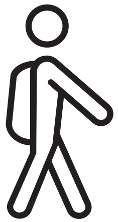
Within this feature, the willingness to use the product over and over again will be taken into account. Examples like receiving rewards for the progress or challenges will reveive a higher score. Also the WOW factor is included in this feature.

The ease of use

This feature describes the difficulty to use the product. If a product is really easy to use, it will receive 5 points. In comparison with a hard to understand product, which will receive 1 or no points.

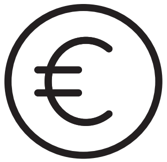
Outdoor use possibilities

This feature describes if it is possible to use the designated product in the outdoors. Products that are specially made for outdoor use will receive 5 points and products that are defenitely not suitable for outdoor use will receive 1 or no points.



Portability

This feature describes the possibility to take the product everywhere the user want to. Large heavy products will score 1 or no points, while a wearable will score 5 points.



Affordability

This feature describes the amount of money to pay when buying the product. A free product will receive 5 points, up to €75,- will recieve 4 points, €76,- to €500,- receives 3 points, €501,- to €5000,- will receive 2 points ans above €5000,- will receive 1 point.

Figure:13 Nexersys

Figure:14 Rugged interactive

5.3 PHYSICAL ENVIRONMENT PRODUCTS

Some examples of hardware components which are used to create a physical environment can often be found in the gym. The company *Nexersys* created an interactive fitness instructor that stimulates the user in their training. The instructor tells you the score you have and the order in targets to be challenged. Pressure sensors within the foam strike pads will assure the 'instructor' to know where the user places a hit and what the actual force behind punch is. The nexersys has a selling price of €2378,- (Nexersys, 2018).

The company *Rugged interactive* creates a whole range of products that stimulate the user while exercising. The Cardiowall, can be compared with the Nexersys in physical effort. The Trailblazer is focused on interactive wall climbing and stimulates to maintain your position or challenge you to increase the difficulty. LEDs within the grip holes, assisted with sound effecs and voice commands, will tell the user where he/she should place his/her hands of feet, according to the selected level of difficulty. The Trailblazer has a selling price of €5450,- (Rugged-interactive, 2018).

5.3.1 Designed for children

Some physical environment products are specially designed for children. The Canadian company *Kidzpace*, for instance, offers an extensive line of products designed to turn any environment into a more relaxed space where children of any age can play fun games and enjoy themselves. These unique gaming products like the Sport Bike and Skate/Snowboard, require kids to engage in physical activity to play. Potentiometers within the product provide the information to tell the user its speed and steering direction. Kidzpace has a selling price of €1732,95 (Kidzpace, 2018).

Yalp interactive create outdoor products, which stimulates not only physical activity, but also interaction between other children. By interacting with each other simple games can be played. Sona the sound-arc, enables children to perform dance battles together by making use of sensors and buttons connected with a 3G network. The Sutu soccer-wall enables children to play soccer in an interactive way. Speed radars measures the velocity of the shot and together with pressure sensors and a 3G internet assures the user to connection with others all over the world. Sona has a selling price of €30.000,- and Sutu costs €70.000,- (Yalp, 2018).

The company *I3-technologies* created the Imo-learn. This interactive piece of hardware enables the child to learn by movement. The motion detection sensors inside the IMO-learn take notice of any change in position, which result to a specific answer. Children will be engaged with challenging quizzes and fun activities while performing 'embodied' learning. The IMO-learn costs €3000,- (I3-technologies, 2018).

Figure:16 Sona Yalp

Figure:15 Sutu soccer-wall

Figure:17 Imo-learning

Figure:18 Kidzpace interactive bike

5.4 DIGITAL ENVIRONMENT PRODUCTS

Beside physical environment products, digital environment products really found their way in stimulating physical activity the last couple of years. The aim for these programs is to keep track of any kind of movement and provides needed input to challenge the user. This is done by some features included within the smartphone, such as GPS, camera, mobile data connectivity and the gyroscope. Some examples of these products will be taken into account.

One of the most commonly known physical activity apps of the last few years is *Pokémon Go*, created by Niantic (Niantic, 2018). This free application was one of the first to use AR in their app and provide the needed stimulation to play the game not only indoor, but especially outdoor. Users of all ages are challenged to go outside to walk and collect various of these little virtual monsters. The longer a user walked with their smartphone/smartwatch, the quicker the little monsters are hatched. In the near future, spinoffs like Harry Potter Go and Jurassic Park Go will be introduced as well.

For sport-enthusiasts, *Strava* is a well-known free app regarding keeping track of your activities. Due to their large community platform, it also enables the user to show their online friends the live runned/cycled distance or afterwards (Strava, 2018).

Figure:19 Pokemon go app

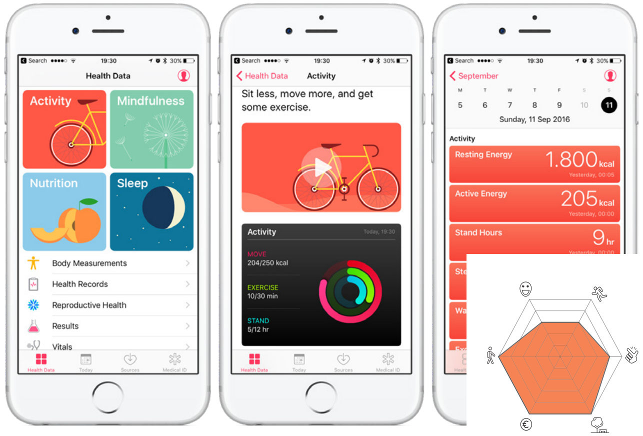


Figure:20 Iphone health app

Strava is just one of the many apps that enables the user to keep track of their activity. Other apps also embrace activity tracking (like the Fithub app, Sworkit app, Runkeeper app, Carrot Fit app, Endomondo app), while others also provide health indicators at the same time (Integrated *Iphone health app*, Clue app). All of these apps are free to download in the app store or google play store. Remarkable for almost all of these apps, is the lack of the actual stimulation of activity. Users are only stimulated by the goals they dedicate to themselves, or stimulated by achievements of other users/friends.

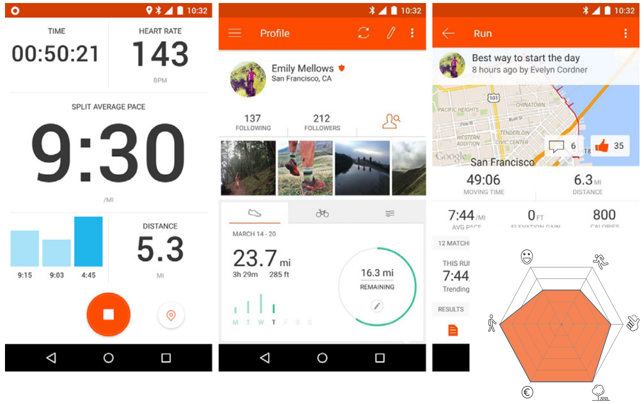


Figure:21 Strava app

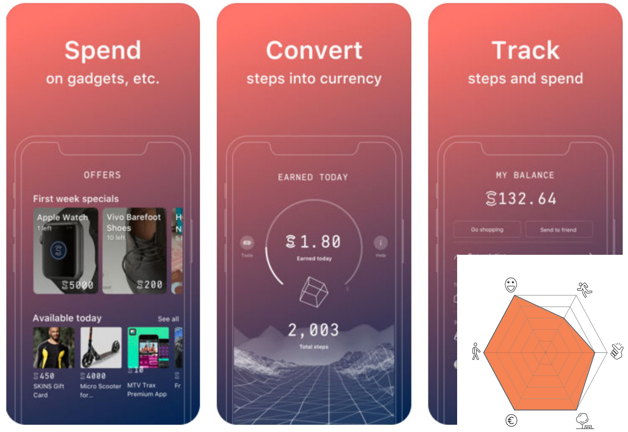


Figure:22 Sweatcoin app

A recent trend among activity apps is the possibility to earn rewards, which can be used in daily life. Like the Charity miles app enables a user to earn money for the chosen charity project by running specific distances. The *Sweatcoin app* (free) gives you cryptocurrency rewards for walking. Every 2000 steps can be turned into a currency of your choice (Sweatcoin, 2018). Or the Achievemint app, where you can earn up to 80 points per day for exercise activities. They pay $10 for every 10.000 points you earn.

Figure:23 Superstretch yoga

Figure:24 Sworkit-kids.jpg

Figure:25 LU interactive

5.4.1 Designed for children

All of the apps in chapter 5.4 are designed for a relatively large target group, while mainly focussing on adult users. Of course there are also some apps especially designed for children.

The *Super Stretch Yoga app* is a free yoga kids program, which is teaching kid friendly yoga moves to children. The children will be stimulated by cartoons of animals who tell a quick story and demonstrate the exercises to be done. (Rozenburg, 2018).

Sworkit Kids is a app that let children, between the ages of 7 to 14, turn fitness into a game. The app includes workouts for strength, agility, and flexibility. The app has a 3-month fee of $29,99. A full year membership costs €69,31(Sworkit, 2018).

Lü is a smart digital space, specifically designed for children, that understands the real time behaviours of the users. 3D cameras will use the perceived information to let the user experience virtual games on a projected wall. This digital environment costs €24.695,- (Lu, 2018).

5.5 PRODUCT-SERVICE COMBINATION

Another large group of products can be included in the so-called category ‘product-service combination’. This product category can be divided into Wearables, Game devices and product-services that are specially designed for children.

5.5.1 Wearables

Since 2005 we see an increasing amount of electronic accessory activity trackers available for the consumer market (Van Abbema, 2018). These so-called wearables contain wristbands, glasses and jewelry for instance. Some of these well known wearables will be taken into account.

The *Fitbit* wearable can maybe be seen as one of the most well know wearable. In 2007 the company created their first model and up till now they created an entire Fitbit-community with a large variety of products. The Fitbit keeps track of your activity during any part of the day by using GPS sensors and a heart rate sensor. Because of the community, challenges, exercises and progress can be shared. The Fitbit costs €120,- (Fitbit, 2018).

Moov is another wearable which, besides tracking, is more focussed on stimulation during workouts. Moov can be seen as a personal fitness coach and pushes the user to the limit by taking health (by a heart rate sensor) into account. Stimulating is done by motivational sentences through an earpiece, while performing an activity. Like the Fitbit, the moov also has a large community to share any gained progress. Moov costs €51,68 (Moov, 2018).

Cosinuss is an innovative earpiece wearable. Due to the in-ear sensors, vital signs are monitored and will be analysed and supported by artificial intelligence when needed. Cosinuss costs €120,- (Cosinuss, 2018).

Figure:26 Moov

Figure:27 Cosinuss

Figure:28 Fitbit.

Figure:29 Wii

Figure:30 Wii balance board

Figure:31 Nintendo Switch

Figure:32 Nintendo labo.

Figure:33 Xbox kinect.

5.5.2 Game devices

The products that can be found in this topic can be categorized into Active Video Games (AVGs). AVGs require body movements (eg, swinging arms, stepping) beyond that of conventional hand-controlled games. Hand controlled games will be left out of this research, since the level of physical activity stimulation is nil.

A large variety of products can be found within this topic. Probably the most known game device, regarding physical activity, is the *Nintendo Wii*. This revolutionary gaming console, released in 2006, was also the first of the big three gaming companies (Sony Playstation, Microsoft Xbox) to introduce a gaming console which allows the user to move actively, instead of only using your fingers to activate the game (Wikipedia, 2018b). It uses bluetooth connection and accelerometers to connect with the computer. The introduction price of the Wii was €250,-, nowadays a second hand version costs €30,- - €50,-. The introduction price is used for the analysis, since it can be compared to other gaming platforms. Additional accessories like the *Wii Balance* (€89,99) enhanced the level of activity even more.
The recently released *Nintendo Switch* (€300,-) also had a great impact on commonly known AVGs Especially due to the innovative accessory *Nintendo Labo* (€69,99), which allows the user to build a physical gaming element from cardboard, which stimulates the user even more.

One of the other big gaming companies also released a game device which was revolutionary at the time of release (2010) (Wikipedia, 2018a). The *Xbox Kinect* allows the user to play a digital game by using his/her own body as a controller, without any necessary accessories. The Xbox Kinect is still used in many AVG applications nowadays to stimulate physical activity. The introduction price of the Kinect was €150,- and a second hand version nowadays costs €30,-.

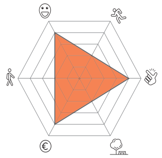


Figure:34 Playstation move

Figure:35 Playstation VR

The Sony Playstation could not fall behind and created the *Playstation Move* (€80,-) as a counterpart of the Nintendo Wii. Nevertheless, this console was not that popular as the Wii.
Recently the *Playstation VR* was released, which allows the user to experience gaming in virtual reality. This virtual gaming console costs €240,-.

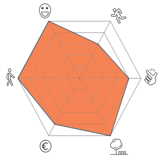


Figure:36 Geopalz

Figure:37 Unicef kids power bands

Figure:38 Super suit

5.5.3 Designed for children

Besides the more regular and common product-service combinations, some products are especially designed for children (of the family as a whole). These products will be taken into account in this topic.

Zamzee is a product where kids and their family experience physical activity together through play. Activity trackers keep track of their movement and the website will get the users motivated to play. This stimulation is done by rewarding the users with gifts. For instance, children can receive new avatar features to create their own customized online character. Zamzee costs €29,95 (Zamzee, 2018).

A similar product is the Geopalz Ibitz (€34,95). This product also keeps track of the children and activity can be visualised on the website. The remarkable difference between Geopalz and Zamzee is that Geopalz allows the user to receive gifts within other games like Minecraft and Disney Pinguin Club. The eagerness to obtain these exclusive in-game rewards makes a good stimulation for the child. Also, the tracker itself is customizable and enables the user to choose his/her own activity figure. (Geopalz, 2018).

The American retail chain company Target and Unicef, collaborated on a project called Kids Power Bands (€39,99). This product is specially designed for children to combat childhood obesity. Beside the general fitness purposes and rewards, this product allows the user to earn points which could be used to send food packets through UNICEF to children in developing nations (Slashgear, 2018; Unicef, 2018).

Super Suit is one of the first wearable gaming products specially designed for children. When mounted with the suit, the children can experience both physical and digital gaming. This suit can be compared with a Laser-gaming suit, only this suit allows the user to play a large variety of games and accessories for specific gameplays can be purchased. Supersuit costs €135,- (Supersuit, 2018).

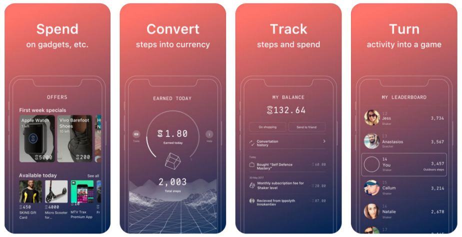
5.6 CONCLUSION

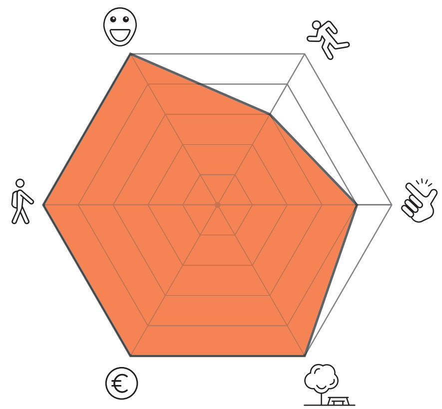
Some of the analysed products, really stood out from others. The six best products can be found on the right.

Sweatcoin scored the highest rank of all the analysed products. At four of the features, it scored the highest rank. The high level of eagerness to use the product, made it stand out from the other digital environment apps. Pokemon Go also ended up as a one of the highest ranked. Another great advantage of digital environment apps is that they are, mostly, free to download.
A lot of digital environment products have features that reward the user. This is a good feature to take into account for the invisioned product. Nevertheless, both of these products scored 3 out of 5 in the level of stimulating physical activity, which shows that there is yet much to improve.

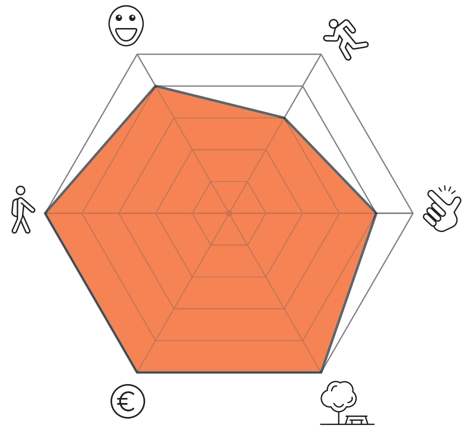
At least 4 of the 6 best products can be found within the product-service category, namely Moov, Kids Power Bands and Geopalz Ibitz and the Super suit. This is due to the high level of eargerness to use the product and the general high level of stimulating physical activity, which is higher than digital products (see appendix B).
Something which both have the digital environment products and product-service in common is the fact that they can be carried around and played everywhere. This suits the need to be able to play outside (3.3 Conclusion at page 16).

Sweatcoin

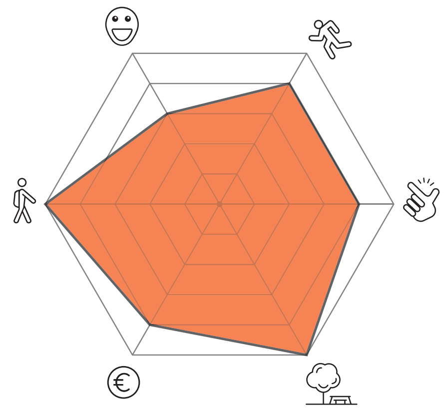


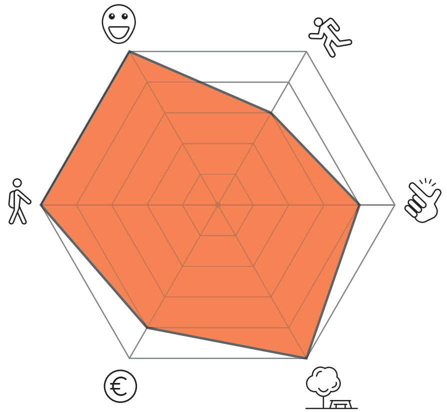


Pokemon GO

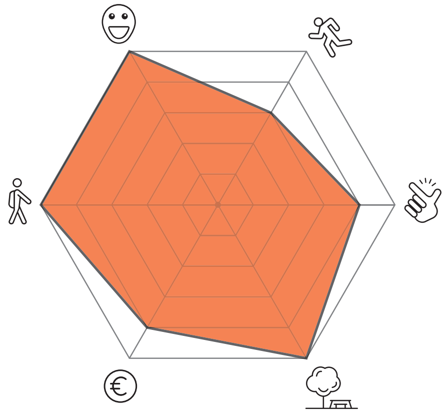


Moov

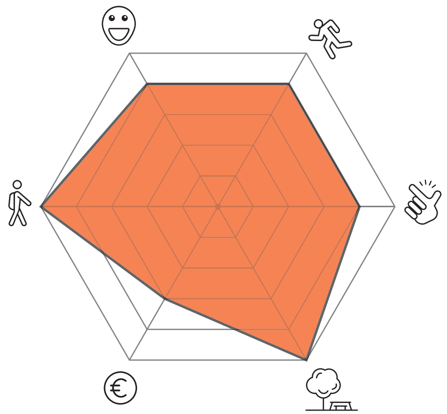




Geopalz Ibitz



Kids Power Bands



Super Suit

Physical environment products in general scored the lowest rank. Althought the level of stimulating physical activity was pretty decent, the other features scored very low. Almost all of these products were hardly able to be moved from one place to the other. This comes with the fact that all of these products are extremely expensive. Since the to-be-designed product should be bought by the user, or its parents, the purchase price should be as low as possible. This is also the fact that the other categories scored much higher in general than the physical environment products.

DESIGN CONSIDERATIONS

- Include reward feature
- Portable
- Gaming element stimulates more than tracking feature
- Easy to understand
- Possibility for outdoor use
- Design for children who need to move instead of the sport fanatics
- Almost no product is especially designed for children between 12-17
- Categorized into product-service combination, it will create a high overall stimulation

6
PROBLEM DEFINITION

Adolescents nowadays are not capable to achieve the recommended amount of physical movement per day. This results in a degrading physical well-being and in the long term even on the degrading of social/emotional well-being. The aim of this project is to find a way to stimulate adolescents, in order to prevent such health issues and maintain their emotional well-being.

Based on the findings that children in the age of 6-17 suffer the most from the inactivity epidemic (Morrisson, 2015) and that almost 85% of the children within 11-14 years old own a cell phone these days (Davis, 2017), I aim to address a specific target group for this assignment, namely, children at the age of 12-17 – the so-called adolescents. Assuming that it is not realistic to expect that we can drastically decrease the amount of time spent on screens by children, I aim to deploy this screen time in a positive way in order to achieve a more effective and efficient approach in stimulating daily physical exercise. Therefore the best of both worlds will enhance each other.

6.1 DESIGN GOAL

"I want to create a product that stimulates the physical activity of adolescents (12-17), in order to prevent health issues and maintain emotional well-being, while focusing on the advantages of screen time".

7
PROGRAM OF REQUIREMENTS

The program of requirements can be seen as the result of the entire design brief. Each chapter of this design brief ended with some design guidelines. All of the previous design guidelines are merged into a few categories: appearance, use, dimensions, and production.

All of these requirements will be taken into account when beginning the next phase of this graduation project: the ideation phase.

Some of the design guidelines turned out to be of less importance or out of reach for this graduation project. Therefore they are mentioned wishes and are only desirable, rather than of importance, to take into account when starting with ideation.

1 APPEARANCE

1.1 The product should be attractive to play with/ on by adolescents between the age of 12-17 years old

2 USE

2.1 The product should stimulate the target group in being physically active

2.2 The product should maintain a fun factor to enhance satisfaction and entertainment while playing

2.3 The product should stimulate the user to achieve the recommended moderate-intensity physical activity of 60 minutes per day for at least 2 times per week

2.4 The product should focus the user to work on his/her gross motor skills, like strength exercises, climbing, walking and skating

2.5 The product should reward the user for the performances or completed challenges to stimulate the eagerness to use the product

2.6 The product should enable the user to gain new experiences while using the product

2.7 The product should enable the user to use the product when he/she is alone

2.8 The product should enhance the ability to discover around and stimulate the adolescent in outdoor play

2.9 The product should provide interaction with the users' smartphone before and after use

2.10 The product should enable the user to play without the need for direct connection to a smartphone

2.11 The product should provide online media communication to enhance social relationship among friends and other users

2.12 When playing for the first time, the product should enable the user to start playing with the product with less than 5 minutes of preparation time

2.13 When playing on a regular basis, the product should enable the user to start playing with less then a minute of preparation time

3 DIMENSIONS

3.1 The product should have a weight of maximum 500 grams, to be able to be carried around

3.2 The product's shape should not provide any obstruction while being physically active

3.3 The product should not be bigger than 10 x 10 x 5 centimeter, to be able to be carried around and connected to the body

4 PRODUCTION

4.1 The product should cost as little as possible, but should not exceed the price of €300 (like other game devices, such as Nintendo switch) in order to be affordable for a large variety of people

5 WISHES

5.1 It is desired that the product should attract adolescents who need to move in order to be healthy

5.2 The product should be considered as a cyber-physical system relying on wearable sensors

5.3 It is desired that the product enhances activities that stimulate the user's balance, since this is key for an adolescent's development

5.4 It is desired that the product support limitation of the moderate-on-screen-use to a maximum of 3 hours per day

5.5 It is desired that the user can be physically active together with other people while using the product

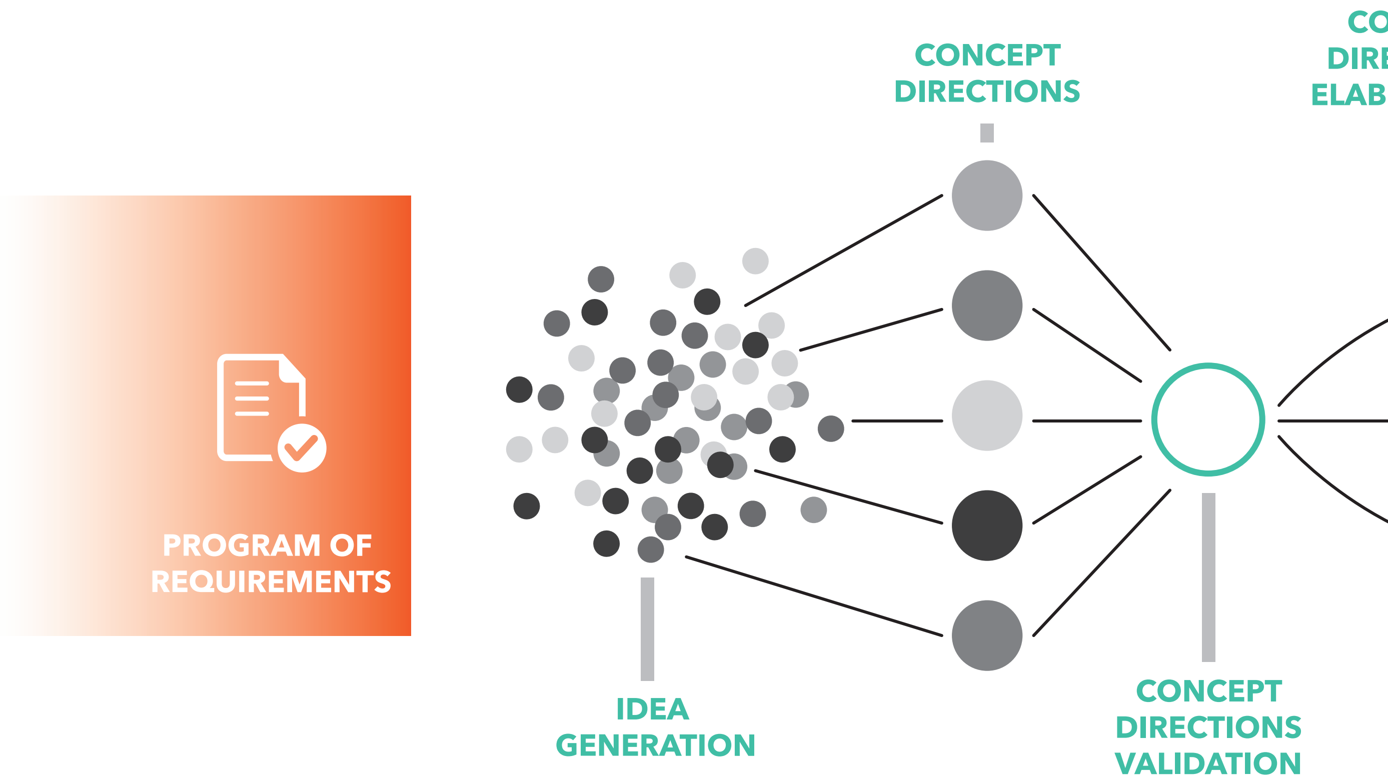
5.6 It is desired that the product stimulates the family to live a healthy live and be more health oriented

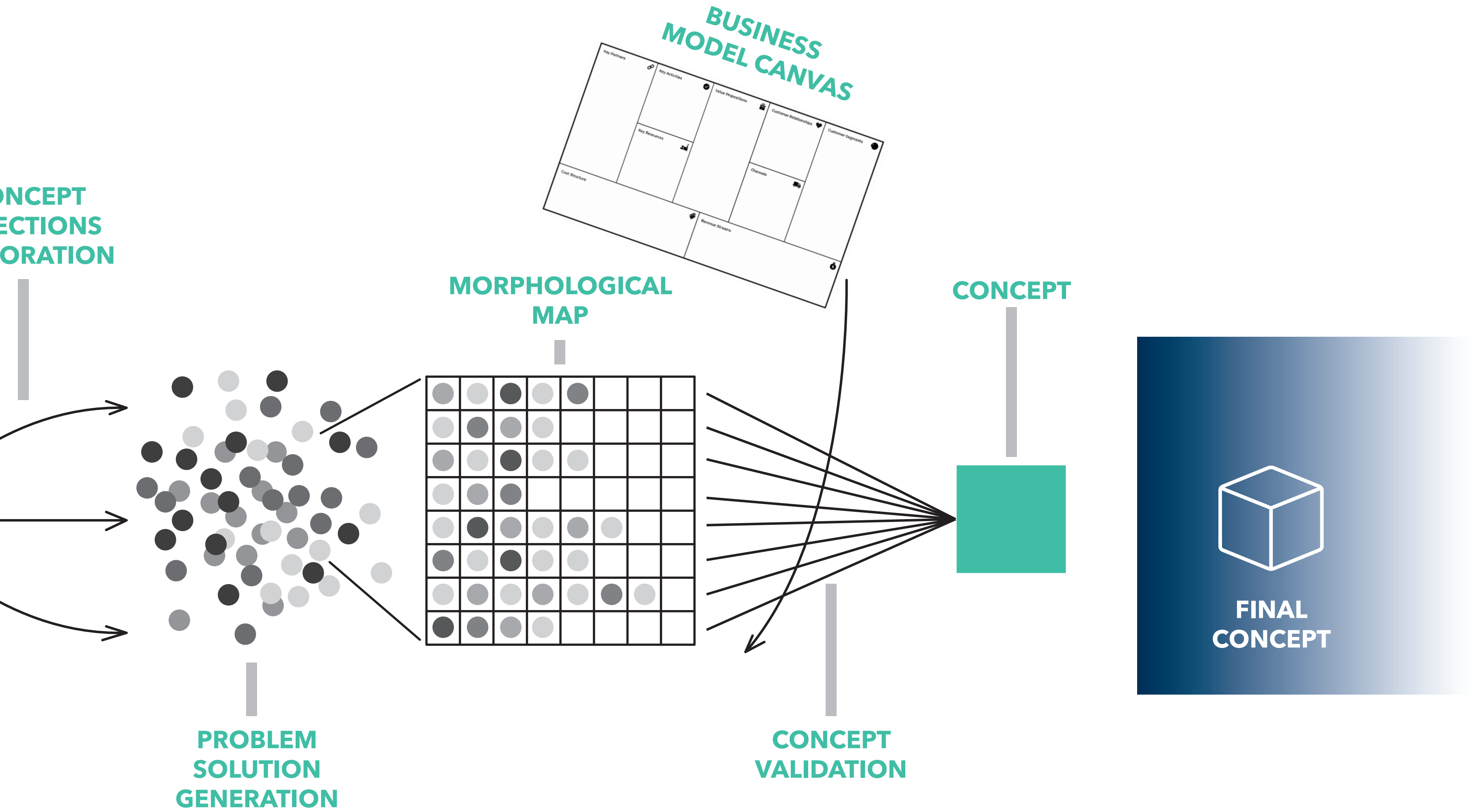
5.7 It is desired that the product minimizes bad eating habits

8
IDEATION

8.1 INTRODUCTION

Within the ideation phase of this thesis, several methods will be used to enhance idea generation and therefore the first diverging stage of the product development cycle.
Methods that have been used are: How to's, several brainstorm, and writing sessions and creative sessions with the determined focus group. The following chapters will give an overview of these methods and their outcomes.

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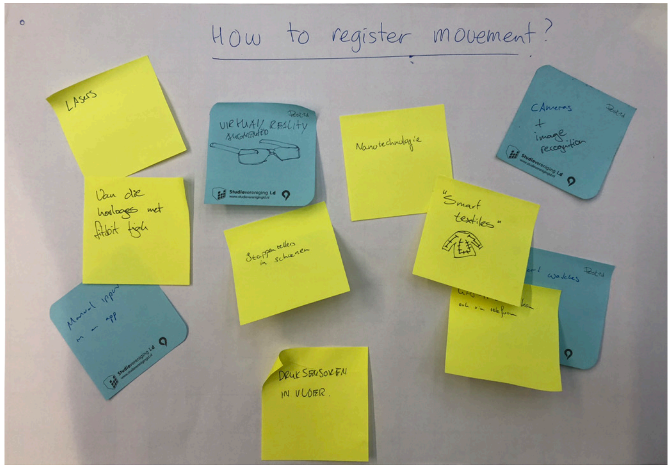


Figure:39 How to register movement

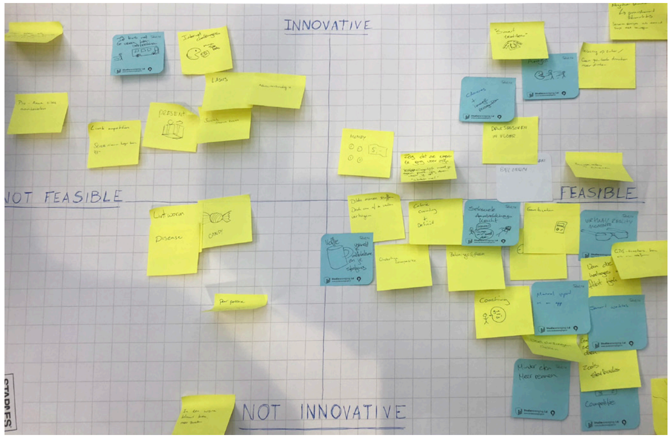


Figure:40 C-box

8.2 IDEA GENERATION (DIVERGING)

The first step in generating concepts is called the idea generation. Within this step it is desired to harvest as much ideas as possible and therefore broaden the range of vision. This overall process is called diverging.

8.2.1 How to's

The first of the methods that is used to stimulate the flow of ideas is *How to's* and guided as a first orientation session in the enrichment of ideas.
This method focusses on the purge for new ideas within a short period of time by answering several how to... questions.

In this case 4 participants (age 23-28) tried to come up with anwers to the several questions with 2 minutes per each round. After each round the participants passed around the paper with the initial question to the participant next to him/her. In this case the participants can hitch-hike on each others ideas.
The participants were asked the following questions:
- How to lose weight?
- How to challenge teenagers?
- How to stimulate movement?
- How to register movement? (Figure:39)

After all the participants answered every question, several simple, challenging, or brilliant ideas came out. The last stage of this method is to cluster all of these ideas to create a stuctured overview. This is done by using a *C-Box*. The C-box is divided in two axis. On the horizontal axis there is feasable vs. not feasable and on the vertical axis there is innovative vs. not innovative. The participants clustered the ideas by placing the ideas into one of the emerged boxes (Figure:40).

The overview of the how to's in combination with the C-box only served as a starting point for the rest of the ideation phase. Via these first methods I gained some insights in the actual problems to solve, which created the base for the next method.

INSIGHTS

- Ways of stimulation like: gamification, competition and rewarding
- Ways of movement registration like: smart textiles, virtual reality and image recognition

QUESTIONS

- What type of game should be implemented?
- What type of movement should be connected to game?

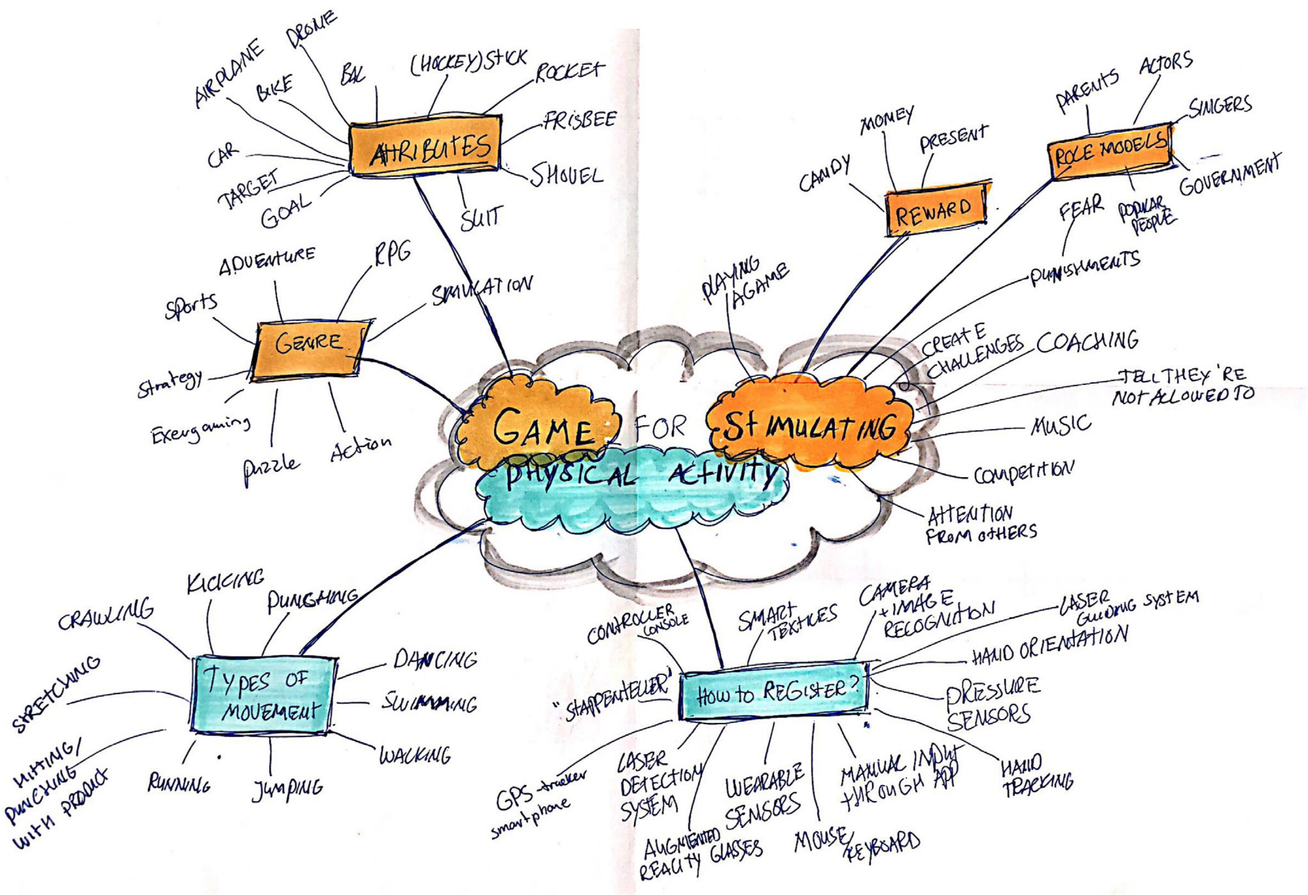


Figure:41 Mindmap

8.2.2 Brain Writing session

The goal for the next method, Brain writing, is to create a large amount of ideas and preconditions with regard to the initial subject. The idea is to hitch-hike on the different categories and therefore gain deeper and broader knowledge of the overal subject.

The insights of the previous method are used as a starting point for this Brain writing session, which resulted in the following starting sentence: *'Game* for *stimulating physical activity'.* The general sentence is divided into three parts and developed further. The outcome of this session is structurized and organised in a mindmap, which can be seen in Figure:41.

All of the categories and its outcomes gave me a lot of perspectives in how to come up with new concepts and specially what I should take into account.

INSIGHT

- Types of movement to be analysed: like running, swimming, walking etc.
- Preconditions of designing a game: like specific genres to choose from and additional game attributes to use

QUESTIONS

- How to specifically stimulate the target group?

8.2.3 Creative sessions

All of the previous methods lead to two *creative sessions*. A creative session is basically a coordinated brainstorm session, wherein people from the target group hitch-hike on each others' ideas to eventually come up with possible solutions that could solve the problem definition.
The goal for these creative sessions is to find out how the actual target group can be stimulated.

These sessions were executed by participants from within the target group (respectively 13, 13, 14 and 17 for the first session and 12, 16 and 17 for the second session). A session plan (Figure:44) was created and specific tools were selected to start the session.
At first the participants were informed about what they could expect. A brief explanation of the problem and therefore the problem statement was given. The problem statement in this case is: How can we make adolescents move more often?
Within the first diamond, the problem as percieved (PAP) is converted to the problem as given (PAG). This is done by asking Who, What, Where and Why. Next, the ideation phase will begin (second diamond) and the participants had to write down their first thoughts on how to solve the problem (Figure:42).
Once the flow of ideas got stuck, some particular words were adressed to function as a triggerpoint for new ideas (such as different ball playing games or board/console games they would like to perform in real life), also called brainstorm pool (Figure:43).
In order to tackle the problem from a different point of view, the participants are asked to pick 5 types of movement (running, jumping etc.), known as Pick-out words. Then they are asked to think about ways to stimulate this very specific type of movement, which resulted in some very interesting new ideas (see page 35). After the ideation phase, it was time to cluster the gained ideas, using the same method as used in the first *how to* session. After clustering, each participant was handed out several coloured stickers, 1x yellow and 3x blue. The yellow sticker stand for the best idea an the blue stickers stand for a good idea. Due to this *hits and dots* method the participants were able to rank their gained ideas, which also gained insights on the way of thinking among adolescents (Figure:45). All of the outcomes of both sessions can be found in appendix D.

Session introduction	Tools	11 min
Explain program		5 min
Brief problem: Why children are moving less		5 min
Problem statement		1 min
First diamond - Problem defenition		**20 min**
4XW (PAG)	Flipover	20 min
Second diamond - Ideation		**60 min**
Purge: Spit out the first ideas	Post-Its	5 min
Brainstorm pool	Post-Its	15 min
Pick-out words	Post-Its	15 min
Break		5 min
C-Box	C-Box ready	10 min
Hits and Dots	Stickers	10 min

Figure:44 Creative session plan

Despite the fact that the ranked ideas will lead to some possible concepts, the interaction between the adolescents, when thinking about how to deal with the problems, really had the most value in these sessions. This, for instance, gave me ways of stimulating the users.

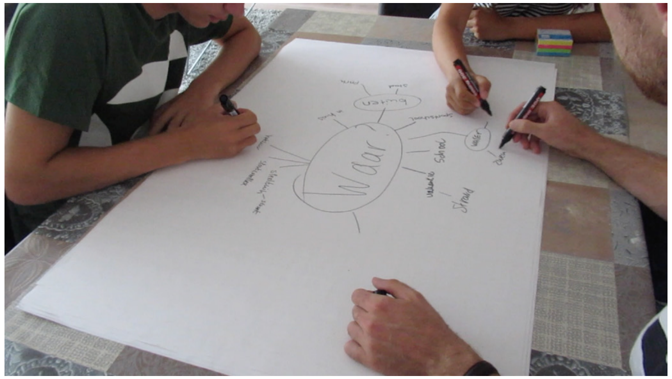


Figure:42 Creative session 1, where

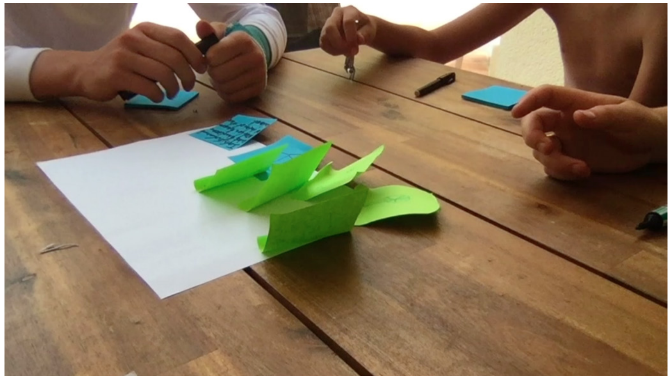
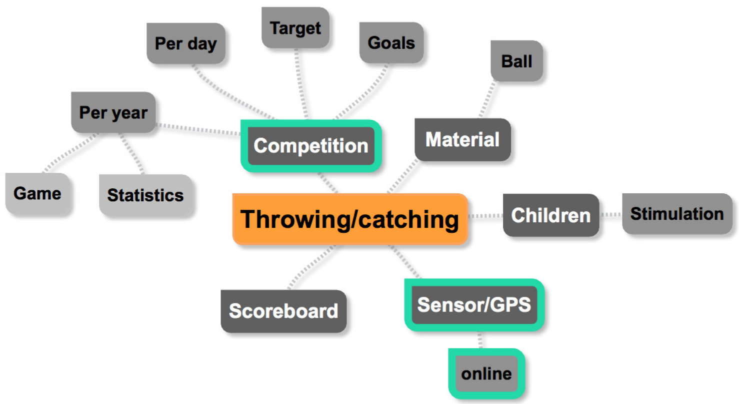
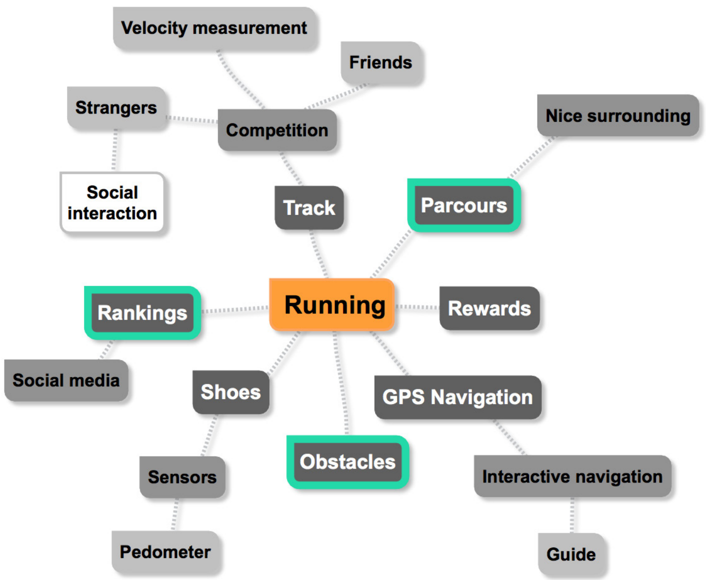
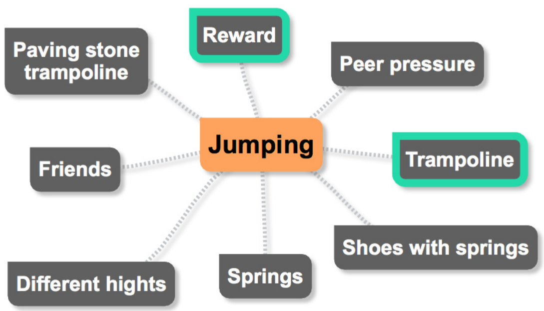


Figure:43 Creative session 2, brainstorm pool

Figure:45 Creative session 1, c-box and ranking



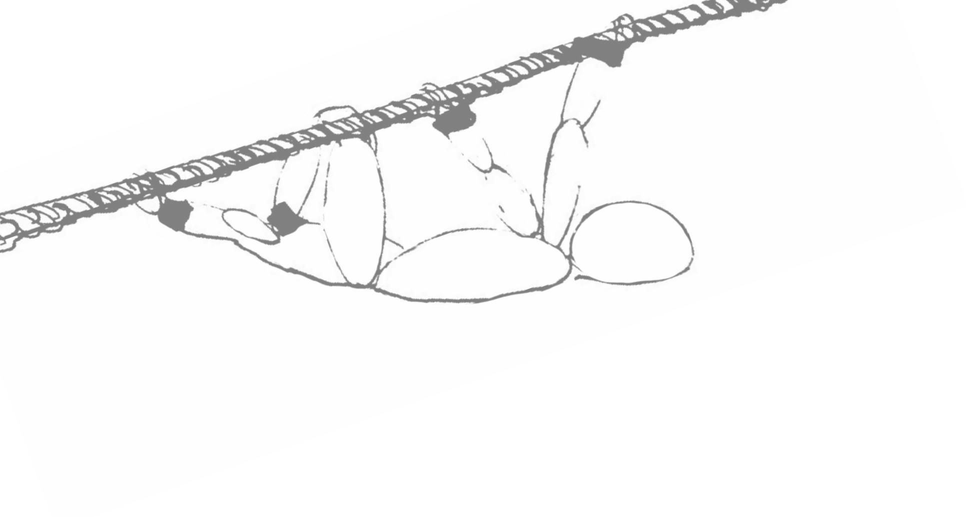


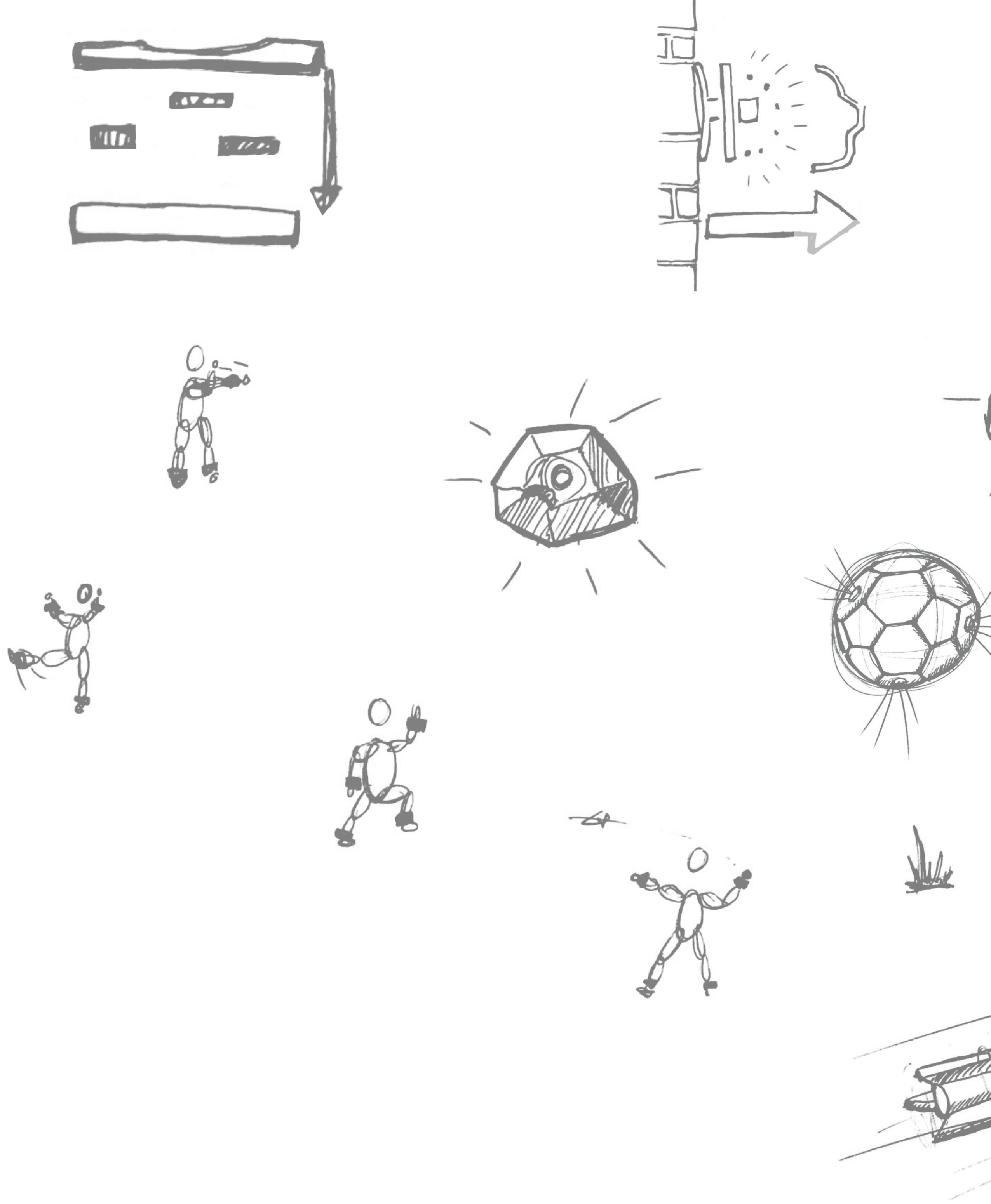


The most important outcomes of the creative session can be seen on this page. These specific outcomes were developed within the 'Pick-out words' section of the creative session. During this section I asked the participants to also integrate digital communication and possible future technologies.
Within each category, some words or combination of words are highlighted, since they enabled the start of new product ideas. Therefore these mindmaps can be seen as the most important outcomes, also due to the direct users' influence, which therefore can be considered as highly stimulating.
Eventually the outcomes of each category describe the first steps of a concept direction focusing on a specific type of movement.

INSIGHTS

- Various type of ideas to stimulate the target group like rewarding, competition, rankings and gamification
- Possible concept directions for: climbing, throwing/catching, dancing, running, jumping





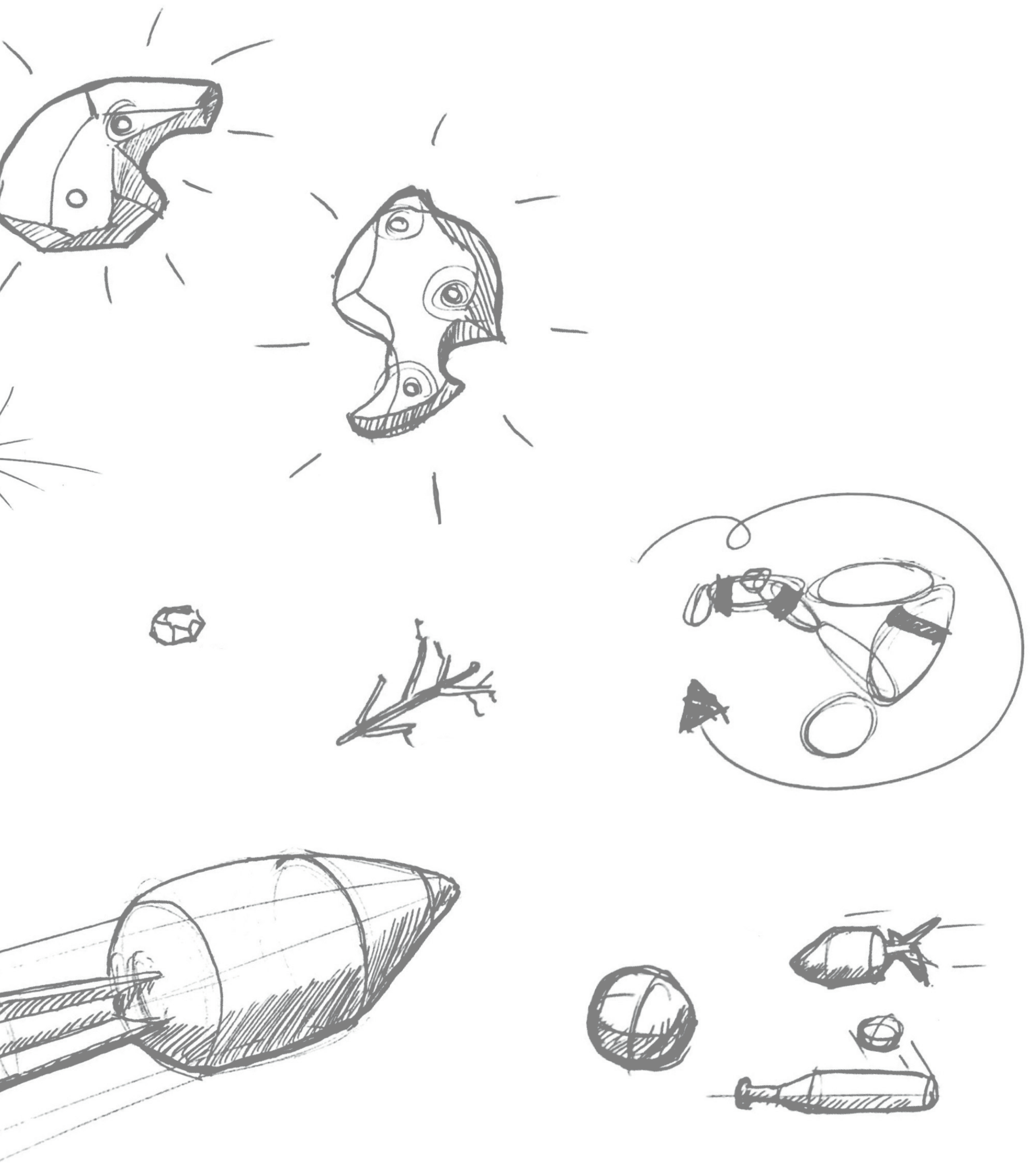
8.2.4 Conclusion of idea generation

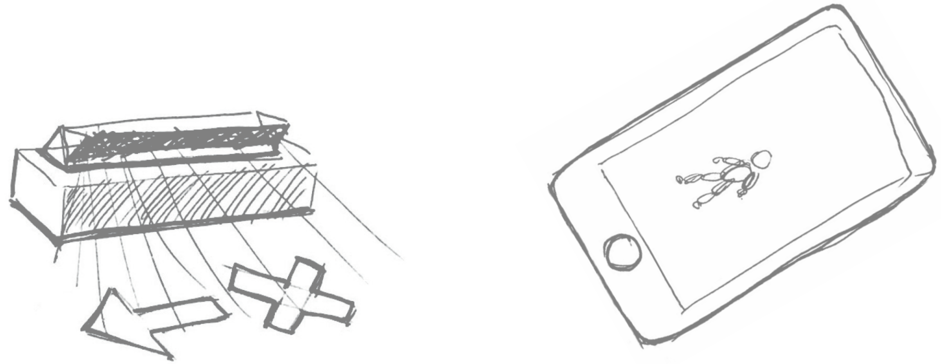
The idea generation started without any prejudices for specific concepts.This led to a very unclear and openminded way harvesting ideas.
The first 2 methods, how to's and brainwriting, were focused on exploring new areas within the problem definition without the need to actually end up with new concepts.
The creative sessions on the other hand were more focused on new ideas and therefore also led to some very interesting insights that can be helpfull for the concept directions.

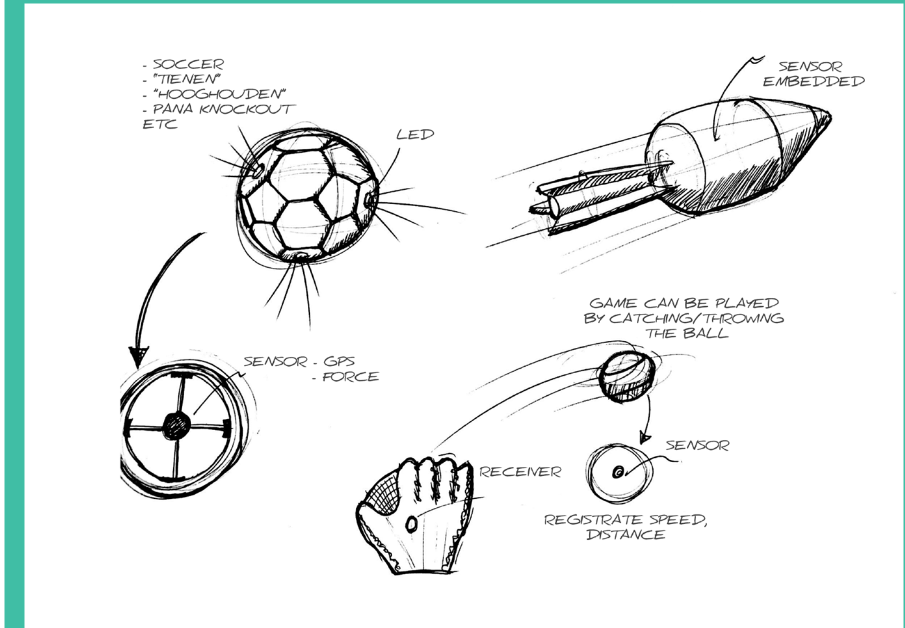
8.3 CONCEPT DIRECTIONS (CONVERGING)

All of the previous diverging steps lead to some good ideas in how to tackle the initial problem definition. But these ideas need to be developed further in order to become an actual concept. This chapter will describe the several concept directions that could solve the problem. Those directions are obtained by various sketching sessions and insipired/based on the previous chapters.
This concept direction in not yet a concept though, this is still a possible direction to head for without any elaborated decisions concerning the actual development of the concept. A clear overview of the concept directions can be found at page 38-39.

This next phase in the development of ideas is called converging. Unlike diverging, converging is mainly focussed at minimalising the amount of ideas, and cluster any if possible, to eventually come up with a couple of good solid ideas to develop into concepts.



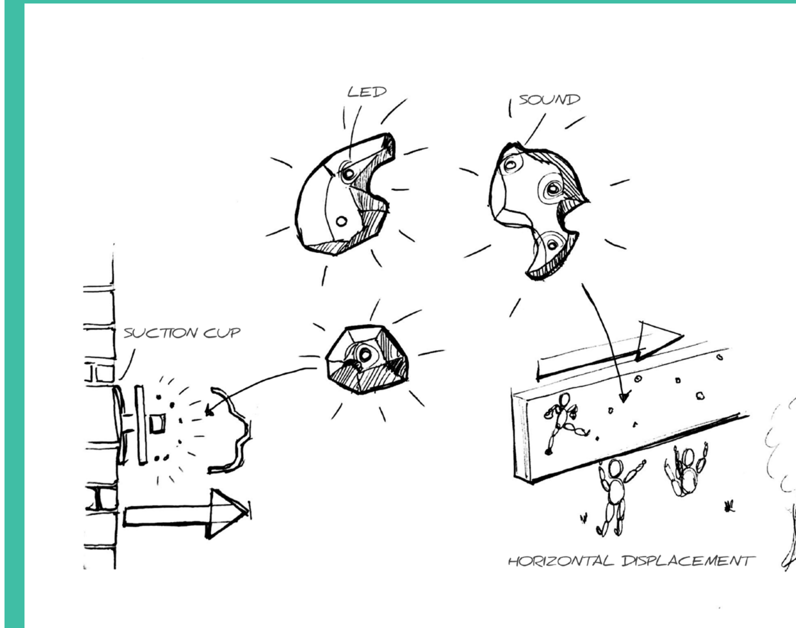




CONCEPT DIRECTION A

Interactive attributes

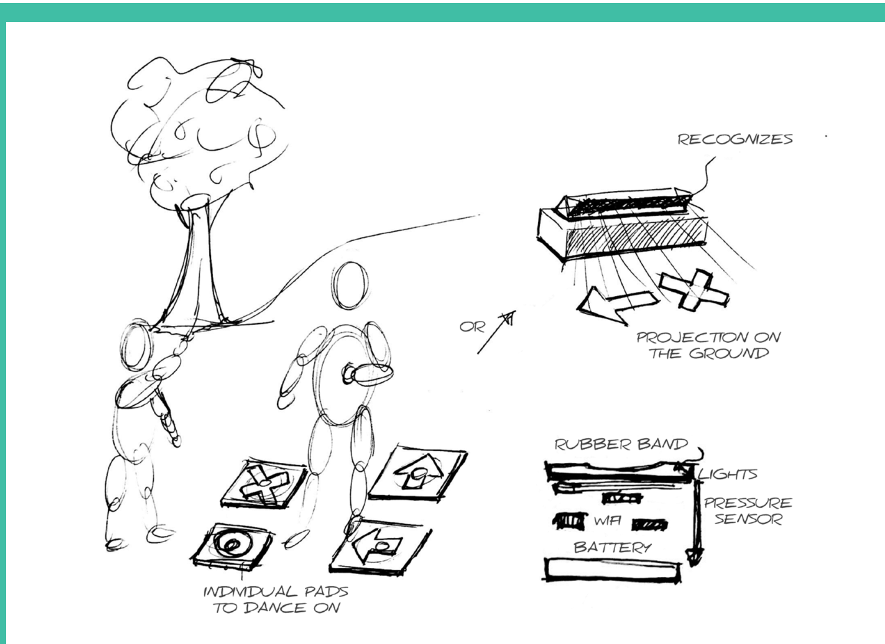
- Interactive ball/toy to play several games
- Statistics can be shared online



CONCEPT DIRECTION B

Outdoor dance

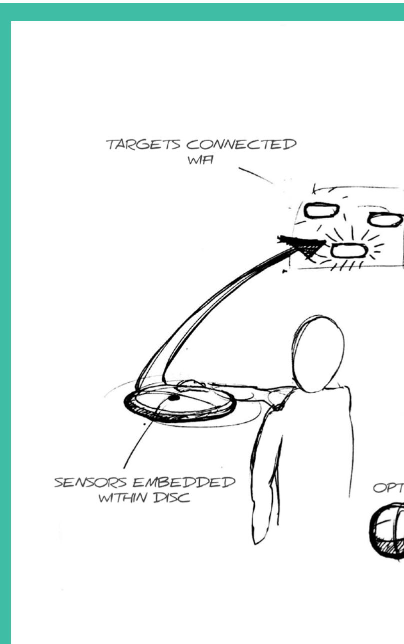
- Interactive dance pads for outdoor use
- Users can dance together, or alone, on the correct moves. Indicated by the pads/projectors
- Statistics can be shared online



CONCEPT DIRECTION D

Target practice

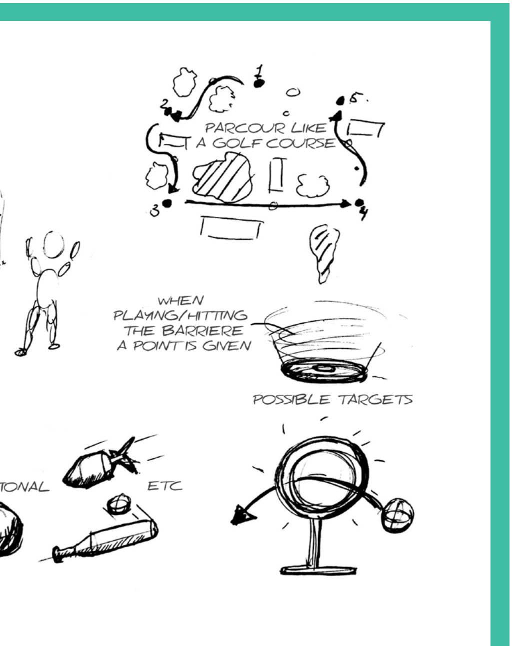
- Throw, hit or kick the interactive targets to score points
- Multiple targets practise uses
- Online rankings among friends/others

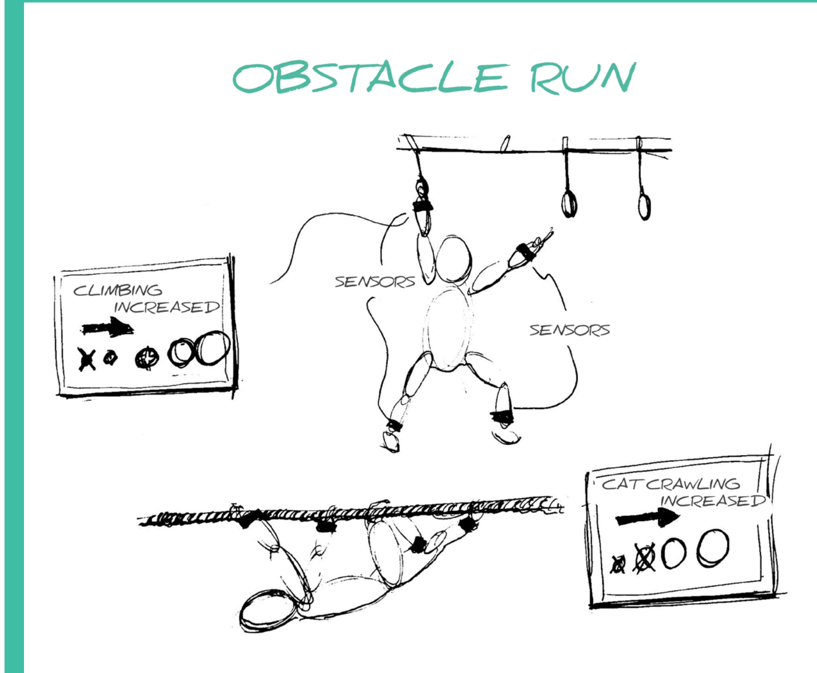


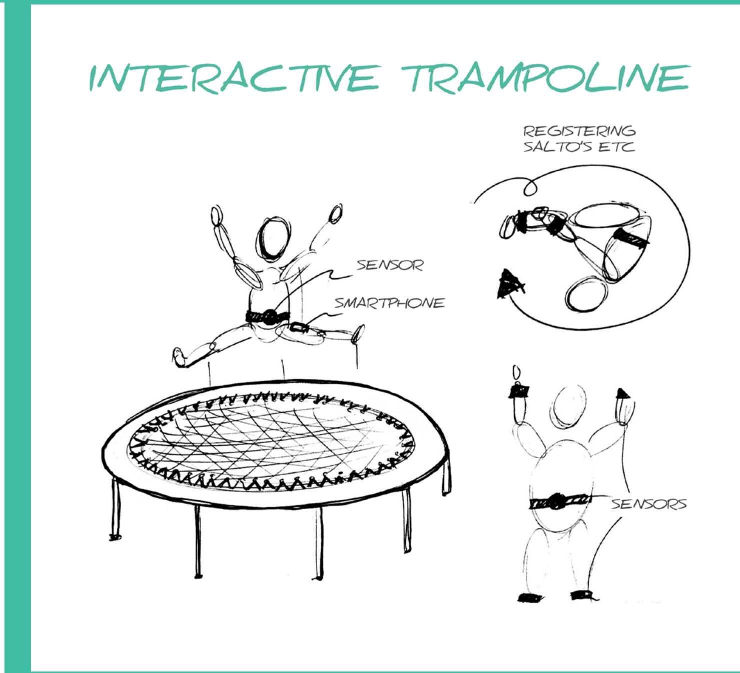
CONCEPT DIRECTION C

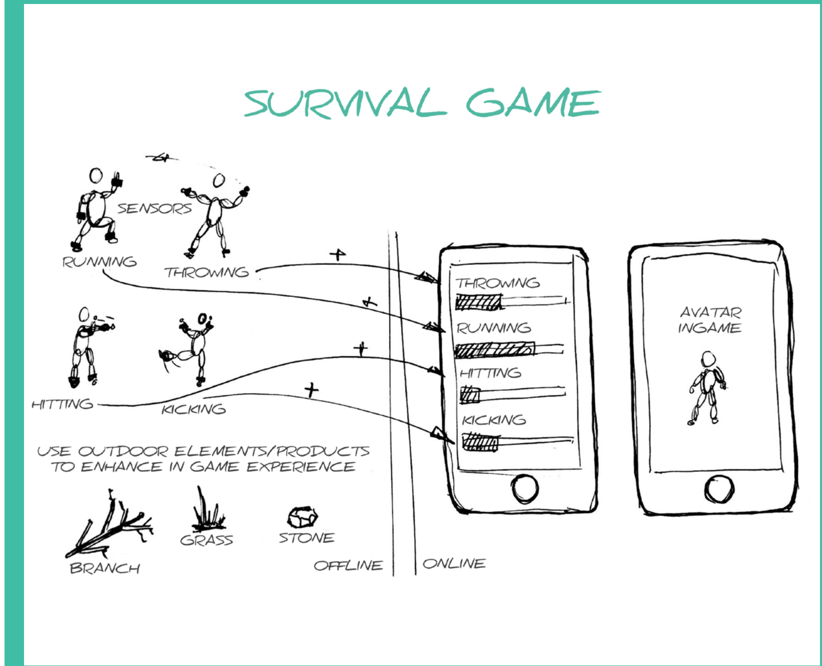
Outdoor climbing

- Interactive horizontal wall climbing
- Suction cup enables climbing holds to be placed anywhere
- Climbing spots and specific experiences can be shared online









CONCEPT DIRECTION E

*Sensor suit**

- Sensors in real life detects motion and new skills will be learned/upgraded in game
- Online game experience can be improved by offline physical activity and serve as extrinsic motivation
- Multiple games can be conected to the sensor suit

*After the concept direction drawing session, there were 3 directions which are relatively from the same category. Therefore those 3 are clustered within the same concept direction: Sensor suit.

8.4 CONCEPT DIRECTIONS COMPARISON

In order to choose a specific concept direction, the concept directions need to be validated. Some of the most important requirements (Program of requirements at page 33) are chosen to function as the leading criteria.
The Harris profile method is used for this validation, since a harris profile can give a quick an clear overview of the outcomes without the need for in depth development. The criteria are ranked in terms of influence. The higher the criteria, the more influence it has on the final score, and vice versa.

When looking at the top 3 of the criteria, some concept directions scored low (Outdoor climbing, outdoor dance and target practice). This is mainly because of the limitations in the possibilities and affordability. Outdoor dance and outdoor climbing are concept directions that can only stimulate specific types of movement, eg. dancing and climbing. Due to the need for a highly versatile concept direction, they score low. Since the product should be affordable for the user, Outdoor dance and Target practice scored also relatively low due to the higher development costs and advanced mechanical difficulties (Outdoor dance).
The low versatility of Outdoor dance and Outdoor climbing can also be seen in the score for 'eager to keep using the product'. Target group users want to have a product with endless possibilities and when this does not fit their expectations, they will not be eager to use the product more often.

In general it can be said that Outdoor climbing ended the last of all the concept directions, followed by Outdoor dance and Target practice. Sensor suit and Interactive attributes ended up as the best directions according to the criteria, at which Sensor suit ended at the solid first place.
Sensor suit scored a positive score at almost all of the critera, with even some high values at the top of the harris profile. The only negative score for this concept direction is for the criteria 'analog and digital use', since the product on itself can only create a digital use compared to for instance Interactive attributes wherein the actual product is used for both analog (offline physical activity) and digital (online rankings) use. Once combined with a variety, or specific, game(s), this analog use will be enhanced enough to change the score from negative to positive. Therefore Sensor suit will be used to develop further into a concept.

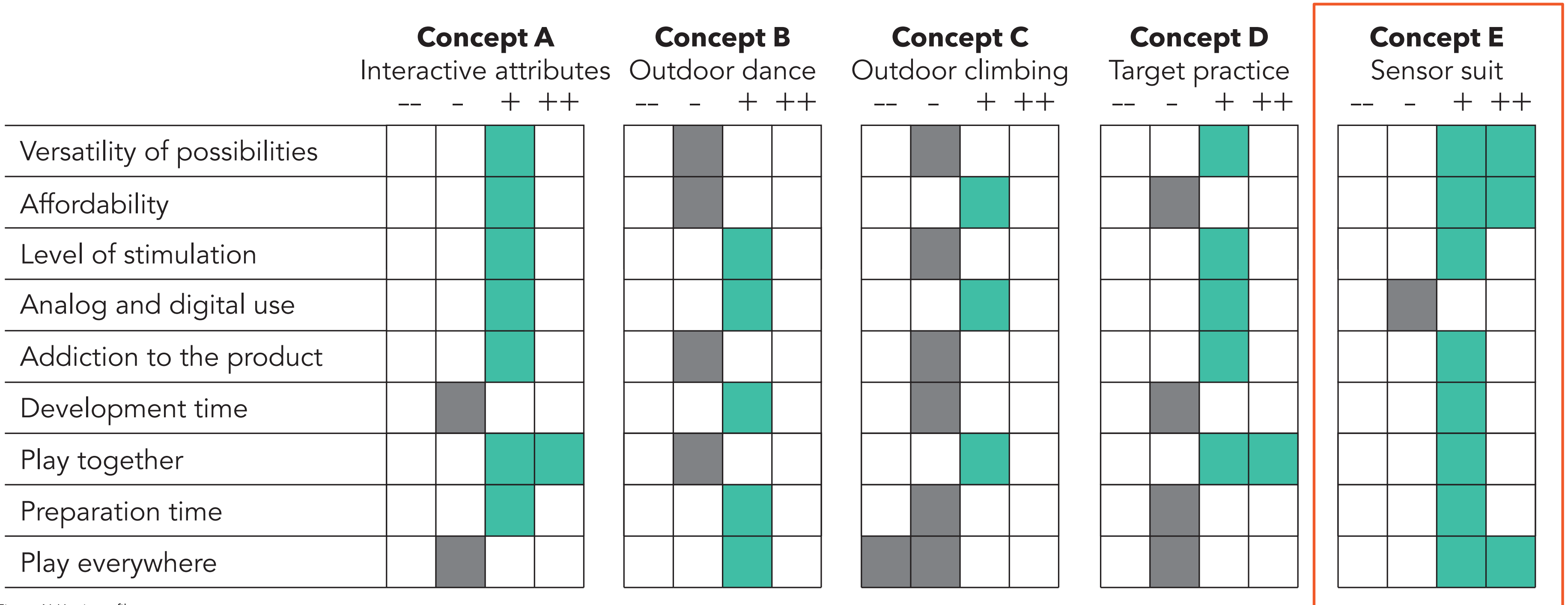


Figure:46 Harris profile concepts

8.5 CONCEPT DIRECTION ADDITIONAL RESEARCH

Within this chapter more research is done with regard to the chosen concept direction: Sensor suit. There was a need for more specific information: What type of game should the Sensor suit be connected to? and What type of moveset should the sensor suit be registrating? Also some potential users are asked for feedback in a pilot, to get a rough indication whether the concept direction is fulfilling the needs of the users.

8.5.1 Pilot

In order to get more clarification whether the chosen concept direction is fulfilling the needs of the potential users and the market, some potential users (by chance male users) are asked whether they would want to buy and also use the 'product'. A first batch of 5 (age 12,16,16,17 and 18) were explicitely asked if they want to use a product where the more physical input will result in more/higher experience within the game. An example of FIFA and Call of Duty was given. All of them responded very positive to this concept.

8.5.2 Survey

Now the potential for the new concept direction is there (see 8.5.1), some elaborated feedback from the potential users should be obtained. The respondents are asked whether they do actually play games. Games in this case is described as a type of (video)game that is assisted by a screen. This could be a game played on the computer, smartphone, Playstation, etc.
Out of the total of 36 respondents (31 male, 5 female), 35 (30 male, 5 female) answered that they do play a game sometimes. Figure:47 shows the categorized playing time per week. More than half of the respondants play more than 5-10 hours per week, more or less 1 hour per day. This is actually comparable

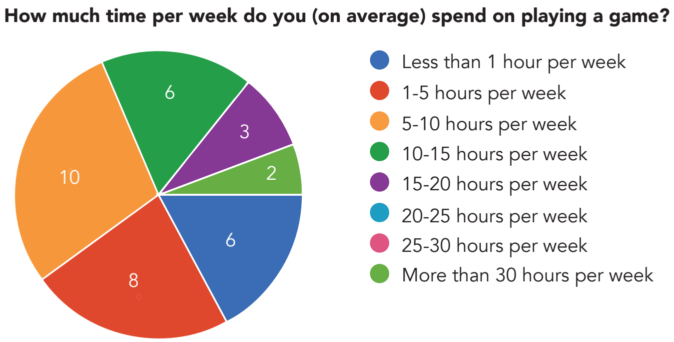


Figure:47 Questionnaire, playing time

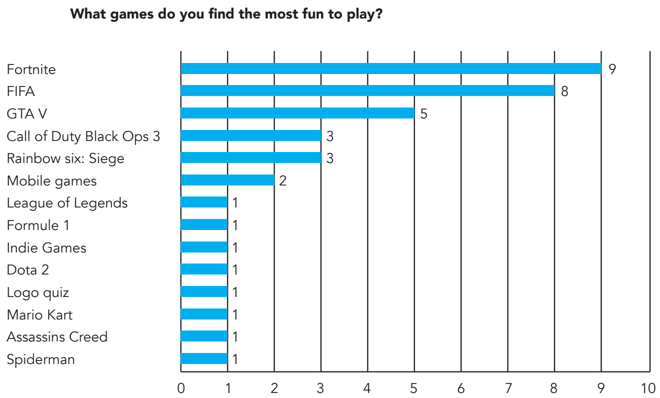


Figure:48 Questionnaire games

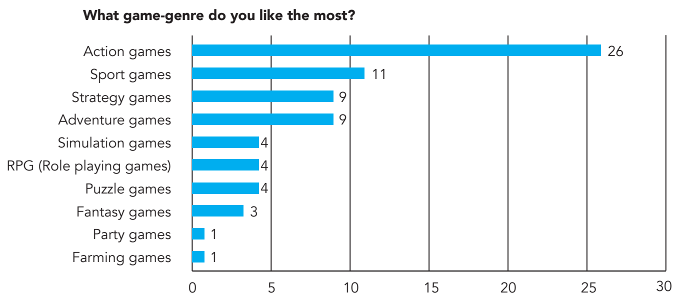


Figure:49 Questionnaire, game genre

with the minimum time of moderate intensity physical activity, suggested by the Dutch Norm Healthy living (Sportzorg, 2018).
Even if some users would only use the Sensor suit for 2 days a week, they are still in line with the Dutch norm.
The respondents were also asked what platform they prefer to play a game. The vast majority answered to play a game on the Playstation.

Since the Sensor suit has to be connected to (a) certain game(s), the respondents are also asked to write down their favourite game and game-genre to play. A top 3 of favourite games can be formulated wherein Fortnite is the outspoken winner, followed by FIFA and GTA V (see Figure:48). The overall preferred game-genre can be seen in Figure:49. The top 3 can be considered as Action games, Sport games followed by adventure and strategy games.
These answers serve as a proper base for further development of the Sensor suit, since it is highly dependent on the actual games to play with.

Beside gaming, the respondents are also asked: What is the amount of time spent on moderate intensity physical activity per week? The average stands around 5-10 hours per week, and 70% of the respondents fulfil this amount of time or even more. Also only 40% answered they spent too much time behind a screen. These contradictory answers are not a clear reflection of the general target group, since a lot of respondents were actively involved with my track and field sports club.
More answers and remarks on specific answers can be found in appendix F.

If we compare the results of this survey to other literature, some interesting findings can be obtained. Dindar, 2018 looked if gender difference have influence on video game play. His research, based on multiple other research, involves 479 high school students

(around 16 years old of which 209 females and 270 males). He found out that males had more experience and skills in video gaming than females (around 7 years of experience in comparison to 3 years). Males also spend more time playing video games than females (around 3 hours a day in comparison to 1 hour).
Interesting to see is that females actually play video games more frequently than males (around 4 days a week in comparison to 1-2 days a week).
Females also have a different interest in terms of game genre. They prefer to play sports, brain and skill games whereas males prefer to play shooters, action and sports games, in general.

8.5.3 Survey conclusion

In the executed survey, a very small amount of females participated, in comparison to the amount of males (5-31). In order to gain a more grounded conclusion extra literature research has been conducted. When looking at the researches together it can be stated that the Sensor suit will be suitable for both male and female users. However, the connected game to be played by the users can vary (Sports, brain/skill games for females and shooters, action and sports games for males), also the frequency of use will differ.
In the executed survey, only 1 participant (out of 36) answered that he never plays any type of game. The literature study shows that only 14 participants (out of 479) never played any type of game. Thus we can conclude that the vast majority does play a game on regular basis. Therefore the target group can be specified to gaming adolescents, both male and female (between 12 and 17).

INSIGHTS

- Both female and male adolescents can be defined within the target group
- Sensor suit applicable for different type of game-genres
- Target group specified to gaming adolescents

8.5.4 Motion analysis

The next step in elaboration of the Sensor suit is to find out what specific type of movement is needed to register. Therefore the top 3 games of the survey outcomes are investigated in terms of motion and in-game abilities/skills.
For each game, all of the movements have been broken down to some general features like strength and acceleration. This is required to be able to compare the different set of moves among each other.

8.5.4.1 FIFA

The in-game player statistics of FIFA show a lot of different abilities a player can have. The numbers of these statistics make the player a good or a bad one. The general topics are: Ball skills, Defence, Passing, Physical, Mental, Shooting, and Goal Keeper. All of the subset moves are broken down into the core features shown in Figure:50. An overview of the different subset moves according to the core features can be found in appendix G.

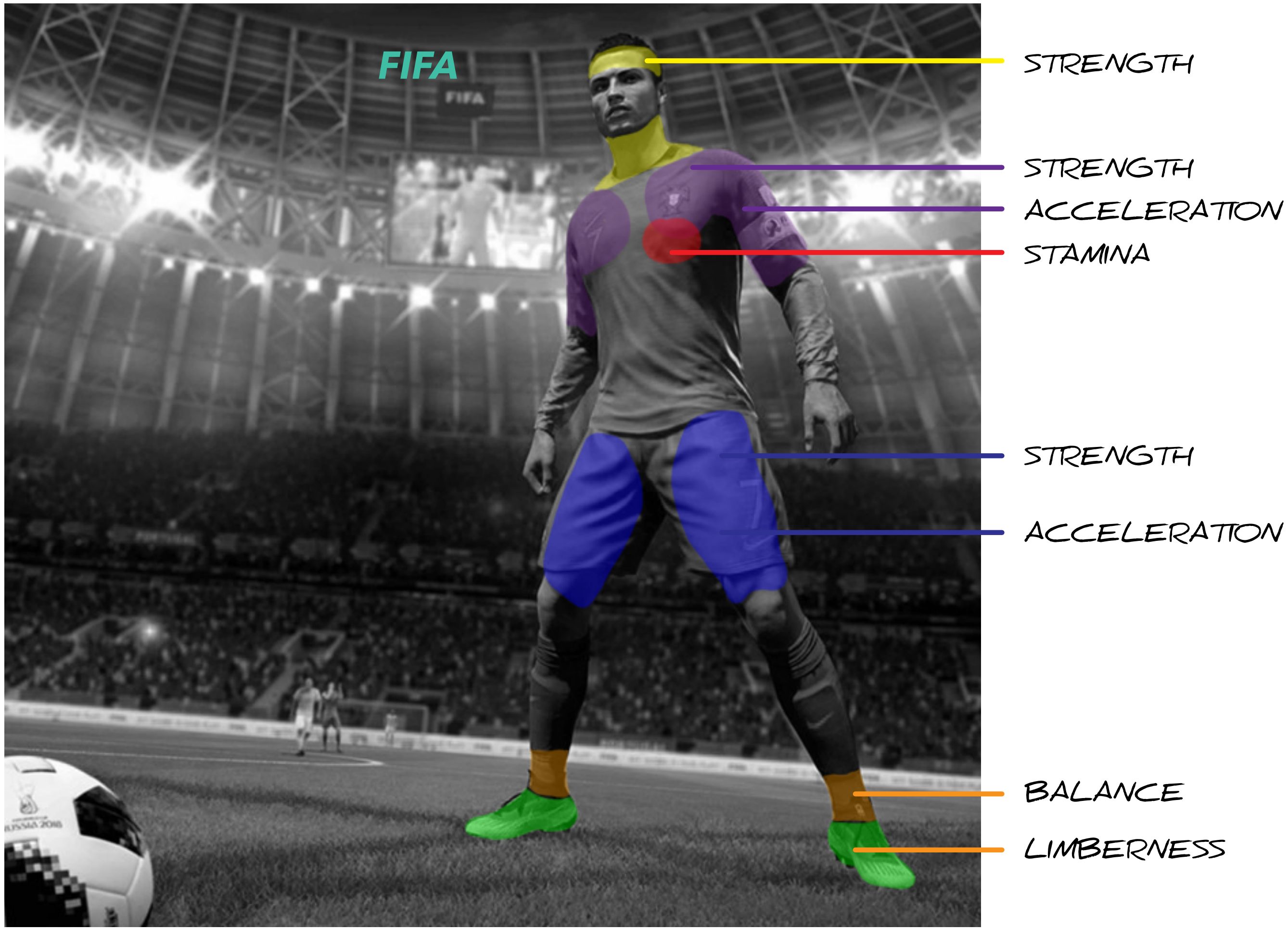


Figure:50 FIFA motion

8.5.4.2 Fortnite

Fortnite does not have such a highly detailed list of skills/abilities a player can have, yet every character have its own set of skills. These skills can be improved by spending *research points* or *skill points.* Skill points can be achieved by completing quests or gain experience while playing. Research points will be gathered, even if the player is offline.
To look for specific type of moves, gameplay footage is investigated. The core features of these moves can be found in Figure:51. But since the initial moves (appendix G) do not form a correlation with the skills/abilities of a player, Fortnite as a game has less potential than FIFA for instance.

8.5.4.3 GTA

Like FIFA, GTA also has a variety of skills per character. The type of skills are broken down into: Stamina, Shooting, Strength, Stealth, Flying, Driving, and Lung capacity. By executing specific challenges these skills can be improved.
To come up with the core features, all of the possible moves have been investigated. These can be found in appendix G. Figure:52 shows the core feature results of those investigated moves.

8.5.4.4 Motion analysis conclusion

When looking at the comparison between the 3 investigated game results, some core features can be pointed out. **Strength** (both arms and legs), **Acceleration** (both arms and legs), **Stamina**, **Accuracy** (both hands) and **Balance** (both ankles/feet). These new insights will guide as the new base for the Sensor suit components. Since limberness and Strength (head/neck) is only used in FIFA, this will not be taken into account for the development of the Sensor suit, for now. Possibly, these specific core features can be add-ons in the future.

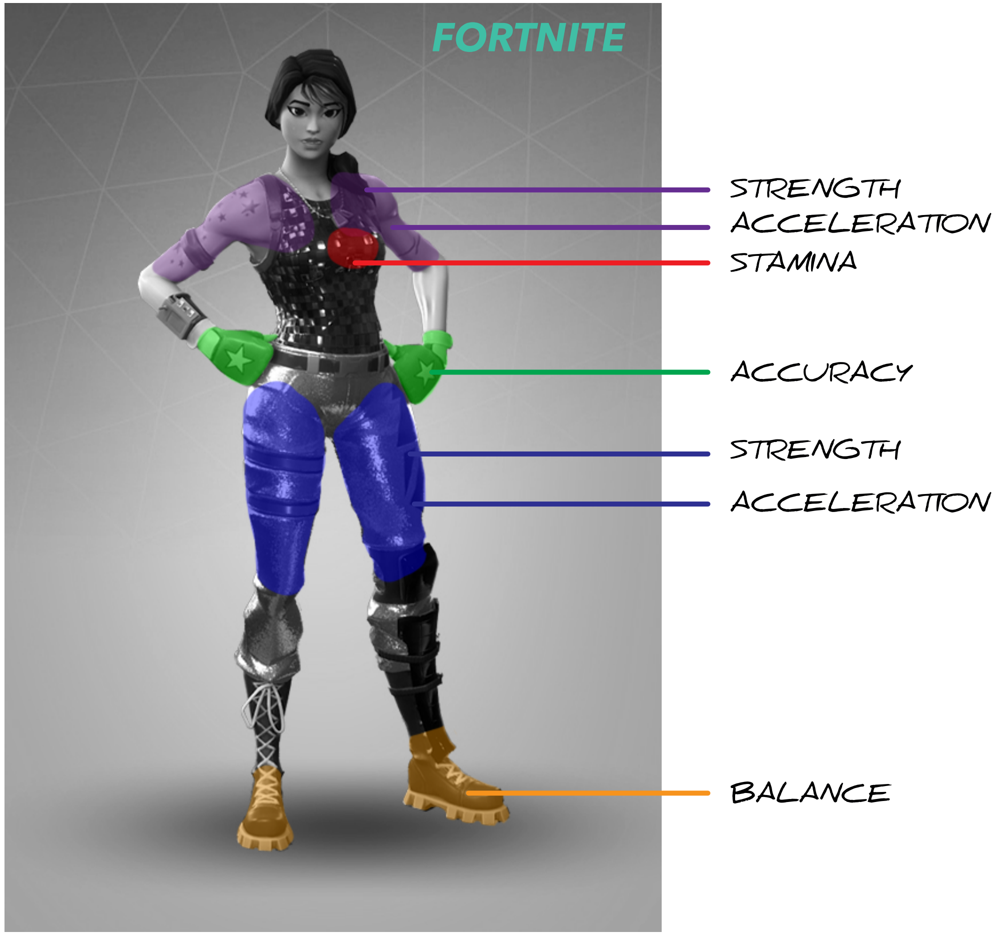


Figure:51 Fortnite female motion

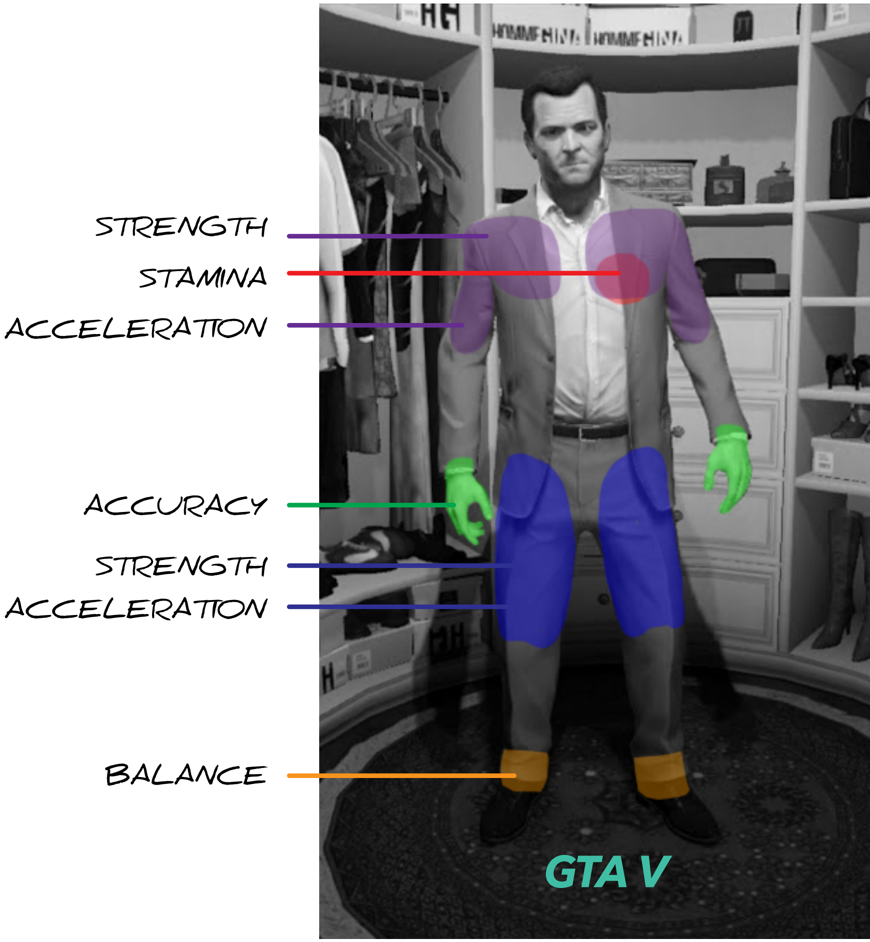


Figure:52 GTA motion

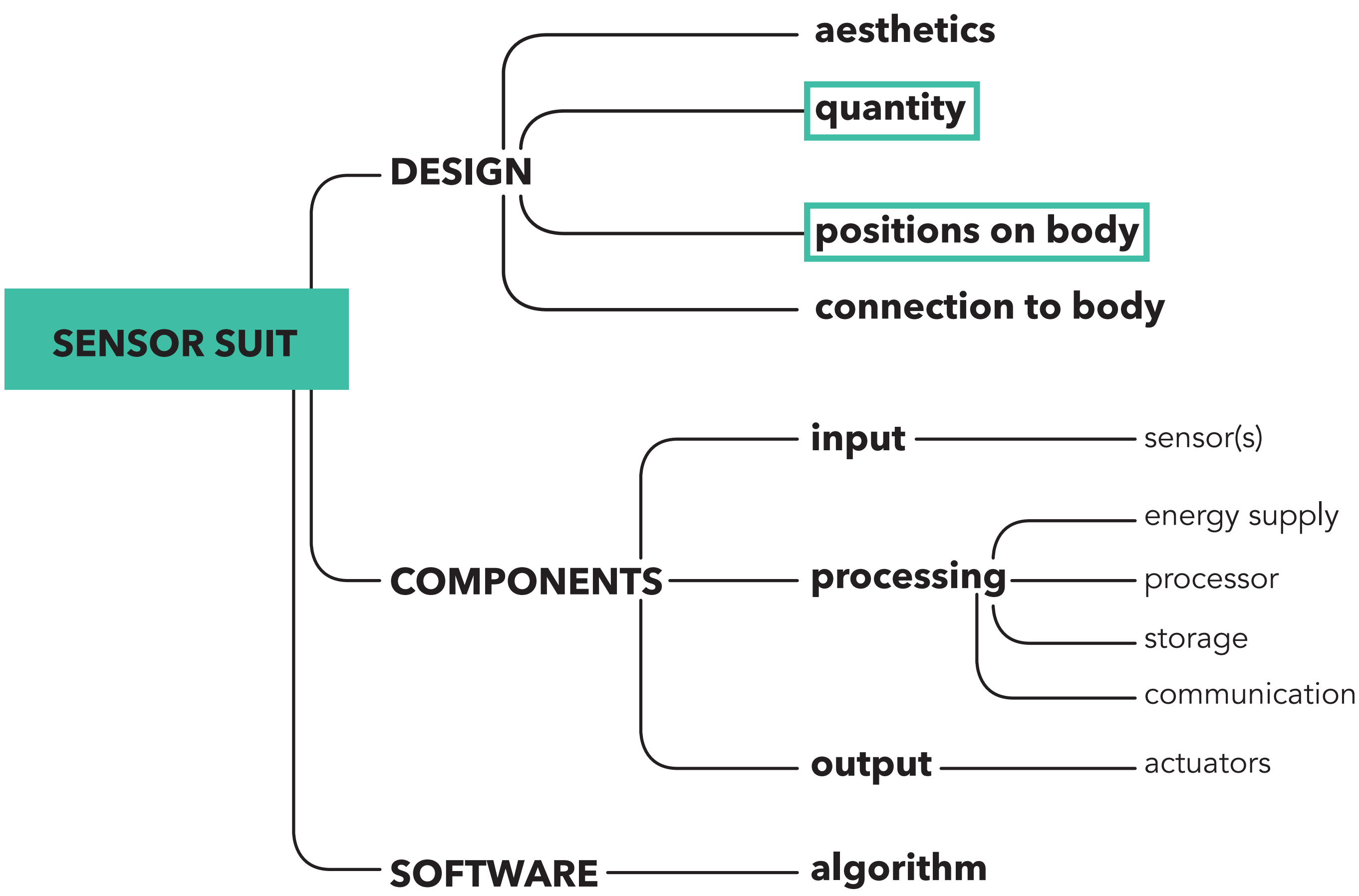


Figure:53 Concept overview

8.5.5 Elaboration overview

All the previous chapters gained new insights in the development of the concept direction. These new insights resulted in an overview of new partial problems to be investigated. This overview of the partial problems can be found at Figure:53.

Positions on body

According to the conclusions made in chapter 8.5.4, 5 core features can be addressed. Those core features correspond to specific places of the human body. Legs, arms, ankles/feet, hands, and heart. While having in mind that we want to have as few products connected to the human body as possible while still achieving the desired accuracy, the positions on the body can be broken down to 4. Wrist/hands and Ankle/feet. These places will give enough accuracy to register the desired core features.

Quantity of products

The result on the positions on the body will have a direct influence on the quantity of the products needed for the sensor suit. Since we want to register the difference between the left and right side of the human body (because of the diversity and additional gaming elements/experience), the minimum amount of products that will be needed to achieve these requirements are also 4.

Two partial problems are already solved (marked grey in the concept overview), the rest of the partial problems: design, connection to body, input (movement), input (communication), processing (energy supply), processing (storage), output (connectivity) and output (communication), still need to be discovered in order to create a solid concept. The next chapters will dive deeper into the partial solutions of these problems.

8.6 PARTIAL PROBLEM SOLUTIONS

In order to receive the solutions for the partial problems mentioned before, a new idea generation phase had to be executed. This new ideation phase resulted in a mix of research, expert meetings, and how to's.
The obvious solutions were gathered during a how to? session. Unlike the previous how to? session in the first diamond, this session did not have any time limit in order to really get some indepth solutions. This session is also executed by 1 person instead of multiple.
When the first batch of solutions was gathered, some research was done on the internet to come up with some new/innovative ideas. These ideas were even further complemented by two experts from the faculty, my chair Dr. ir. W.C. van der Vegte and assistant professor Ing. A.J.C. van der Helm.
Finally all of the different problem solutions are structurized in a *morphological map*. An overview of this map can be found at Figure:54 and a detailed version can be found in appendix H.

The partial problems processing (processor) and processing (storage) are not included within the morphological map, since these solutions are relatively straight forward and of high influence on the outcomes of the rest of the partial problems.
Also the partial problem of aesthetics is not included within the morphological map, since the dimensions rely too much on the components solutions.
Therefore these partial problems will be elaborated in later chapters.

PROBLEM SOLUTIONS

PARTIAL PROBLEMS	1	2	3	4	5	6	7	8	9	10	11
Processing: Energy supply	(RECHARGABLE) BATTERY	ELECTROMAGNETIC CHARGING	ENERGY GENERATED BY MOTION	ENERGY STORAGE SPRING	SOLAR PANEL	THERMOELECTRIC GENERATION					
Output: Communication	ELECTRONICAL PULSE	LCD/OLED SCREEN	LED	PROJECTOR	SPEAKER	VIBRATION MOTOR	FAN				
Input: Communication	BUTTON	MICROPHONE	TEMPERATURE SENSOR	TOUCH SCREEN	TOUCH SENSOR	WATER DETECTION SENSOR	CAMERA				
Connection to body	BAND STRAP	BOA CLOSING WHEEL	CLOTHING	ELASTIC SQUEEZE CLIP	FLEXIBLE STRAP	FORM CLAMP	MAGNETIC CONNECTION	PIN-HOLE CONNECTION	SQUEEZ CLIP	TEMPORARY TATTOO	VELCRO
Output: Connectivity	BLUETOOTH	INFRARED	ULTRA WIDE BAND	WIFI	ZIGBEE	WIRED	NFC/RFID	ULTRASONIC			
Input: Movement	ACCELEROMETER	GPS LOCATION	GYROSCOPE SENSOR	IMAGE RECOGNITION	MAGNETIC SENSOR	MOTION SENSOR	PEDOMETER	RADAR	THERMAL CAMERA	HEART RATE SENSOR	

Figure:54 Morphological map

9
EXPLORATION OF BUSINESS OPPORTUNITIES

Since this graduation project will guide as a base for a future start-up company, the business aspects have to be integrated within concept development. Some business aspects will have impact on the decisions that have to be made and will therefore be integrated before the solution validation.

After meeting with some experts in Product Innovation Management (Msc. V. Pavlic, Dr. Ir F. Smulders, and Ir. R. van Heur), the first brief Business Model Canvas (BMC) is created (see Figure:69). The BMC is a brief overview of the core values for the company. A detailed version can be found in appendix I. Some new insights in response to the expert meetings resulted in the current BMC, which at their turn have their own influence on the development of the concept.

9.6.1 Product-service combination

The Sensor suit will be sold as a product-service combination. This decision has been made since it will create a high amount of potential users, due to the connection to any console, with relative little investments (an app vs. development of a new game) and a higher value proposition.
It is also a safe decision, because if the potential partners are not willing to collaborate, an own game design could be easily integrated within the product-service combination. Beside, a product-service combination is also described in chapter Program of requirements at page 33.
The product-service combination, with the product, being the set of sensors and other electronics embedded within the hardware components and the service, being a smartphone app that combine all of the registrated information. This information can therefore be connected to any desired console and the information can be exchanged.

9.6.2 Peripherals

As can be seen in the BMC, future revenue streams will also come from the sales of new peripherals. Peripherals are add on products that help to enhance any game experience, like the Donkey Kong drums for Nintendo back in 1995, or the added gun or driving wheel for the Nintendo Wii. These new peripherals for the Sensor suit will enhance the game experience even more. The peripherals will look like the concept directions A-D (8.3 Concept directions (Converging) at page 41). The user can for instance buy a new interactive frisbee, which automatically connects to the Sensor suit and results in new to be enhanced accuracy skills.

9.6.3 Key partners

Because of the product-service combination, some detailed partnership arrangements need to be made. Partners can be gaming-developers and console-manufacturers, like Playstation, Xbox, Nintendo, Guerilla games, Rockstar games and Epic games. When negotiating with these potential partners the way of rewarding should take a big role, since each game could have different ways of rewarding systems. What also should be clear is that the potential partners should be convinced in the market opportunity and competitors advantage regarding serious gaming. To reinforce this argument, health insurances could also play a big role. Involving them, and their funding, will also create revenue for the console manufacturers and game developers for the missed online purchases.

9.6.4 Market introduction

Since this project will guide as a base for a future start-up company, market introduction possibilities should be taken into account. Since the Sensor suit is highly dependent on specific key partners, the introduction will also be dependent on these arrangements. After these arrangements the first production size should be determined, partly depending on the wishes of the partners. As a first batch size 100 product-service systems will be produced, to have a user-trial period in order to optimizing the product.

9.6.5 Conclusion

The "Exploration of business opportunities" lead to some changes in the preliminary design. The new product-service approach enables the user to always connect the Sensor suit with the smartphone when exchanging data. Due to this change the smartphone can be seen as a platform or communication tool between the user and the Sensor suit which enables connection to multiple gaming platforms. Of course, the gaming platforms does not get integrated within the product that easily. Therefore arrangements with potential key partners should be made and market introduction will depent on these arrangements.
The peripherals will also create much higher value for the Sensor suit and eventually enhance the user's game/physical activity experience even more.

INSIGHTS

- Product-service combination. Smartphone connected to the Sensor suit when exchanging data
- Enhance game/physical activity experience by offering peripherals
- Key partners can be found in health insurances, console manufacturers and game-developers
- Production on arrangements key partners

Key Partners

Possible potential partnership with different type of both gaming-developers, console-manufacturers and health insurances

- Playstation
- Xbox
- Nintendo
- Microsoft

etc.

- Guerilla games
- Rockstar games
- Epic games

etc.

- Achmea
- VGZ
- CZ

etc.

Key Activities

- Looking out for new partnerships with other game-developers or console manufacturers. By integrating as many games as possible, more users will come and therefore revenue streams will grow.
- Developing new peripherals for new in game experiences.

Key Resources

Algorithm to detect specific type of movements and connect to the app on the smartphone.

Value Propositions

The ability to let the user be more physically active by extrinsic stimulation of their favorite game.
These values are combined into a day-to-day product-service combination

Customer Relationships

The customers will enhance their online game experience, healthiness and become part of an community, which make them want to keep using the product.

Channels

Customers can buy the product at several physical stores, like Mediamarkt. At experience centres around the country, the sensor suits can be tried out and new products will be exposed.

Customer Segments

Adolescents (or parents) in the age of 12-17 years old.
- The target group does, in general, not comply to the Nederlandse Norm Gezond Bewegen, average of 1 hour moderate intensity physical activity for a minimim of 2 days a week.

Cost Structure

Product-level

- Development of the algorithm, to registrate the specific movements
- Developing electrical system for sensors
- Developing housing for components
- Developing new peripherals

Company-level

- Negotiating with key partners
- Assembling costs

Revenue Streams

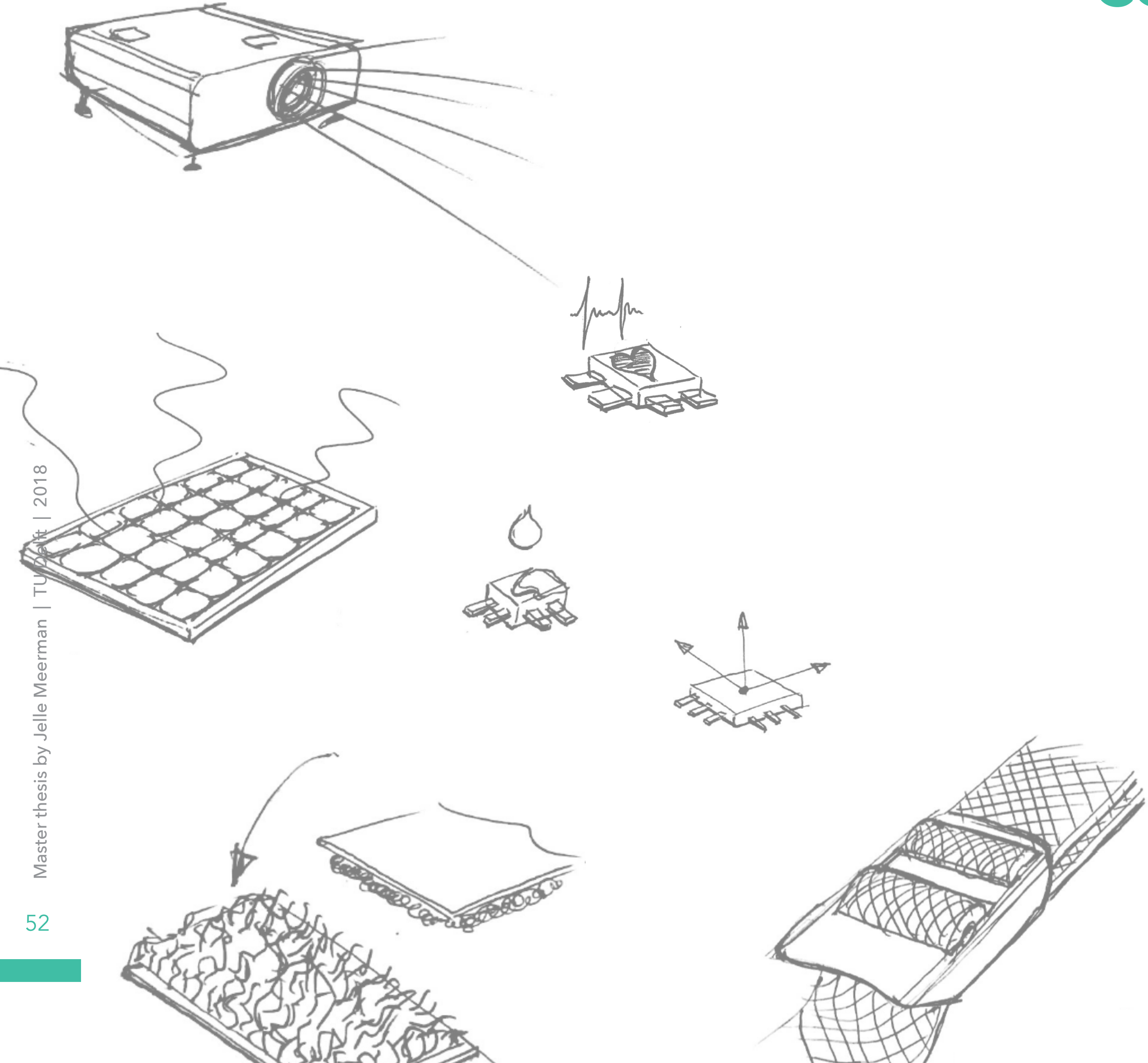
Financial revenue

- Sales of the Sensor suit.
- Possibility of subscription fees for several games.
- Sales of new peripherals to enhance other types of motion for experience

Social/emotional revenue

- Improvement of users' health
- Improvement of user' social well-being
- Improvement of users' emotional well-being

Figure:55 Business model canvas



10
CONCEPT DEVELOPMENT

In this chapter the concept direction “Sensor suit” will be developed into an actual concept. This will be done by finding solutions for the partial problems described in Figure:53 at page 48. New insights and experiences from the previous chapters will be used to answer these questions.

10.1 COMPONENT ELABORATIONS

The concept is highly dependent on the type of sensors and other components used within the hardware devices. Therefore I have chosen to start elaborating the components first to eventually create an 'internal bounding box' for the design of the Sensor suit.
As can be seen in Figure:56, within this chapter the input components, processing components and output components will be taken into account.

A known technology within wearable and connecting devices is the Master-Slave communication. Master -slave is a model of communication where one device or process has unidirectional control over one or more other devices. In some systems a master is selected from a group of eligible devices, with the other devices acting in the role of slaves. (Wikipedia, 2018d)
This configuration allows the concept to have one device with more electronical components and battery than the three smaller devices, which results in lower investment costs. Also beneficial for slave devices are tinier processors and smaller storage which will drop the investment costs even more.
Ing. A. van er Helm, (Lecturer/researcher at IDE faculty specialised into computer technology and interaction design) adressed this configuration and advised me to use this within the concept. Also Prof. dr. G. Kortuem (Professor of Internet of Things at IDE faculty) and Mr. J. Bourgeois (researcher in computer science at IDE faculty) strengthened this advice.

Since the Sensor suit only requires 1 communication to another device (a smartphone) at a time, this Master-Slave technology could be easily implemented.
Wherein the Master device will enable communication to the smartphone and the Slaves only communicates with the Master device.

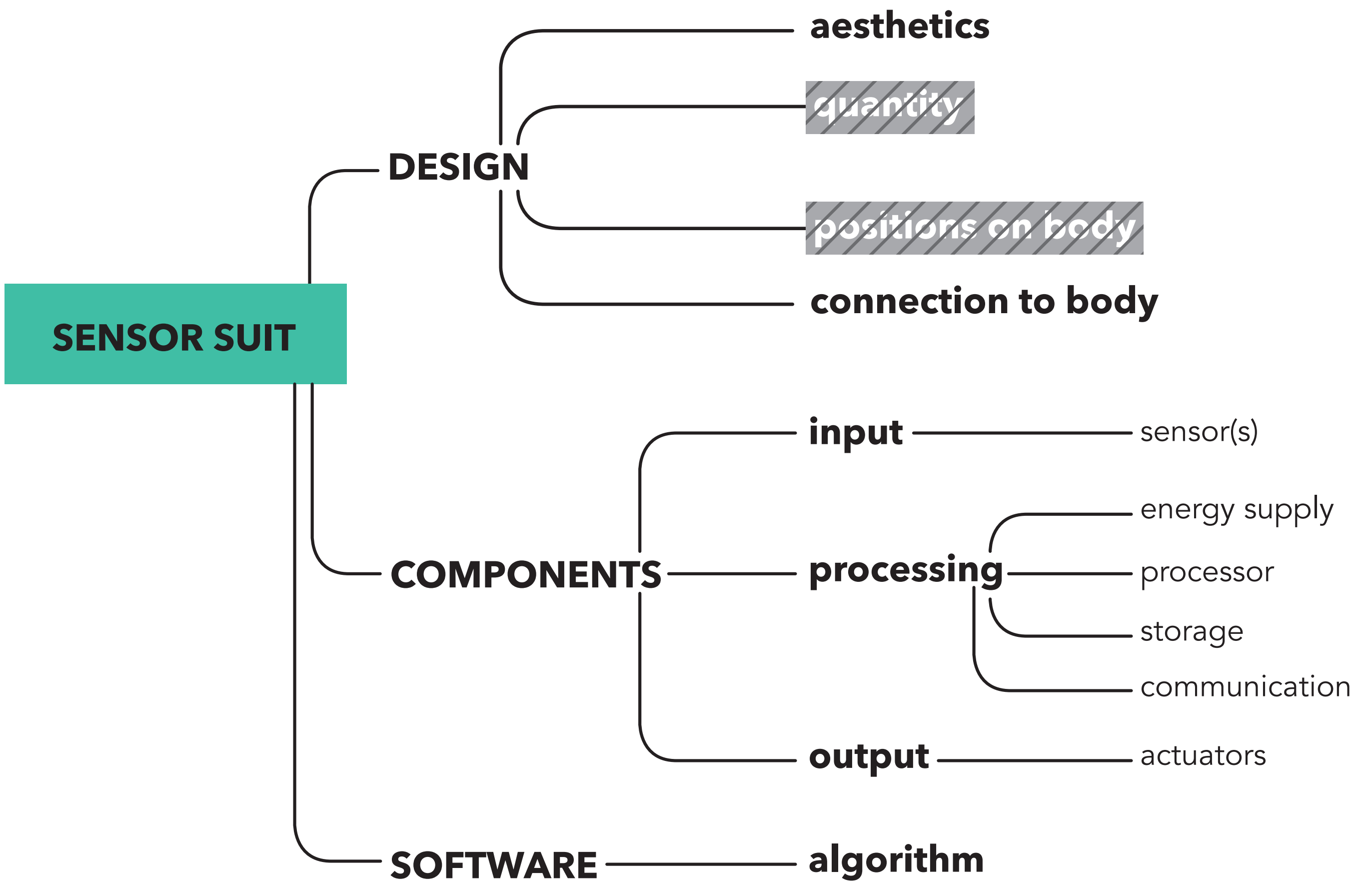


Figure:56 Concept overview components

This technology is especially usable when speaking in terms of affordability, since the Sensor suit need to be as affordable as possible in order to fit to a large quantity of the target group.
Due to the affordability, together with the outspoken advices, I have chosen to use this way of connecting within the concept.

In the next chapters the component list of this Master and Slave device will be elaborated and an overview of both type of devices will be given.

INSIGHT

- Making use of the Master-Slave technology

1 User input starts the master device.

2 This user input signal is communicated to the slave devices by the master device.

3 User starts being active and the devices (both master and slave) start registering the user's motion.

4 When the user is finished with his motion, individual data is transferred from slave to master and registering stops when connected.

5 All of the data is combined and tranferred from the master to the smartphone.

6 The smartphone is running the data through an machine learning algoritm to detect the type of motions performed by the user.

7 The smartphone is running the data through an machine learning algoritm to detect the type of motions performed by the user.

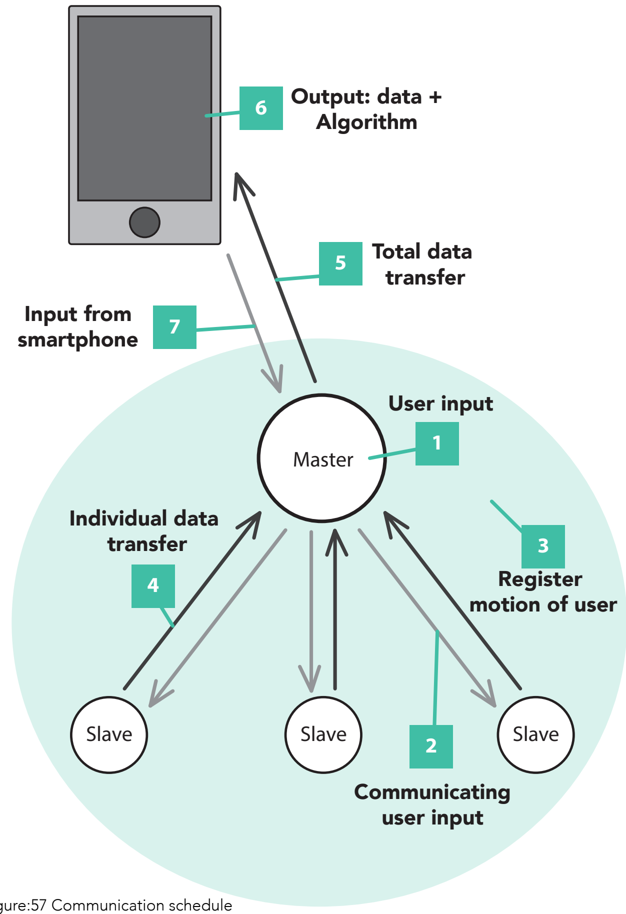


Figure:57 Communication schedule

10.2 DEVICE COMMUNICATION

In order to find a solid solution for the way of communicating between the devices, an overview of the Sensor communication is made (Figure:57). This overview shows an walkthrough of the entire Sensor suit communication together with the elaborated steps (steps 1-6).
Beside the overview, an input-output model is created (see Figure:58 and Figure:59). This model describes each input and output of respectively the master and the slave device, together with the processing step within the device. The steps of the overview correspond to some of the input-output.
These 3 overviews created some new insights with regard to the way of communication between the master and slave devices. These insights lead to the boundary for the possible hardware components that could be used for communication and thus what kind of solution to be chosen. The next chapters will dive deeper into finding the proper hardware solutions for the master and slave.

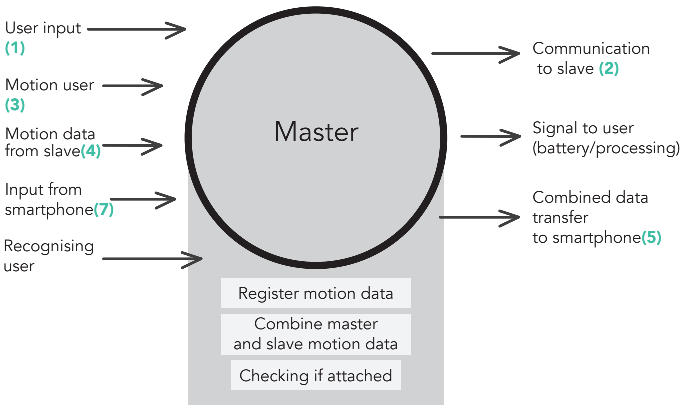


Figure:58 Input-output Master device

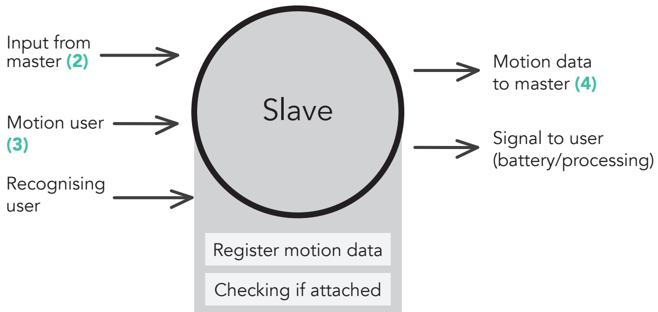


Figure:59 Input-output Slave device

INSIGHT

- No additional user input is needed for the slave devices
- Low boundary (simple) communication between master and slave device
- Low boundary (simple) actuators within master and slave devices to communicate with user
- Enabling user recognition

10.3 MASTER DEVICE

10.3.1 Input: Sensor(s)

A conversation with several experts (Aadjan van der Helm and Arjen Janssen), together with the motion analysis, lead to three components that together enable registrering the desired data. These three components are: the accelerometer, the gyroscope, and the heartrate sensor. The accelerometer will measure the acceleration in every direction and assisted with the gyroscope, the orientation of the human limbs can be detected. Due to this combination the force of the limbs can be measured as well.
Together the components can measure the Strength, Acceleration, Accuracy and Balance, as mentioned in 8.5.4 Motion analysis. The heartrate sensor is needed to measure the stamina of the user.
Beside the sensors registering data, the master device should also enable the user to create direct input. These sensors should be as tiny as possible als consume very low energy. When looking at the Program of requirements at page 33, a lot of the partial solutions does not fit in. The only low energy, small dimension solutions are the button and touch sensor. Since the costprice of the touch sensor is higher than the button, the final solution for the user input will be the button for now. It is possible that this decision still changes according to the new design/looks of the product.
To make sure the master device is always connected to the body of the user when registering data, a proximity sensor is added. This will measure if the Master device is touching the skin and therefore minimize the foul play of the users.

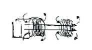
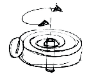
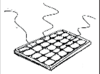
	Factor	Rechargable battery 	Electromagnetic charging 	Energy generated by motion 	Energy storage spring 	Solar panel 	Thermoelectric generation 
Affordable	**4**	8 **32**	7 **28**	6 **24**	6 **24**	5 **20**	4 **16**
Energy storage	**1,5**	9 **13,5**	6 **9**	6 **9**	4 **6**	6 **9**	6 **9**
Robust	**2**	9 **18**	5 **10**	2 **4**	7 **14**	6 **12**	6 **12**
Recharging speed	**0,5**	10 **5**	8 **4**	4 **2**	6 **3**	5 **2,5**	3 **1,5**
Lightweight	**2**	7 **14**	6 **12**	7 **14**	4 **8**	5 **10**	5 **10**
Total score	**10**	82,5	63	53	55	53,5	48,5

Figure:60 Energy supply Weighted criteria Master.

10.3.2 Processing: Processor

The microcontroller of the system also needs a processor to enable controlling all of the different components. An indication to this problem will be given after a proof of concept (POC) has been made, since there is yet no specific information with regard to speed calculation and power consumption. For the first POC an Arduino Nano will be used as a processor.

10.3.3 Processing: Storage

The sensors will together gather a lot of data, which have to be stored somewhere. Since the product will be synchronized to the smartphone after being physically active, some storage must be included within the components. The most important criteria of storage is energy consumption, reliability, and high density. Since there is yet no specific information of the data to be stored, indication of specific storages will be done after the POC.

10.3.4 Processing: Energy supply

To select which partial solution is the most efficient to use within the Sensor suit master device, a *weighted criteria method* is used. 5 criteria (Affordability, Energy storage, Robust, Recharging speed and lightweight) are chosen and each criteria have its own factor. Then a ranking from 1 to 10 is given for each possible combination and then multiplied with the specific factor. Once all of the combinations are made, the sum of the partial solution is displayed at the bottom. The higher the score, the better the solution. The outcomes can be found at Figure:60.
It can be seen that one of the solutions (rechargable battery) has by far the highest score and will therefore be chosen as the final solution for the energy supply.

10.3.5 Processing: Communication

Figure:61 shows the weighted criteria method for the partial solutions of connectivity. The criteria selected for this method are: Affordability, Ease of use, Exchange speed, and Distance.
After calculating the final scores, 2 solutions ended up as the best ones. Bluetooth and Wifi. Since the Sensor suit will also be used in combination with the mobile phone, a Wifi connection is desired but not neccesary. For this reason, and keeping in mind that the hardware of the Sensor suit needs to be as small as possible, the choise was made for the Bluetooth as a final solution for the connectivity.

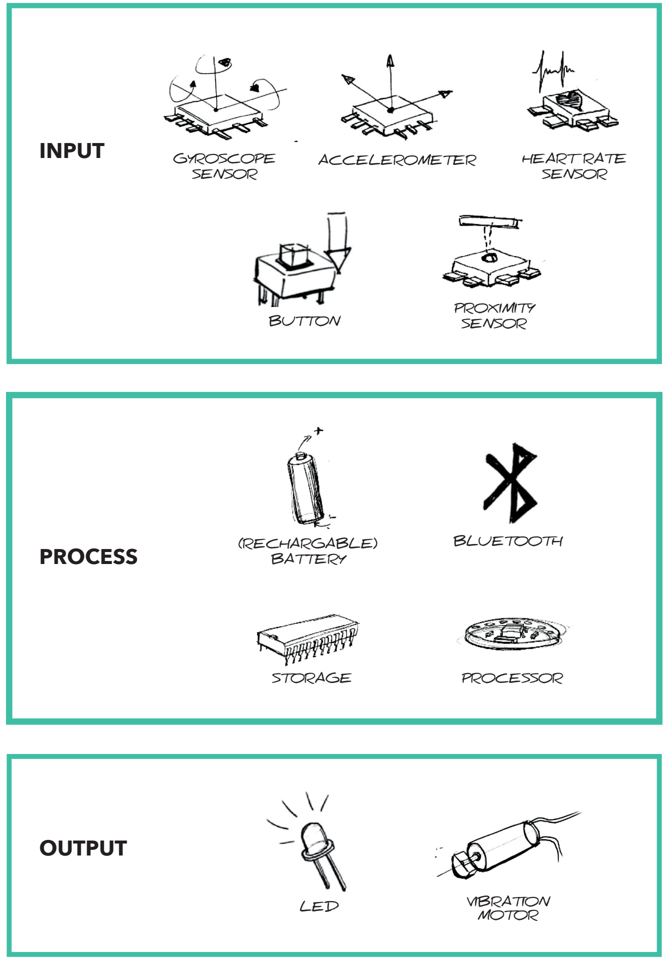
10.3.6 Output: Actuators

Since the master device wil be the first connection between the Sensor suit and the user, it will need some actuator to let the user know that for instance the battery is running low, that a new milestone is reached or that the connection is establishing.
Since the components have to spend as little energy as possible, the decision is made to choose for the LED and the vibration motor. These 2 tiny and low energy components will fit within the hardware of the Master device.

	Factor	Bluetooth	Infrared	Ultra Wide Band	Wifi	Zigbee	Wired	NFC/RFID	Ultrasonic
Affordable	3	8 **24**	8 **24**	6 **18**	8 **24**	5 **15**	10 **30**	9 **27**	8 **24**
Ease of use	1.5	8 **12**	8 **12**	8 **12**	7 **10.5**	7 **10.5**	2 **3**	6 **9**	6 **9**
Exchange speed	0.5	7 **3.5**	7 **3.5**	7 **3.5**	8 **4**	6 **3**	10 **5**	3 **1.5**	7 **3.5**
Range	2	8 **16**	4 **8**	6 **12**	7 **14**	5 **10**	1 **2**	3 **6**	2 **4**
Energy consumption	1.5	7 **10.5**	8 **12**	7 **10.5**	6 **9**	7 **10.5**	10 **15**	9 **13.5**	6 **9**
Reliable	1.5	8 **12**	4 **6**	8 **12**	8 **12**	8 **12**	10 **15**	9 **13.5**	7 **10.5**
Total score	10	78	65.5	68	73.5	61	70	70.5	60

Figure:61 Connectivity Weighted criteria Master

MASTER DEVICE OVERVIEW



10.4 SLAVE DEVICE

10.4.1 Input: Sensor(s)

For the slave device, the same conclusion can be made as for the master device. The slave device will therefore also have an accelerometer and a gyroscope as a registering sensor. The heart-rate sensor will not be included within the slave device, since only 1 is neccesary to measure the heart-rate and it will cost too much energy.
Since all of the slave devices will be actuated by the master device, it is not neccesary to let the user give input to the slave devices. The communication input will only be given to the master device by a button or the smartphone application.

10.4.2 Processing: Energy supply

Like the weighted criteria considering energy supply for the master device, the slave device will also use this method to come up with a final solution in energy supply.
Since there is a lot of overlap between the master and the slave, the weighted criteria method almost looks the same. Only in this case the factor values have been changed. This is done because, for instance energy storage and recharging speed does not have that much of an influence.
Not so surprisingly is the outcome for the slave device. The rechargeable battery ended up as the solution with the highest score and will therefore be the final solution.

	Factor	Rechargable battery		Electromagnetic charging		Energy generated by motion		Energy storage spring		Solar panel		Thermoelectric generation	
Affordable	**4**	8	**32**	7	**28**	6	**24**	6	**24**	5	**20**	4	**16**
Energy storage	**1**	9	**9**	6	**6**	6	**6**	4	**4**	6	**6**	6	**6**
Robust	**2**	9	**18**	5	**10**	2	**4**	7	**14**	6	**12**	6	**12**
Recharging speed	**1**	10	**10**	8	**8**	4	**4**	6	**6**	5	**5**	3	**3**
Lightweight	**2**	7	**14**	6	**12**	7	**14**	4	**8**	5	**10**	5	**10**
Total score	**10**	83		64		52		56		53		47	

Figure:62 Energy supply Weighted criteria Slave

10.4.3 Processing: Processor

Like the master device, the microcontroller for the slave has to be determined. This will be done after the first POC.

10.4.4 Processing: Storage

Just like the master device, the slave device sensors will also gather data, which have to be stored.
An indication of the storage for the slave devices will also be given after the first POC.

10.4.5 Processing: Communication

Also the weighted criteria with regard to the connectivity of the slave device will show a lot of similarities, but also in this case the factor value has changed. The affordability became more of an influence and also the factor for distance has dropped. In contrast to the master device, the slave device does have one solution which stands out from the others. The solution wired will not be the only final option. Direct contact is also a solution which looks very similar to the wired solution and can therefore be also implemented thanks to design aspects.

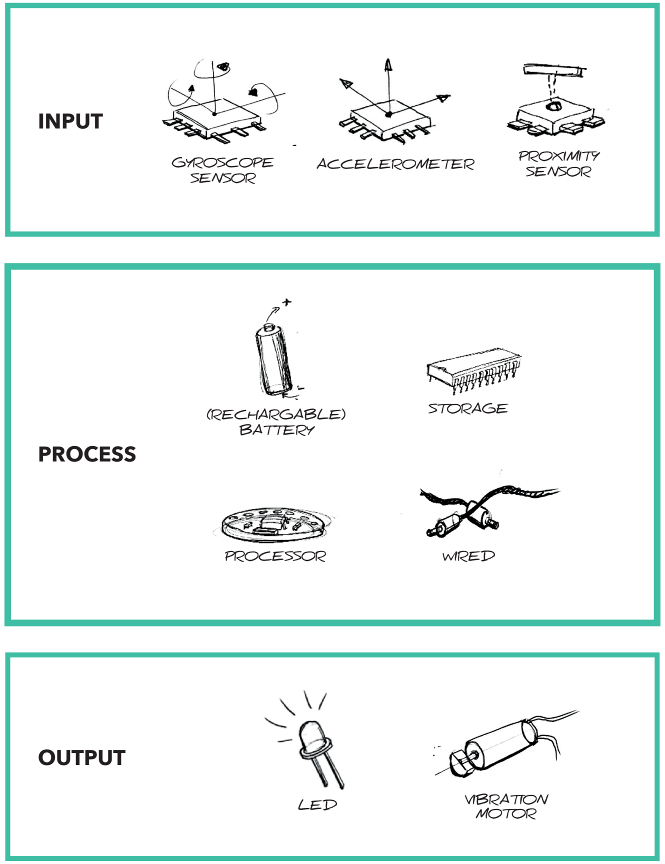
10.4.6 Output: Actuators

The slave device will also consist of a LED and a vibration motor. This is decided because every slave should have its own indication for battery level for instance. Since it is possible that some devices will have to give specific feedback, on the leg for instance, the vibration motor will also be included within the slave device.

	Factor	Bluetooth	Infrared	Ultra Wide Band	Wifi	Zigbee	Wired	NFC/RFID	Ultrasonic
Affordable	4.5	6 **27**	6 **27**	5 **22.5**	5 **22.5**	5 **22.5**	10 **45**	8 **36**	7 **31.5**
Ease of use	1	8 **8**	8 **8**	8 **8**	7 **7**	7 **7**	4 **4**	6 **6**	6 **6**
Exchange speed	0.5	7 **3.5**	7 **3.5**	7 **3.5**	8 **4**	6 **3**	10 **5**	3 **1.5**	7 **3.5**
Range	1	8 **8**	4 **4**	6 **6**	7 **7**	5 **5**	1 **1**	3 **3**	2 **2**
Energy consumption	1.5	7 **10.5**	8 **12**	7 **10.5**	6 **9**	7 **10.5**	10 **15**	9 **13.5**	6 **9**
Reliable	1.5	8 **12**	4 **6**	8 **12**	8 **12**	8 **12**	10 **15**	9 **13.5**	7 **10.5**
Total score	10	69	69	62.5	61.5	60	85	73.5	62.5

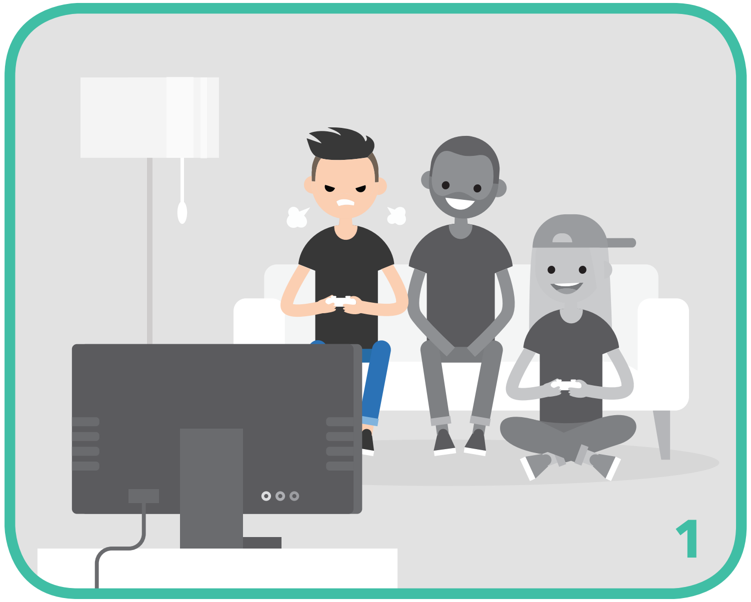
Figure:63 Connectivity Weighted criteria Slave

SLAVE DEVICE OVERVIEW



10.5 USER SCENARIO

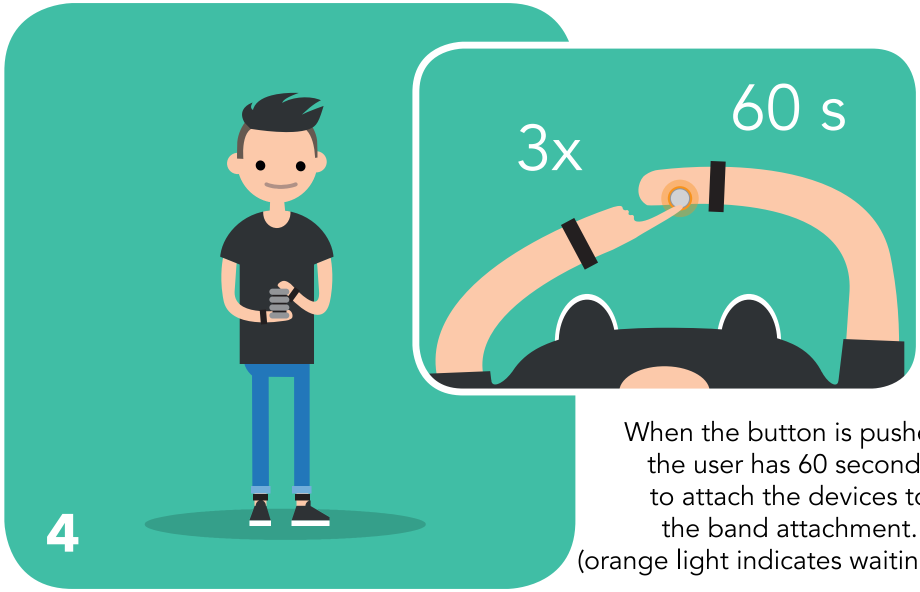
An overview of a potential user scenario will be described in this chapter. This user scenario will elaborate more on how the Sensor Suit will be used and specifically how the interaction between a smartphone and gaming console is situated.



User keeps losing his favorite game : FIFA.

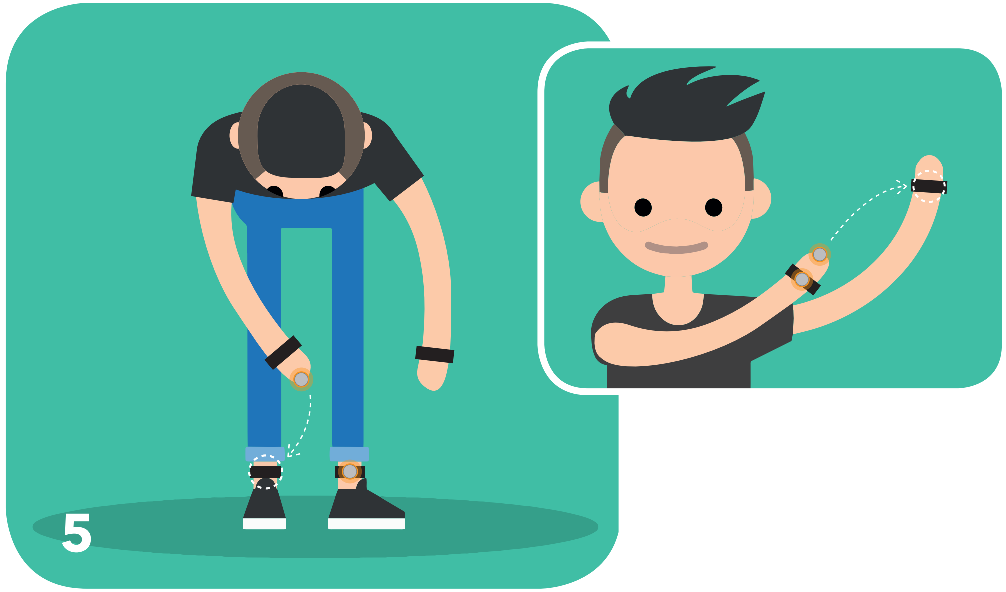
User checks his FIFA avatar and sees the lack of athleticism.

User attaches the band attachment to his body.



When the button is pushed,
the user has 60 seconds
to attach the devices to
the band attachment.
(orange light indicates waiting time)

User starts the Sensor suit by
pushing the Master device button 3 times.



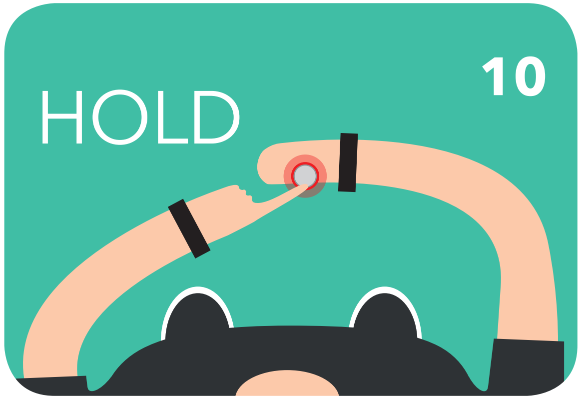
The user attaches the Master and slave devices to both the ankles and wrists.

After 60 seconds, the user is ready
to be physically active. (light turns green)

User starts being physically active:
Enhancing his leg force by jumping on the trampoline.

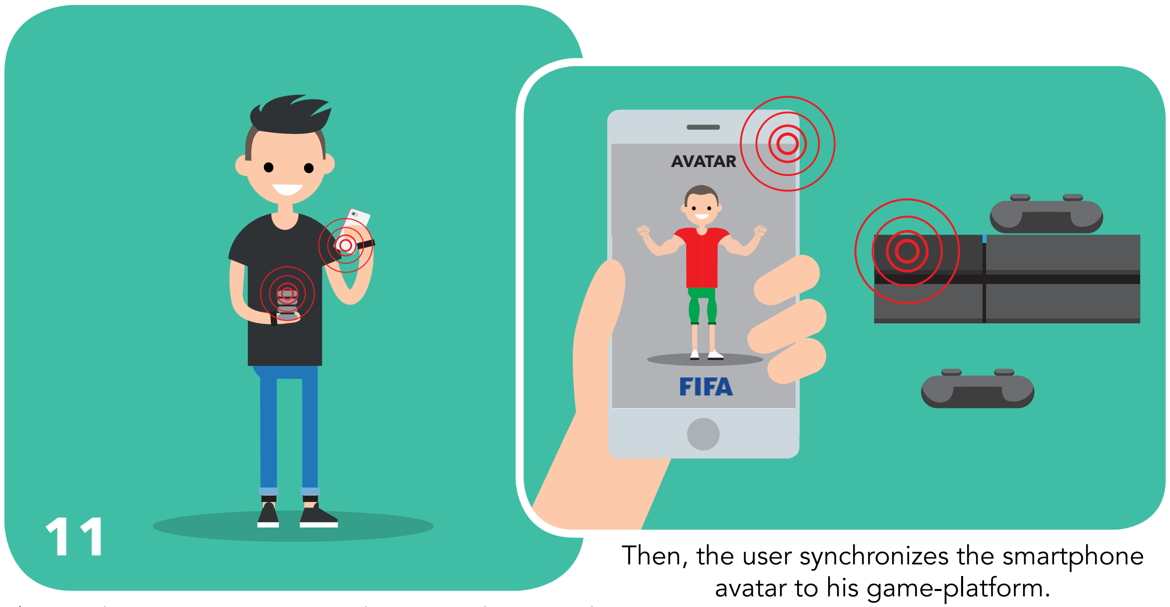
After jumping,
the user starts running to enhance his stamina.

Session is finished. (light turns red)



After finishing, user holds the the master device button to start Bluetooth connection.

When user is finished excercising, he disconnects the devices from the band attachment and joins the devices together to synchronise data on the master device.



Then, the user synchronizes the smartphone avatar to his game-platform.

The Bluetooth connection among the smartphone and master device can be settled and data for the avatar is synchronised.

Due to his strong avatar, the user won from his friends!

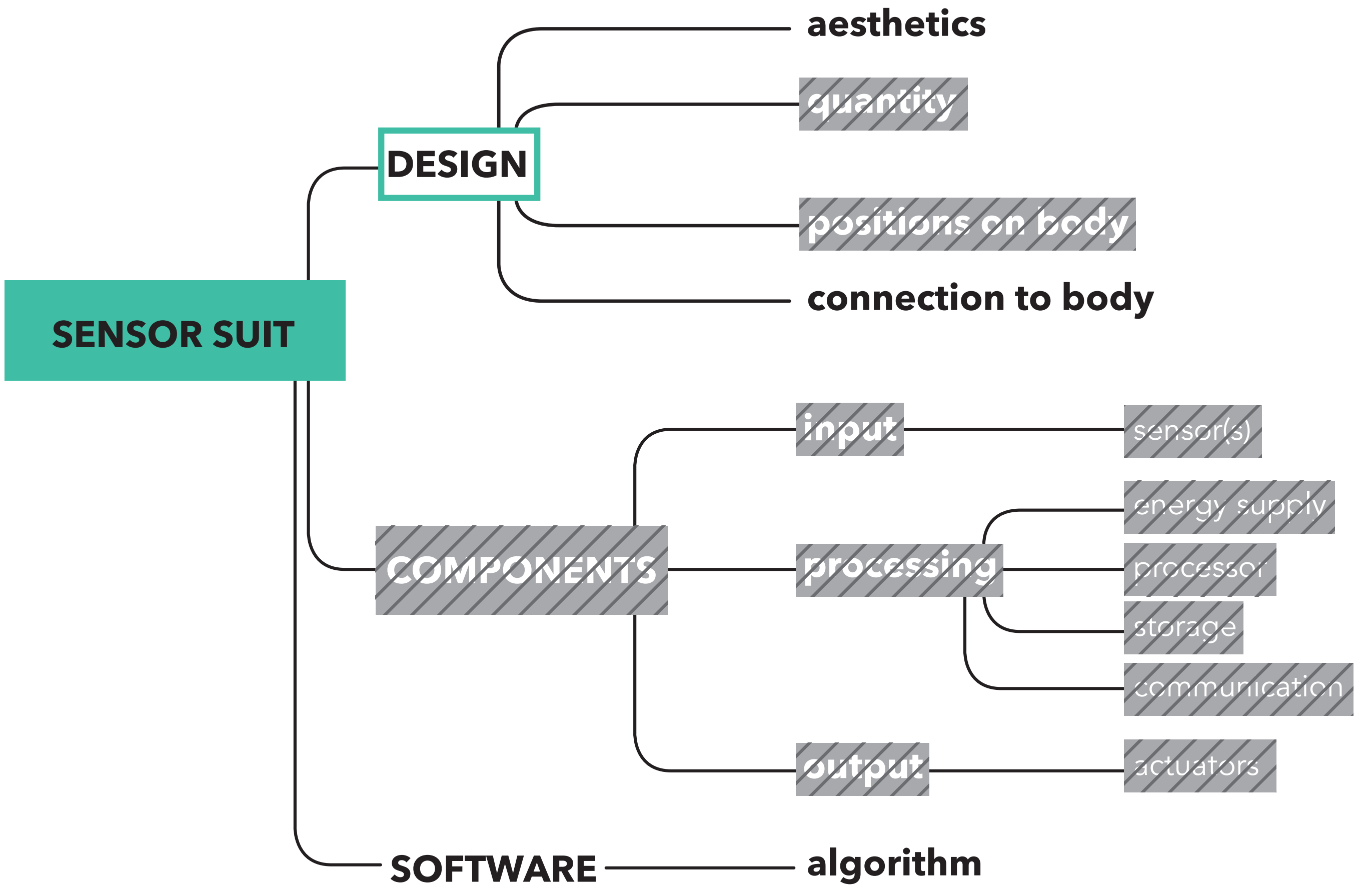


Figure:64 Concept overview design

10.6 DESIGN

In this chapter the design of the Sensor suit concept will be elaborated. Since all of the components are selected, the internal boundaries for the design are finished.
The next phase will elaborate on the specific aesthetics of the concept. The connection to body will also be taken into account.

10.6.1 Aesthetics drawings

When looking at the Program of requirements at page 33, some are of high influence within this phase. These requirements are simplified and shown below, together with some desired wishes.

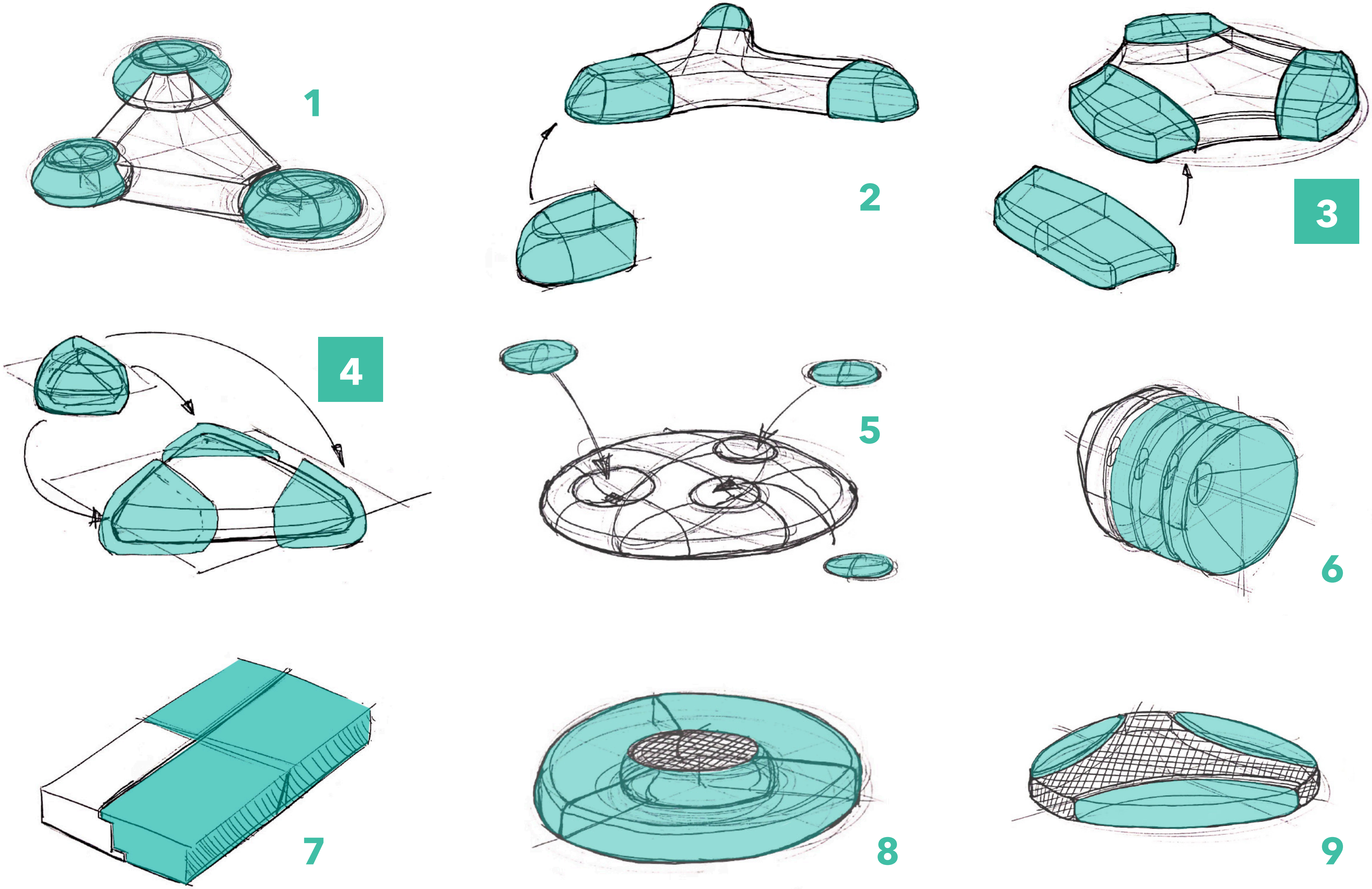
The first step in reaching the aesthetic design of the concept started with a lot of basic 2D shapes, which can be seen on the right. These shapes created a base for the next elaborated product shapes, while taking the requirements and wishes into account. An overview of the developed 3D product shapes (1-9) can be found at page 57. The parts in green highlight the various Slave devices in combination with the Master device.

REQUIREMENTS

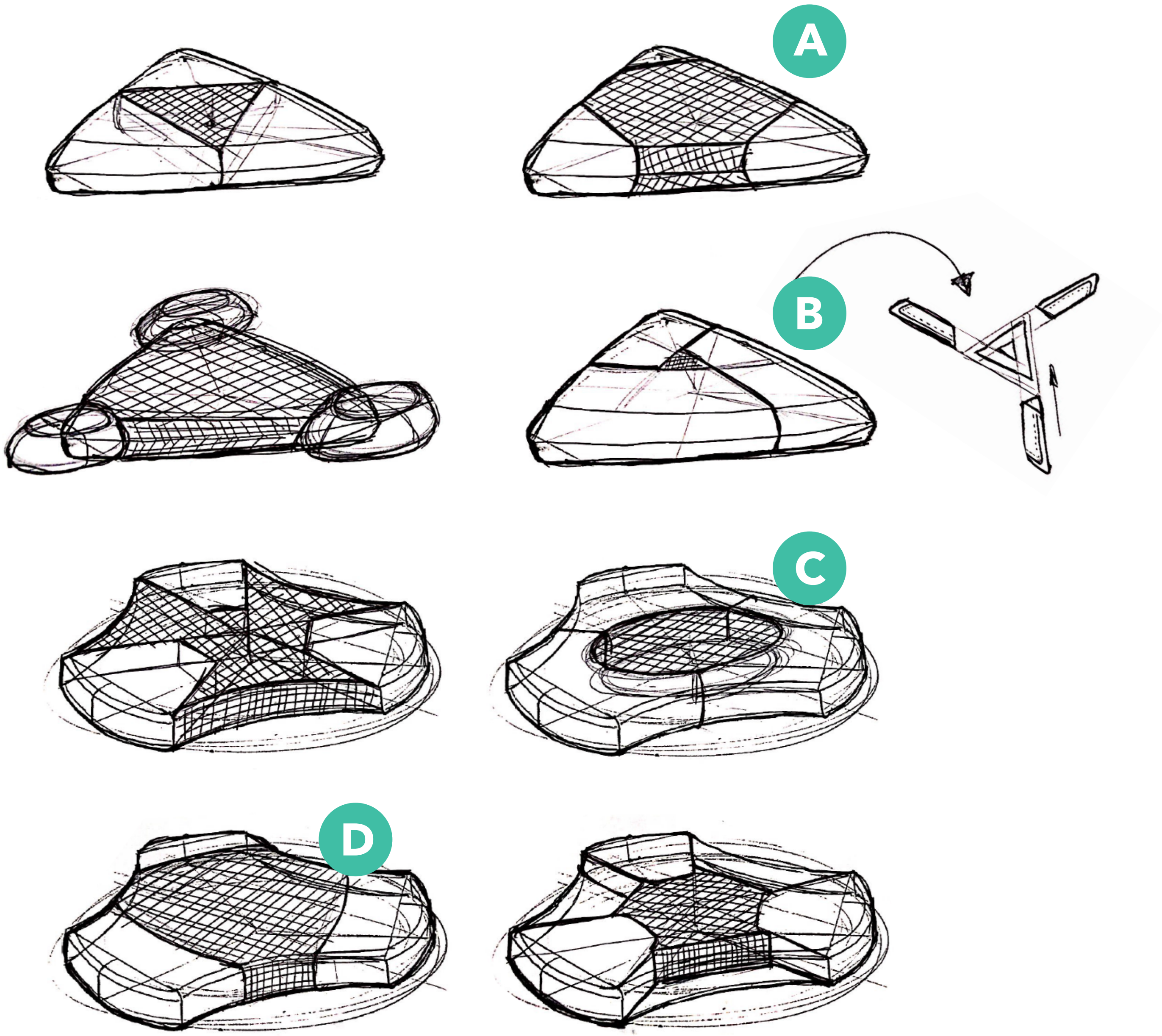
- Small
- Master device should fit on attachment
- Easy to use
- Master-slave aesthetics
- Contact data transfer (Master-Slave)

WISHES

- Desirable to fit in pocket
- Closed, combined shape
- Form follows function
- Contact data transfer also enables battery charging possibilities
- Easy connection to wrist/ancle attachment



All of the 9 shapes have their own form language. But some of the shapes do not fulfill some of the wishes. When choosing one or more shapes, the level of attractivesness to adolescents is also taken into account. Combined with the suitable wishes and level of attractiveness I decides to take shape 3 and 4 to a next level of shape iterations, while keeping this shape as a base.



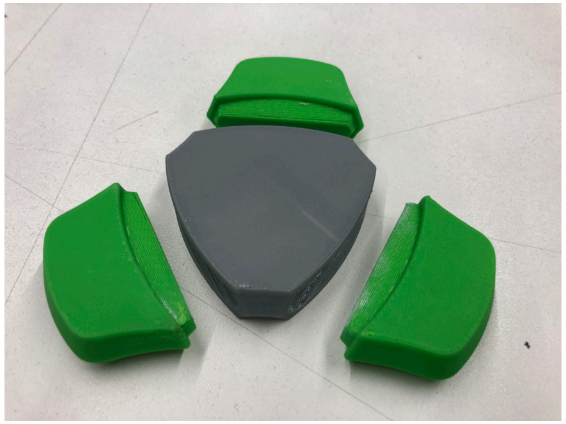
The shapes on the left show the iteration steps of the previous shape 3 and 4. The Master device is highlighted by the dark, hatched area.
In order to make a decision on the concept aesthetics of the Sensor suit, some physical models need to be created. This enables the room for improvement for connecting the slave devices and create an overall physical feeling of the dimensions appearence.
Since there are a couple of designs that I really like (and each have their own addition to the wishes adressed at page 56) I decided to take 4 shapes (A,B,C,D) to the next level and develop them into some physical models.

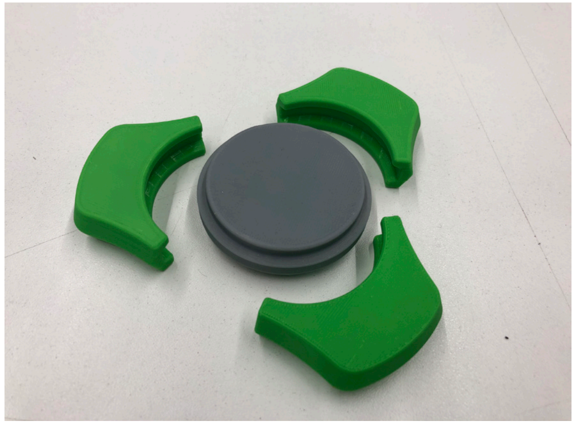
10.6.2 Aesthetics physical model

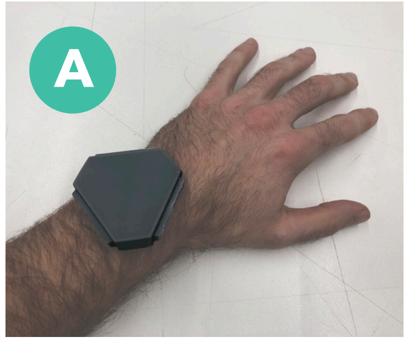
In the first steps of creating a physical aesthetics model, a 3D model of each shape design have to be created in Solidworks. But to do so, the dimensions have to be determined first.
10.3 Master device and 10.4 Slave device, give an overview of the components to fit within the hardware devices. Based on some devices with more or less the same components in the market (Fitbit, Apple watch and Wearnotch) a first impression of the desired dimension is made. With the slave devices being approximately 50x30x15mm and the master devices being approximately 55x55x15mm. These dimensions, in combination with the proposed shapes are elaborated in the Solidworks models.

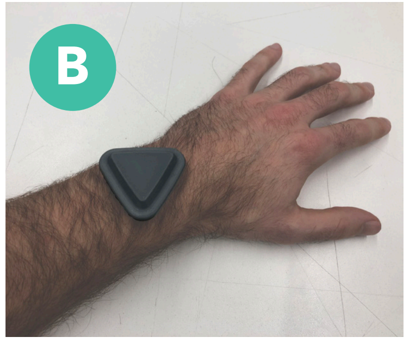
After modelling in Solidworks, the models are 3D printed to enable interacting and checking if the shapes match the expectations.

The first impression of both the master and slave concepts look quite tempting. Unfortunately for some concepts, specifically A, C and D, the master device is just too big. I also noticed that the slave device of concept C does have a lot of extra material, which can hardly be filled up with components (electronics). If the concept will be adjusted to have less extra material, it will look too much like concept D. Therefore concept C is eliminated for further iteration steps.









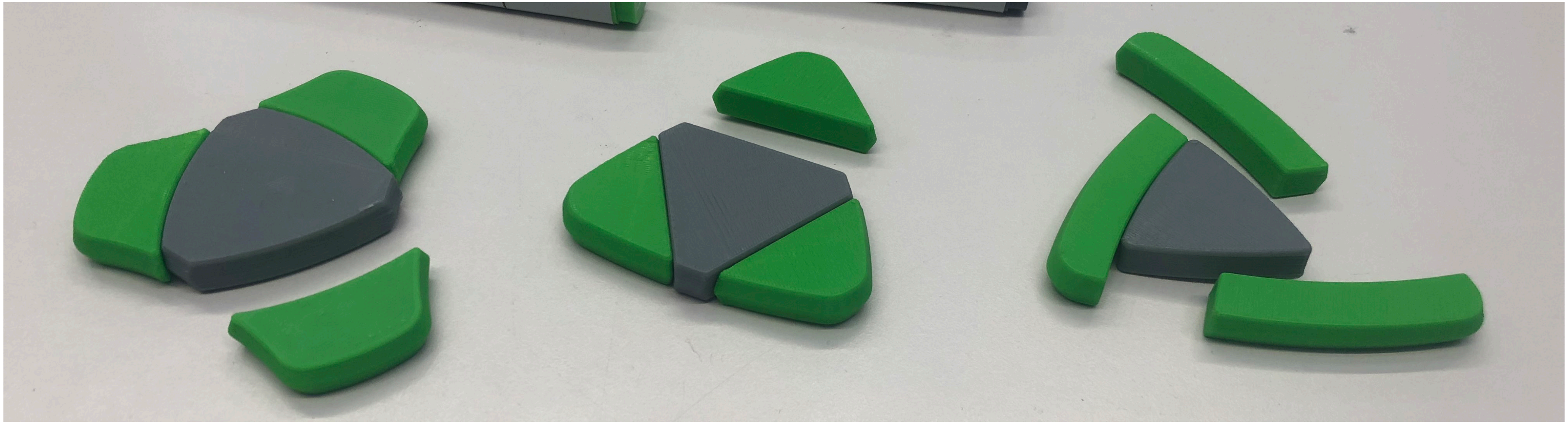


Figure:66 Adjusted concepts

Within the next iteration step the dimensions of concept A, B and D are changed a bit in order to make an equal comparison and eventually make a grounded decision for the ‘best‘ concept to develop further. (see figure 66)

Figure:65 shows a Harris profile of the adjusted 3 concepts (A,B and D). Beside the aesthetic appeal of the concepts, also some technical criteria have been taken into account, such as the room for the attachment connection and the room for electronics. Concept A scored relatively low on both of the shape design criteria, but since the devices have a lot of volume, the technical criteria scored quite good. Concept B scored the opposite of concept A. The shape design is appealing, but the volume (especially of the slave devices) is quite low. Which is less desirable and harder to realise when looking at the attachment and electronics.
Concept D scored the highest overall score and will therefore be developed further.

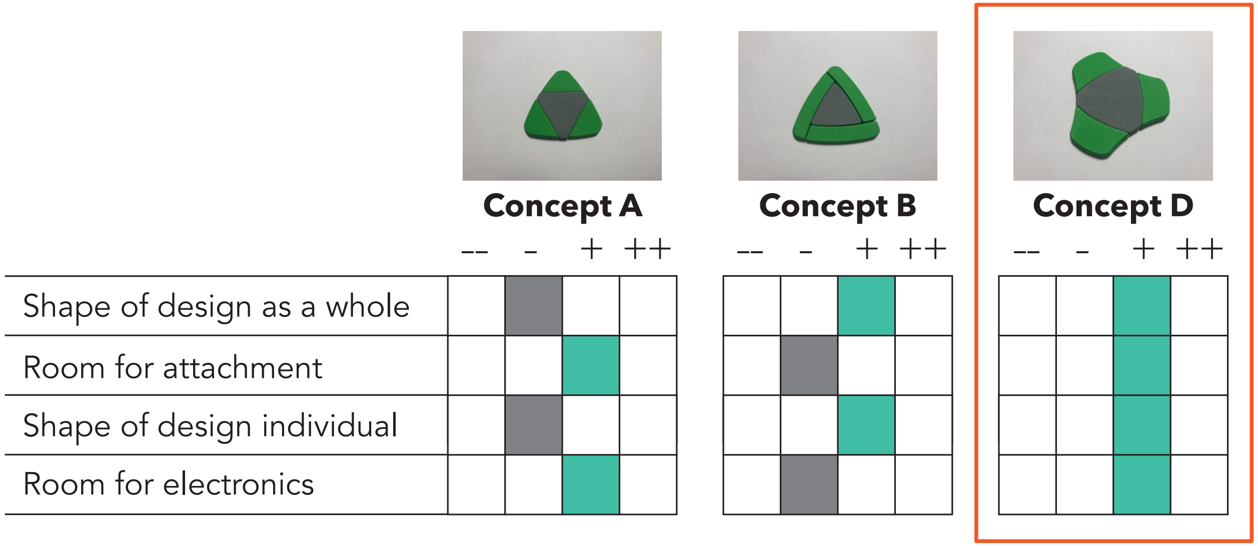


Figure:65 Harris profile concepts

10.6.3 Connection to body

As mentioned before, all of the devices will have to be connected to the users' body. Two devices should me mounted on the ankles and two devices should be mounted on the wrists of the user. The user can decide whether he want to have the master device attached to his ankle or wrist (since this will enable possible future interactive peripherals like a soccer bal, kicking, or an american football, throwing, for instance).

When looking at the Program of requirements at page 33, some are of high influence within this phase. These requirements are simplified and shown below, together with some desired wishes.

REQUIREMENTS

- Attachment should fit for every user
- Rigid connection between the device and attachment
- Device should be taken off the attachment when connecting devices
- Easy to mount
- Attachment should remain in place while being physically active

WISHES

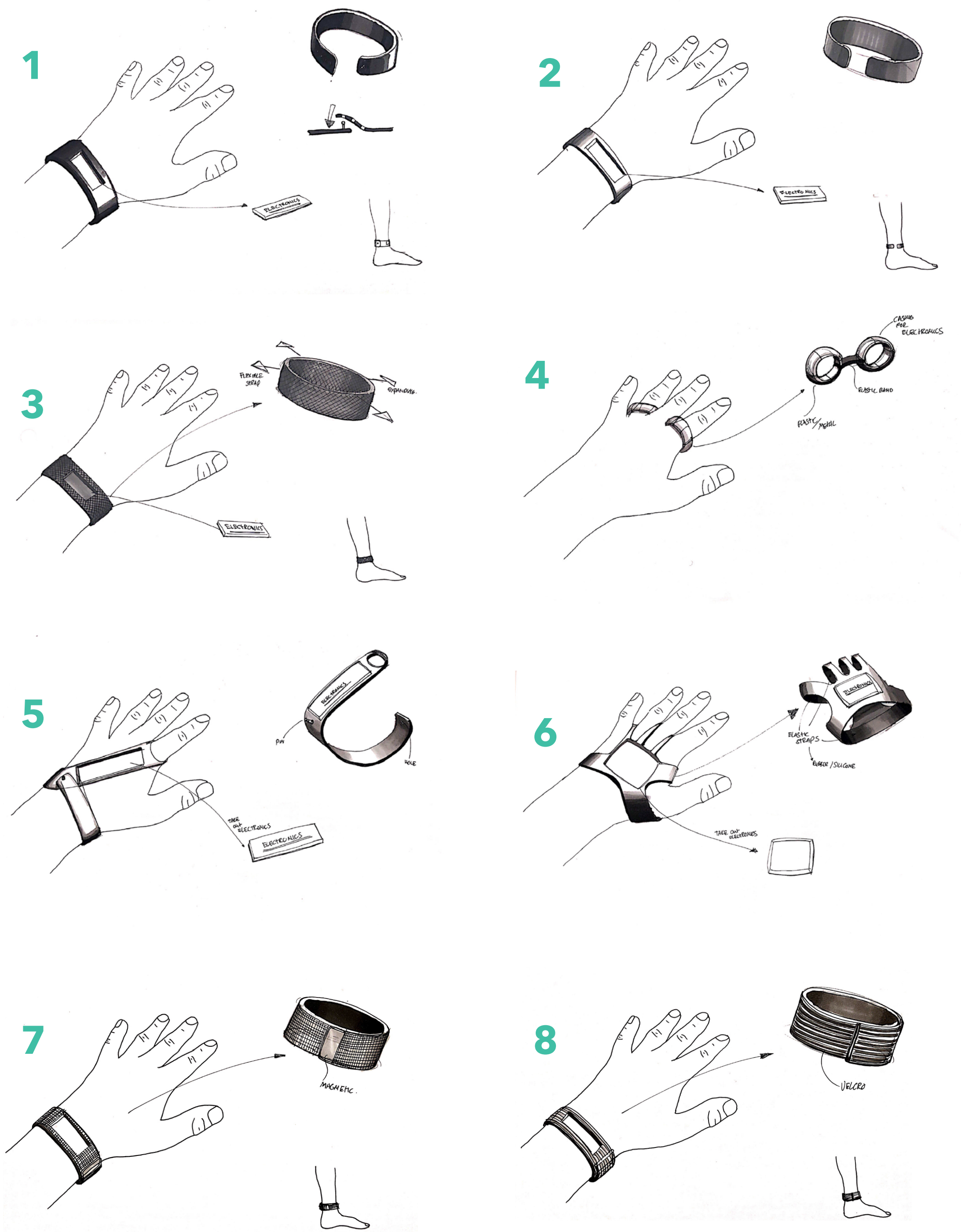
- Desirable to be easy stored when the product is not in use
- Desirable to integrate the design of the attachment with device(s)

There are already a lot of solutions for connecting a device to particularly the wrist of the user. The first step in finding the best solution is to look into the solutions which are already on the market.
We take a look at the Apple watch for instance (Figure:68). Apple has multiple solutions for bands that attach the watch to the user. Solutions like a magnetic band, silicon band, velcro and traditional. Each band have their own attitude and purpose.
Competitors like Fitbit (Figure:67) and Garmin also have a large variety in bands for multiple purposes.

Figure:68 Apple watch bands

Figure:67 Fitbit models

The solutions on the market together with the Partial problem solutions at page 49 lead to some first concepts of connecting the devices to the users' body. These concepts can be found left.
In order to choose an appropiate concept to develop further, several criteria is formed, based on Program of requirements at page 33. These criteria, together with their validations are visualised into multiple Harris profiles, which can be found on the next page.



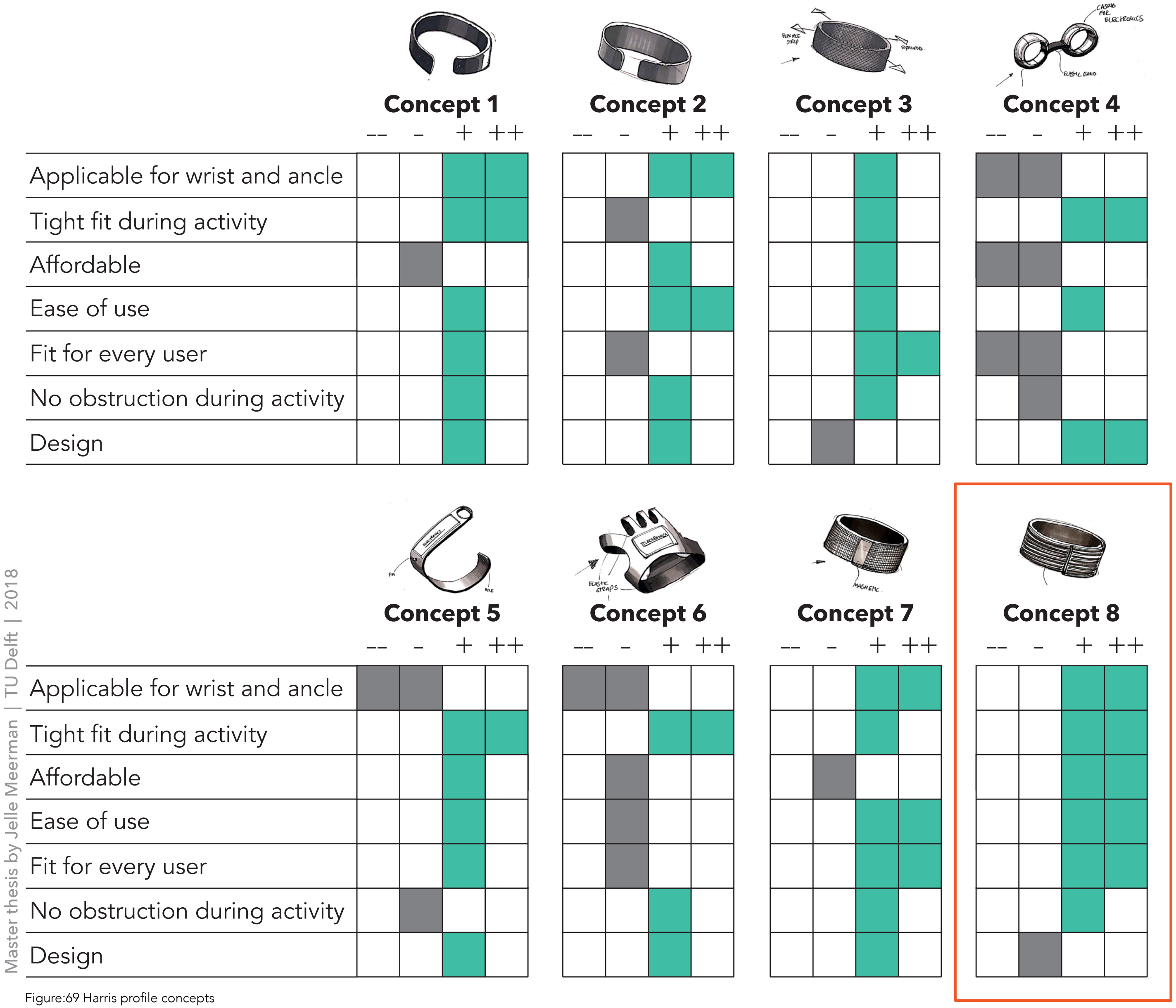


Figure:69 Harris profile concepts

As can be seen in Figure:69, Concept 8 (based on a velcro-like material) received the highest overall score. The only negative point to this concept is that the design of these velcro-like product does not always look appealing. But if we take a look at the velcro-like solutions of the Apple watch for instance, we could say that a proper design could be made from this concept, that a lot of people already want to buy/use.
Concept 8 will be developed further in the next stage: final design.

10.7
IDEATION CONCLUSION

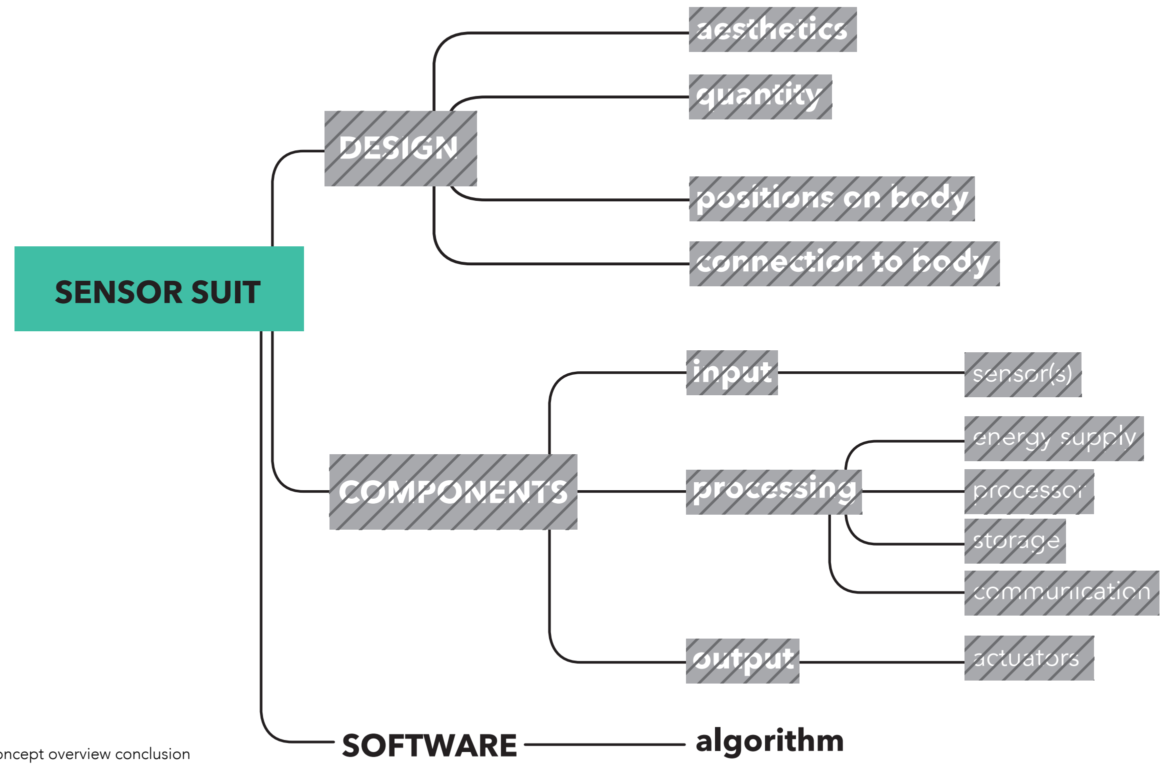


Figure:70 Concept overview conclusion

During the ideation phase, some additional insights were obtained. Within this chapter, the insights of previous chapters will be converted to requirements. These additional requirements can be seen in the green box.

If we take a look at the sensor suit overview Figure:70, more or less every subject is addressed and the proper solutions are found. The only subject which is not adressed within the ideation phase is software.

The reason why this is not included within the ideation phase is basically because software depends too much on the specific components and scenarios to be used. Due to this dependency, the software part of this product is reaching beyond the scope of this graduation project and is therefore left out.

All of the individual concept solutions will be integrated within the next chapter: Final concept.

ADDITIONAL REQUIREMENTS

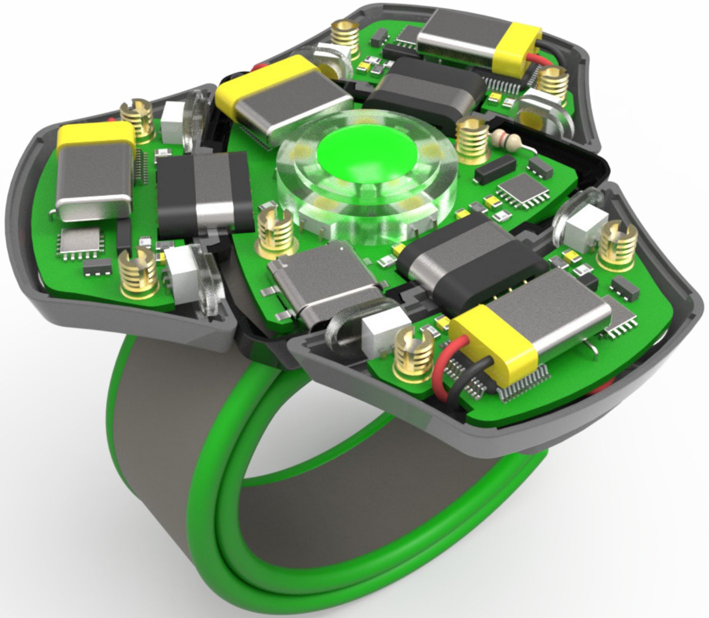
- The product should engage gaming adolescents
- The product should be suitable for both female and male adolescents
- The product should be applicable for different type of game-genres
- The product should consist of a product-service combination
- The product should make use of Master-Slave technology
- The product should recognise when the devices are attached to the body
- The product should enable low boundary (simple) communication between master and slave device
- The products should enable low boundary (simple) actuators within master and slave devices to communicate with user
- The product should be able to connected to possible future peripherals, to stimulate the physical activity even more

11
FINAL CONCEPT

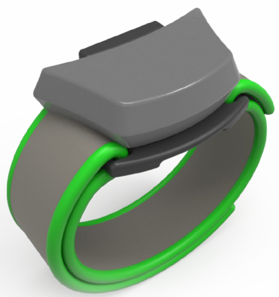
11.1 INTRODUCTION

Within this chapter, the aggregation of partial solutions, as mentioned in the previous chapters, will be described. These solutions together form the final concept.
First the overview of the final concept will be elaborated, followed by a materialization/production chapter, a cost price estimation, and a proof of concept.

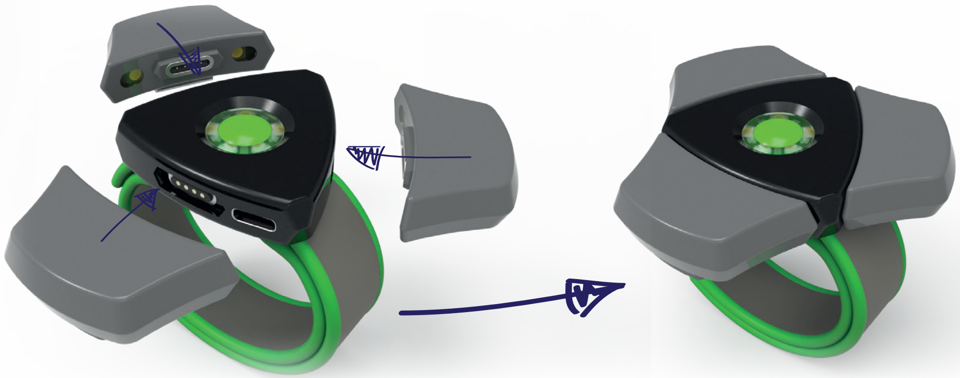
11.2 FINAL CONCEPT ELABORATION



The final concept called Move on, consist of 4 devices. 1 Master device and 3 Slave devices.
As mentioned before, the LED will indicate the state of the devices, whereas orange being the waiting time of 60 seconds when button is pushed, green being active and measuring, and red being the measurering session is finished and devices will shut down within 60 seconds. The different LED states can be seen at page 72.
Furthermore, each device will have its own strap connection and band, in order to attach the device on the users' body. Depending on the activity, the user will have 2 devices attached to his/her wrists and 2 devices attached to his/her ankle.
The following paragraphs will elaborate more on the specific components, attachment and internal structure of the Master and Slave device.



SLAVE DEVICE



ATTACHING DEVICES

MASTER DEVICE

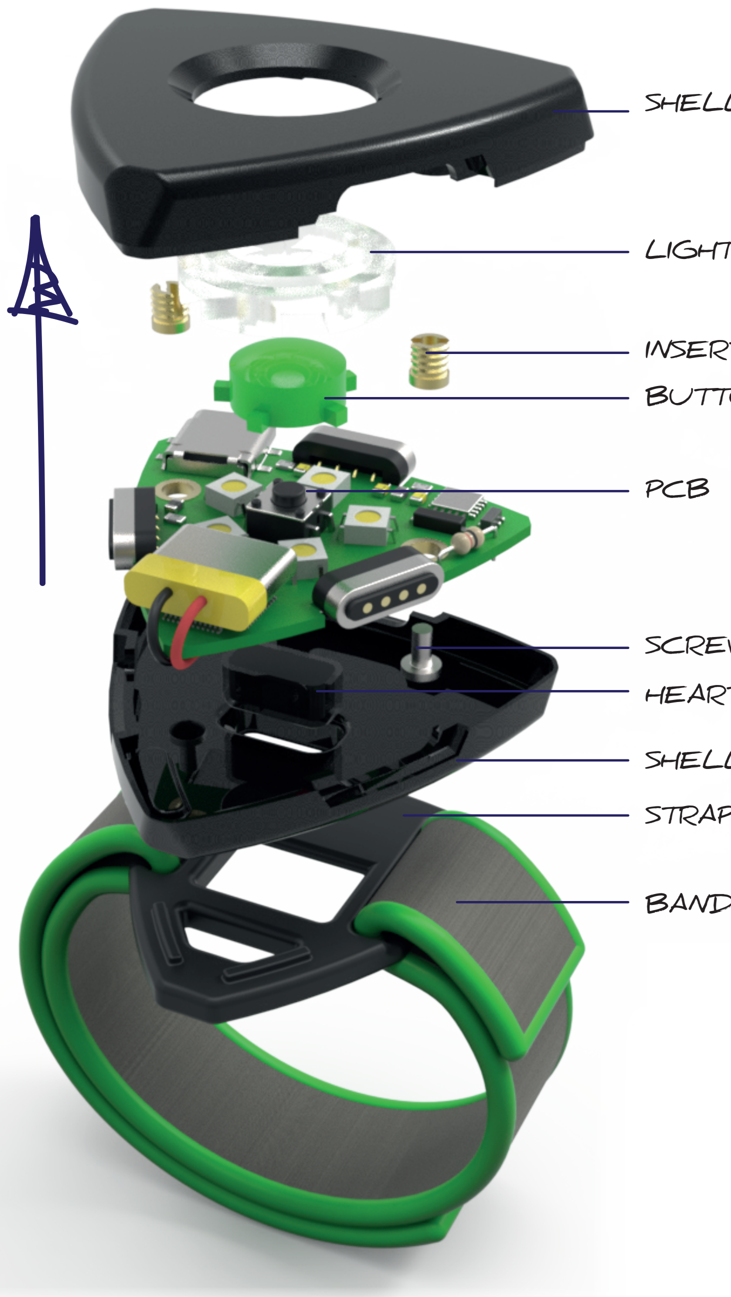


Figure:71 Exploded view master

Figure:73 Master bottom view, heartbeat sensor

11.2.1 Master device

As mentioned before, only 1 master device will be used within the final concept. An exploded view of the master device can be found in Figure:71. All of the different components are described in this figure. The device exist of two shell parts, the top shell and the bottom shell. These parts snap together when assembling the device.
The PCB can be considered the 'brain' of the device. To mount the PCB securely to the device, an M2 insert is integrated within the top shell in order to attach the screw.
Since the master device enables user interaction, such as lights and a push button, some extra parts are inserted, such as the light diffuser and the button. The light diffuser will make sure the LED light will be equally divided over the visible surface area. The button is held in place by the PCB and the light diffuser, while enabling minor displacement of the button when pushed.

The master device also includes the heartbeat sensor. This sensor is integrated in the bottom shell, in particular the clip, since this has to be closely connected to the user's skin (see Figure:73).

Figure:72 describes the attachment of the master device to the strap connection. The clip of the master device will fit the hole of the strap connection and will therefore be held in place.

Figure:72 Strap connection Master

Figure:74 shows an overview of the components mounted on the PCB. Some of them are elaborated below.

The USB-C component enables charging the battery via a USB cable which is plugged into the power socket. This component also enables the possibility to exchange data to a computer, for instance.
The 3 magnetic connectors enable data exchange between the master and slave, while charging the slaves' battery at the same time.

The vibration motor is mounted on the bottom of the PCB to enable the vibrations to have a direct inpact on the user.

Figure:75 shows the master device attached to both the wrist and the ankle of a user.

The technical drawings of the master device can be found in appendix J.

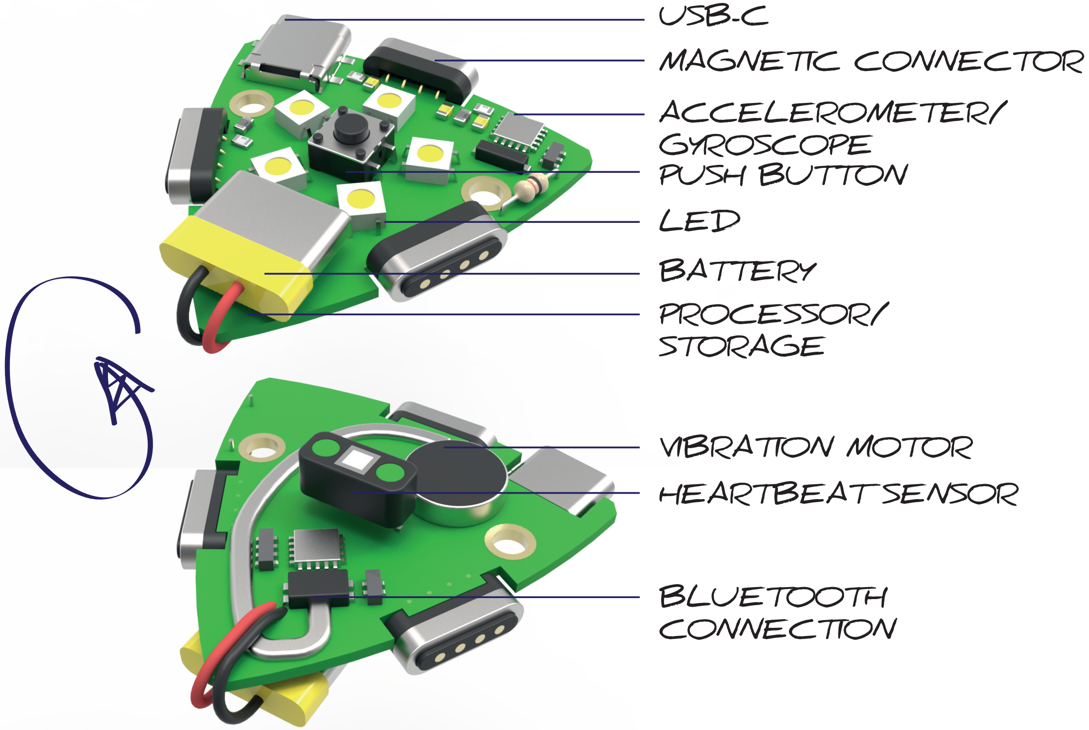
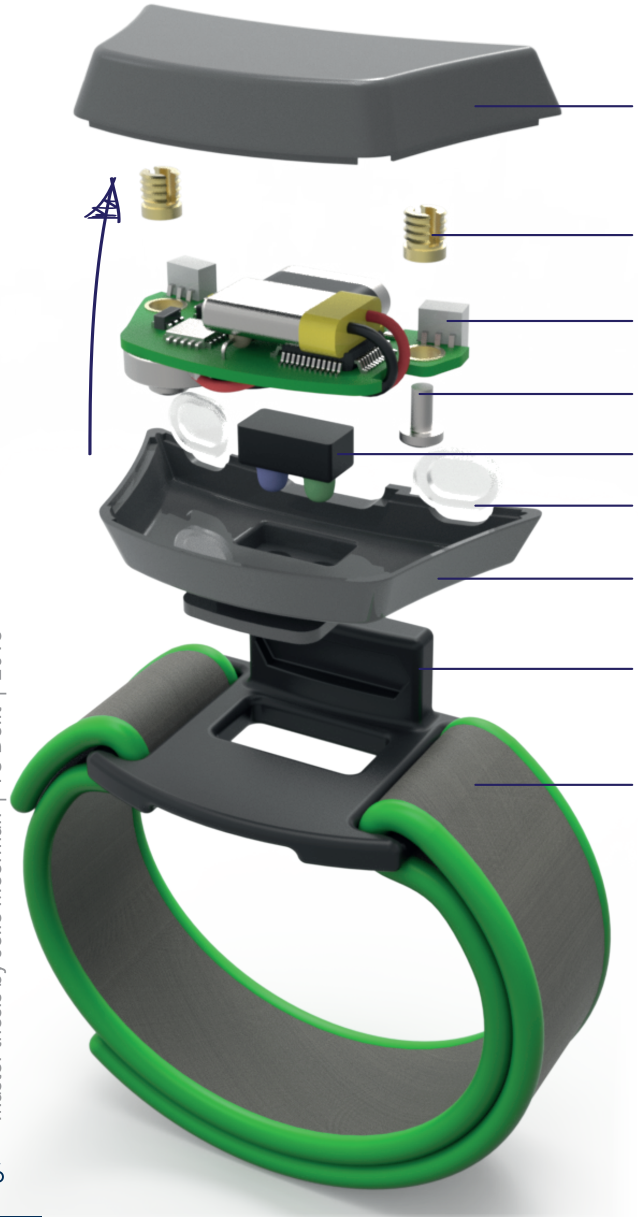


Figure:74 PCB board Master

Figure:75 Master device attached to user



11.2.2 Slave device

The final concept consist of 3 slave devices. The exploded view in Figure:76 shows the internal parts of the device.
The composition of the slave device is more or less the same as the master device, with a top shell and a bottom shell surrounding the parts. Also the PCB is mounted in the same way as the PCB in the master device, by an M2 insert on which a screw is mounted to secure the PCB.

The slave device does not contain a push button, unlike the master device. Also the LED diffuser is positioned in an other way than the master's. The LEDs of the slave device will shine in forward direction and are much smaller. This is done to form an embracing effect when connecting the slave devices to the master device (see page 72).

The proximity sensor is positioned in more or less the same way as the heartbeat sensor in the master device. Since the proximity sensor also needs to be touching the user's skin (see Figure:78).

The connection of the slave device to the strap connection is based on the same principle as the master device, as can be seen in Figure:77. The strap connection on the other hand is slightly different than the master's connection, since the 'wall' has an integrated space for the magnetic connector to fit in. This allows for an even more secure fit to the body.

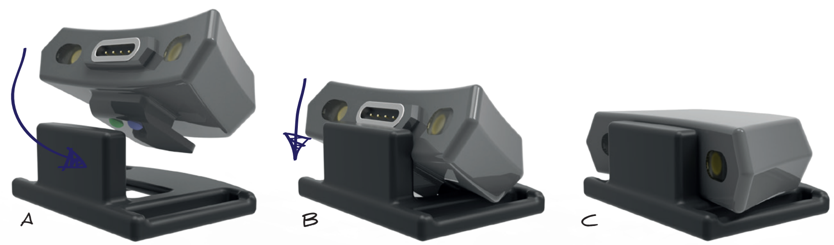


Figure:76 Exploded view Slave

Figure:78 Slave bottom view, proximity sensor

Figure:77 Strap connection Slave

Figure:79 shows an overview of the components mounted to the PCB.
As mentioned before, the LEDs are positioned in forward direction and are therefore mounted on the edge of the PCB. The magnetic connector found a central place on the PCB with the other components surrounding the connector.

The vibration motor is placed at the bottom of the PCB to enable the vibrations to have a direct impact on the users' skin.

Figure:80 shows the master device attached to both the wrist and the ankle of a user.

The technical drawings of the slave device can be found in appendix J.

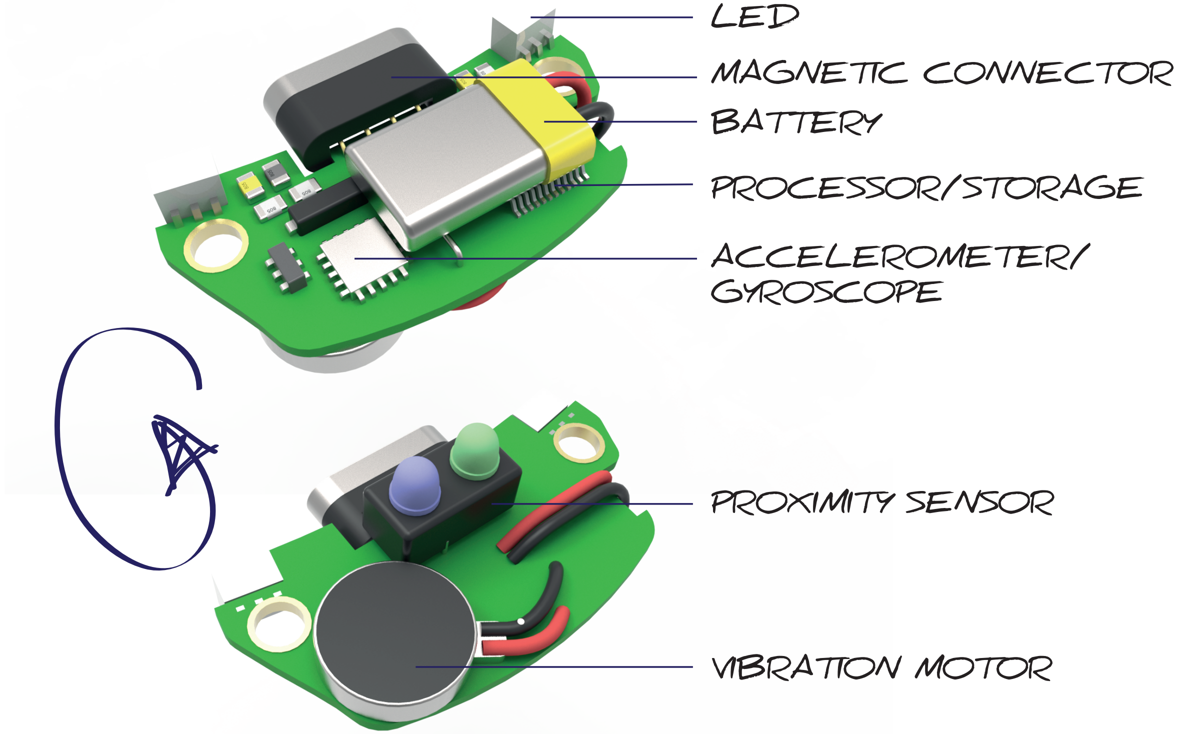


Figure:79 PCB board Slave

Figure:80 Slave device attached to user

11.3 PRODUCTION AND MATERIALIZATION

As mentioned in chapter 9, Exploration of business opportunities at page 50, the production will be divided into the first batch of 100 products to enable a user trial period. After this step the first production of approximately 10.000 products will be executed.
Since the quantities of the first batch and the first production will differ a lot, as for the suitable materials, this chapter will be divided into two sections: first batch and first production.

11.3.1 First batch

As can be seen in Figure:81, there are some parts that require a special design and some products that are already sold on the market and can therefore be purchased.
Products that can be purchased are:
- The PCB's including all of the components
- The inserts and screws
- The band

The rest of the parts require some special design and need to be custom fabricated. As the first batch will consist of 100 product-service combinations, a suitable production method has to be used. 100 products is a relative low amount of products in the world of production. 3D printing is a production method that enables a low amount of products to be made for low costs, while keeping special design characteristics and material properties into account. The shell parts, light diffuser, and button will therefore be 3D printed with an FDM printer.
The strap connection on the other hand has to be flexible to fit ergonomically to the user. Flexible material printed on a FDM printers does give the best result. Therefore the strap connection will be moulded with 3D printed moulds.

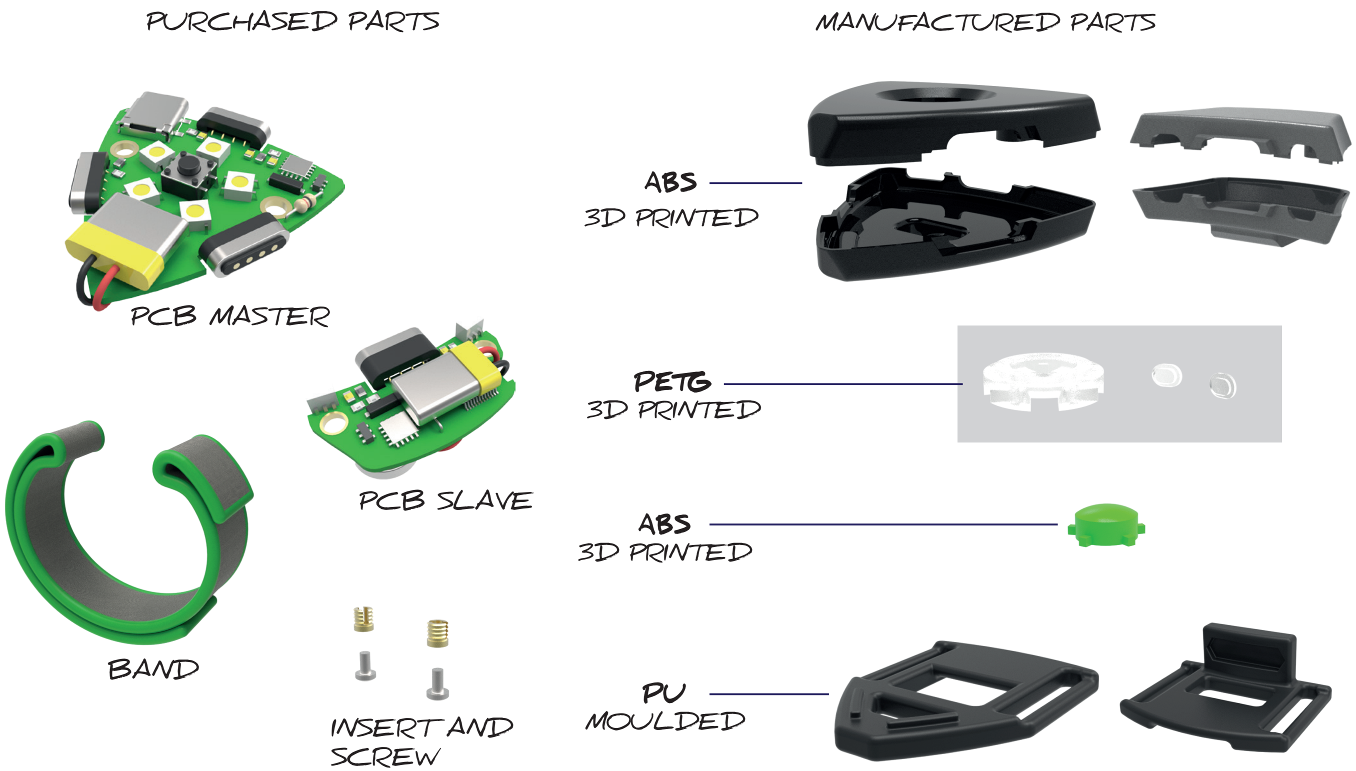


Figure:81 Purchase/manufactured parts first batch

11.3.2 Materials

The most common materials to use for 3D printing are PLA and ABS. The main shells and the button will be 3D printed with ABS, since ABS is a stiffer material than PLA and has a higher impact resistance. But the main reason to use ABS is the post processing advantage. When ABS gets in conctact with acetone vapor, the outer layer of an ABS print will vaporize slightly. Which creates a very smooth and shiny surface.
The diffuser parts for the LEDs will be printed with a translucent material, like PETG. PETG consist of clear filament, but when FDM printed, the layers will create a translucent appearance due to multiple breaking index.

As mentioned before, the connection straps need to be flexible. A good alternative for obtaining this flexible part is to 3D print the outer molds of the parts. This could be done with any ABS filament.
When the moulds are printed, they could be filled with a PU (two components Polyurethane) wax. Once the wax is dried the flexible parts can be taken out and are ready to use.

11.3.3 First production
As for the first batch, some of the parts need to be purchased and some need to be manufactured. An overview of the parts for the first production can be seen in Figure:82.

The purchased parts for the first production are the same as for the batch size, namely the PCB including components, inserts and screws, and the band.
As mentioned, the first production will consist of approximately 10.000 products. For this large amount of products, 3D printing will not be sufficient. A production method should be chosen which can handle a large amount of products.
Injection moulding is a product method that can handle this large amount of products with very high precision and good mechanical properties. Therefore the shell parts, light diffuser, and button will be injection moulded.
Injection moulding is also a good production method for producing rubber-like parts, which is also why the strap connection will be injection moulded.

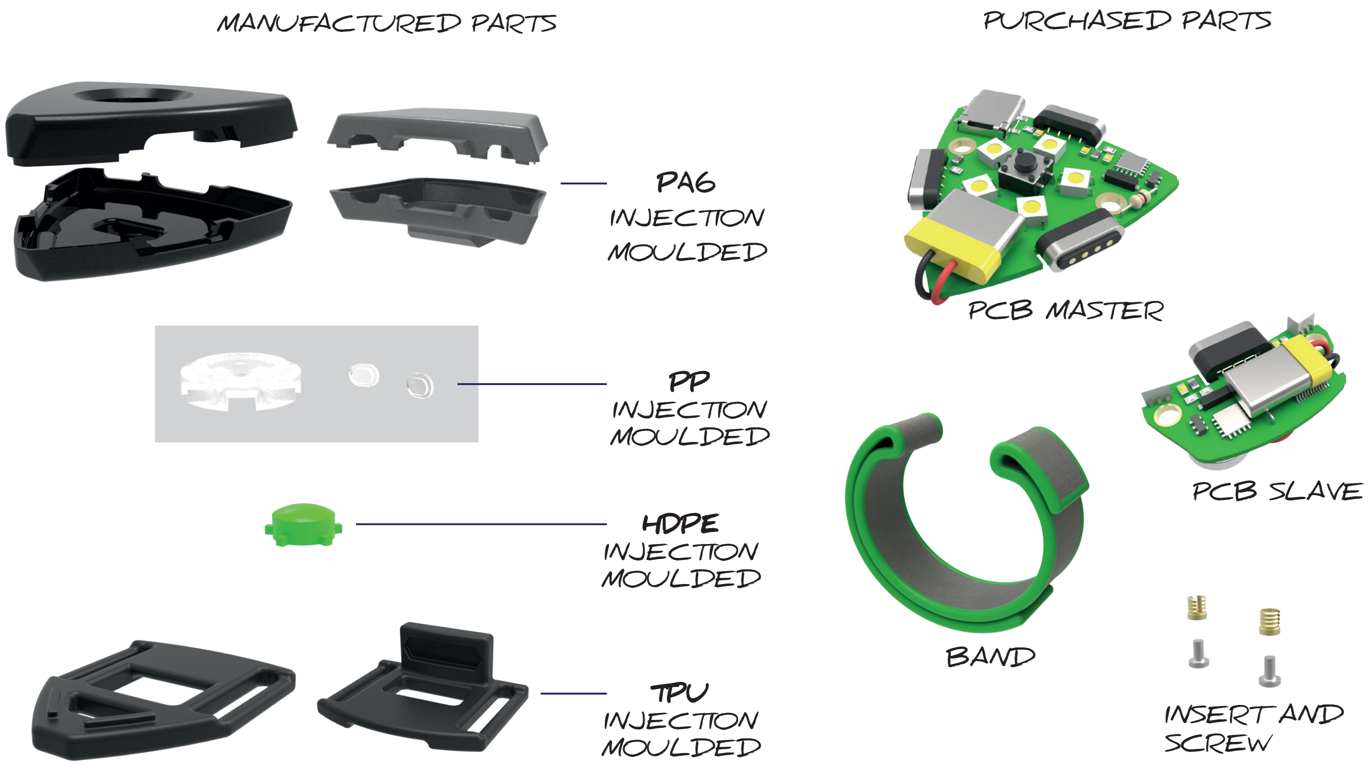


Figure:82 Purchase/manufactured parts first production

11.3.4 Materials
In order to choose a suitable material for the first production, the Cambridge Engineering Selector is used (CES). This program contains a database of a large variety of materials including their properties. For each related parts, a comparison has been made. These comparisons can be found in appendix K.

The shell devices need to have a high tensile strength, fatigue strength, and withstand high impact forces, since the products will be used outside and endure rough handling while being physically active. If we take a look at the comparison of the different polymers, there is only one polymer that stood out in terms of fatigue strength at a relative low cost; PA (Nylon). PA is also a well known material to use for injection moulding and is considered as a stiff and strong material. PA6 is the most common material to use and could even be glass filled (GF 20%, GF30%, etc.) to increase mechanical properties.
The button will not have such a high standard with regard to the fatigue or tensile strength, because it is enclosed within the shell devices. Therefore HDPE (very common for injection moulding, cheap, good mechanical properties) will be used for the button.

The LED diffusers have some special requirements, since they have to be translucent in order to see the lights. The other comparison, transparency vs. price shows that 1 material suits the requirements of being partly translucent and transparent at a relatively low cost.This is why the LED diffusers will be made of PP.

The material for the strap connection should contain a high tensile strength, since the strap connection can be stretched and bend a lot during its life-time. The last comparison is therefore made with regard to the elastomers; price vs. tensile strength. TPU is considered as a rubber-like material which can withstand very high tensile strength and could be injection moulded quite well.

11.4 PRICE ESTIMATION

In order to have an indication about the possible selling price, an estimation for the cost price is made.
This chapter describes the considerations that have been taken into account when determining the cost price for 10.000 products. One product is considered as the product-service combination including 1 master device and 3 slave devices.

	Per product
Investments	€ 14,74
Materials	€ 3,99
Purchase	€ 39,78
Assembly	€ 0,20
Packaging	€ 1,00
Shipping	€ 0,15
TOTAL	**€ 59,86**

Figure:83 Cost price estimation overview

The estimated cost price for the total product-service combination is settled for less than €60,- (see Figure:82). An important note to this price is that it is based on a lot of assumptions and will therefore slightly differ from the final cost price. The marketing costs for instance are not included for this estimation. This is excluded because the price can vary a lot for each game or per partner. What also should be taken into account is the exchange rate. Almost all of the prices are quoted in dollars and converted to euros with the current exchange rate of 1$ = €0.8763.
A detailed version of this estimation can be found in appendix O.

11.4.1 Investments

For the investments a couple of big expenses that have to be done once in the product life time, are taken into account. Expenses such as moulds, software development, and algorithm development.
In order to have an indication of the costs for creating the molds for injection moulding, a quote has been requested from a chinese company called ICOMOLD. The overview of this quote can be found in appendix M. The total costs for these moulds are €20.500,-.
The moulds are made of high quality stainless steel from which an 'unlimited' amount of products can be injection moulded.
For the software investments an estimation is made based on tips and trick achieved from Appspecialisten (2018). The costs for the software development are based on development by an external company, which contains basically the app and internal structure, and are estimated at €75.000,-.
The estimation for the algorithm development is based on conversations with ir. B. de Leeuw, data science engineer at KLM. For the development of this algorithm, experiments, collecting data and data implementation of various type of movements have been taken into account and is estimated at €50.000,-

11.4.2 Materials

The estimation with regard to the materials is also based on the quote of ICOMOLD and can be seen in appendix M. The price excluding shipping cost is used for this estimation.

11.4.3 Purchase

The parts to be purchased can be considered as the highest expenses of the product. An overview of the prices for the purchasing parts with the corresponding web pages can be found in appendix L. Most of the prices are based on bulk purchases and are therefore lower than single or small amount purchases. The parts that have the highest purchasing prices are the battery €8,31, band €7.36 and the magnetic connector €5,84. For the PCB's, two quotes have been requested at PCBway and cost around €0,40 (master device) and €0,30(slave device) per piece. These costs include soldering together of all of the electrical components. The quotations can be found in appendix N.

11.4.4 Assembly

For the assembly of the devices in total a brief estimation is made. Estimated is that a chineese worker costs around €3,00 per hour and can assemble approximately 15 products per hour.

11.4.5 Packaging

For packaging, a very rough estimation is made based on previous projects and contains cartboard and foam to keep the product in place when being transported.

11.4.6 Shipping

The estimation for shipping is based on the shipment per ship from Shanghai to Rotterdam. This contains shipping a 40FT shipping container which can contain up to 20.000 products (based on the assumption that the product will have a volume of 15cmx15cmx15cm).

11.4.7 Conclusion

The cost price calculation will not be the same as the selling price. A rule of thumb says that the actual selling price will be more or less 3 times higher than the cost price, due to distributors and shipping expenses. Thus we can say that the product will be sold for around €150,- to €200,-. Not taking any subscription fees into account.

11.5 CONCEPT VALIDATION

In order to have a validated concept, a proof of concept needs to be made. This chapter adresses the proof of concept, which is divided into several segments to test different parts of the product. First the physical model will be addressed, followed by a functional model, which will continue in a test for recognizing the user's motion.

11.5.1 Physical model

The final concept describes the strap connection between the band and the devices. This concept has not been tested yet. Besides the connection test, the overall appearance and feeling of the concept, for instance when attaching the slave devices to the master, need to be evaluated. Therefore a physical model is needed to test the strap connection of both the slave and the master devices.

11.5.1.1 Strap connection

Figure:83 shows the strap connection of the master device. Two concepts were created: a clip to grasp on the strap connection and a circular connection to twist the master device on the connection.
After 3D printing the clip connection and the circular connection, some conclusions can be made. The circular connection is a very smooth concept and looks appealing, only the mechanism will consume way to much space on the inside of the master device and will therefore not be integrated.
The clip connection does fulfill the need of the master device to stay secured to the users' wrist and does not require a lot of space. Furthermore, it is actually quite easy to attach and disconnect the master device with the clip connection. The only remark for this concept is the small button integrated within the strap connection. This button will consume too much space on the inside of the master device and will therefore be minimized for the next iteration.
Figure:84 shows the strap connecton of the slave device. This strap connection is based on the same principle as the master strap connection, but has a small 'wall' to make sure the slave device will be held in place even more. After 3D printing the connection and slave, it can be concluded that this concept complies to the requirements and will therefore be implemented. This first test does not include a hole for the magnetic connection to fit into, but this will be integrated in the next iteration.


Figure:84 Strap connection master device


Figure:85 Strap connection slave device


Figure:86 Variety of Move on devices


Figure:87 Move on devices


Figure:88 Master device in context of user


Figure:89 Slave device in context of user

11.5.1.2 Appearance

Figure:85 shows the various physical models of the final concept. Some different colours have been used to enhance the appearance. The magnetic connection between the master and slave devices does feel quite satisfying.
Figure:87 shows the physical master device in perspective of a users arm. Figure:88 shows the slave device in perspective of the user. The dimensions do fit the wrist of the user and thus it can be concluded than these are proper dimensions for further development of the final concept.

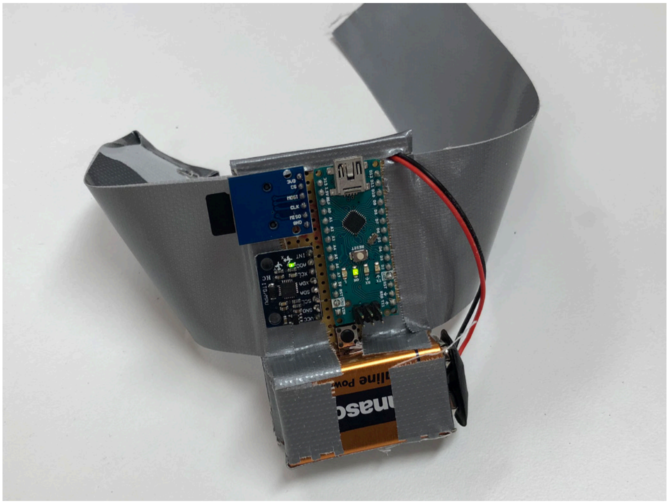


Figure:90 Prototype

Figure:92 Prototype attached to user's ankle

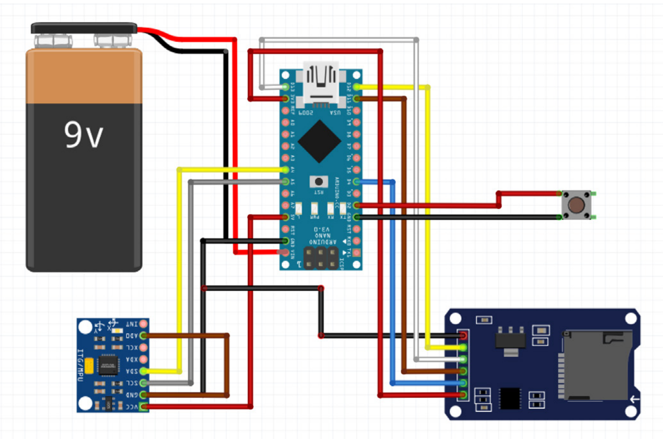


Figure:91 Schematic overview of electrical components

	session_id	G_x	G_y	G_z	A_x	A_y	A_z	is_walking
0	1	-1.55	-0.64	-1.44	0.14	-1.00	0.07	0
1	1	-9.77	0.59	6.98	0.11	-0.99	0.04	0
2	1	-17.57	-6.45	15.56	0.14	-0.98	0.02	0
3	1	-24.29	36.12	4.05	-0.21	-1.01	-0.10	0

Figure:93 Walking session

	session_id	G_x	G_y	G_z	A_x	A_y	A_z	is_running
0	1	-1.21	-3.21	-0.77	0.20	-0.98	0.11	1
1	1	-1.17	-2.42	-0.78	0.20	-0.98	0.13	1
2	1	0.05	-6.04	-3.34	0.19	-0.96	0.10	1
3	1	-1.18	1.92	1.35	0.22	-0.97	0.13	1

Figure:94 Running session

11.5.2 Functional model

In order to get a validated concept, it should be possible to recognize the users motions. To enable this validation step, a functional model has to be built that can actually measure the users motion.
Figure:83 shows the prototype that has been built in order to make registering motion data possible.
This prototype contains an MPU-6050 (accelerometer and gyroscope component) a Micro SD card reader, a push button, a 9V battery, and an Arduino Nano.
Figure:84 shows a schematic overview of the electrical wiring between the different electrical components.

The Arduino Nano is programmed to start a measurement session when the button is pushed. From this moment the MPU-6050 will start to register the orientation (G) in the X, Y, Z, -axis and acceleration(A) in the X, Y, Z, -axis every 0,1 second. The orientation is measured in degrees (°) and the acceleration is measured in G (x 9.8 m/s^2). This data will be uploaded to the Micro SD card in order to have a wearable device (wherein the battery is the external power supply). Once the button is pushed again, the session will end and measuring will stop. A next session will start when pushing the button again and end in the same order, to create a datasheet with multiple sessions following each other.

For the first proof of concept the comparison between running and walking is made. Figure:85 shows a user with the prototype attached to his ankle. This user executed two tests. The first test contained 25 sessions of walking for 30 seconds and the second one contained 25 sessions of running for 30 seconds. Some data of the first sessions can be found in Figure:86 and Figure:87.

11.5.3 Recognizing motion

The list of data obtained by the test sessions, described in the previous chapter, serves as a base for processing the data to recognize the motion of the user.
Ir. B. de Leeuw helped me to process this raw data into some feasable recognition results, the entire processing of data can be found in appendix .
The aim for the results of this machine learning processing is that at least 80% of the user's movement should be predicted correctly.

11.5.3.1 Processing data

In order to start processing the data, it has to be checked for any irregularities first. After this check, the data can be implemented and processed.

The first steps of processing this data begin with calculating the summary statistics of all of the sessions of walking and running. The summary statistics containing: mean, standard deviation, and skewness, are used for this process. These statistics describe the processed variables for the combined data per session. Which basically means that for each session the mean, standard deviation, and skewness is calculated for the combined Gx, Gy, Gz, Ax, Ay, and Az (see Figure:89).

11.5.3.2 Machine learning

The next step is the actual prediction, reflecting, of the data, due to the implementation of machine learning. Since the amount of sessions for this first tests was quite low, the data is divided into two parts. 12 sessions of walking and 12 sessions of running, will guide as a reference for the final prediction (training). The remaining 13 of the walking sessions and 13 of the running sessions will be used for the actual prediction (testing).
This prediction will be done by comparing the summary statistics of a test session to the training session. This is done for each of the 26 remaining sessions.
Eventually a summary is shown for each of these

```
A_x        mean   -0.401600
           std    -0.096396
           skew    0.902116
A_y        mean    0.234508
           std     0.780118
           skew    0.610124
A_z        mean   -0.905986
           std     0.614535
           skew   -0.817065
G_x        mean    0.199314
           std     0.799420
           skew   -0.161461
G_y        mean   -0.301832
           std     0.786469
           skew    0.917505
G_z        mean    0.347096
           std     0.796165
           skew   -0.377987
```

Figure:96 Summary statistics

```
Predicted True  Result
----------------------------
walking   walking  Correct
walking   walking  Correct
running   running  Correct
running   running  Correct
walking   walking  Correct
running   running  Correct
running   running  Correct
walking   walking  Correct
running   running  Correct
walking   walking  Correct
running   running  Correct
walking   walking  Correct
running   running  Correct
walking   walking  Correct
walking   walking  Correct
walking   walking  Correct
running   running  Correct
walking   walking  Correct
running   running  Correct
running   running  Correct
running   running  Correct
running   running  Correct
walking   running  Wrong
walking   walking  Correct
walking   walking  Correct
walking   walking  Correct
```

Figure:95 Outcomes of machine learning data

sessions with the predicted outcome, the actual outcome, and the result (Figure:88).
It can be stated that these outcomes of the machine learning implementation give some good results. Only one of the sessions was predicted wrong which therefore creates an accuracy of 96%.

11.5.3.3 Conclusion

It can be concluded that an accuracy of 96% is really high and a good result. This satisfies the aim of 80%, stated at the beginning of this process.

11.5.3.4 Evaluation

Some remarks need to be made according to the results of the machine learning implementation.

- Although the accuracy was quite high, in future implementations this could become even higher. Sessions of 30 seconds in general do not give the best results, since the amount of data is very low. If the amount of time per training session is increased to 30 minutes for instance, more detailed data and even a higher accuracy could be obtained.

- This test implementation is only done with the motions walking and running. Eventually more specific motiotions should be added to the training session in order to recognise even more. You can think of motions like swimming, climbing, kicking, punching, dancing, jumping, stretching, crawling, etc.

- The sessions for walking and running are performed by one person. Obviously these sessions should be performed by multiple participants to eventually create a substantial general set of data to be used as a reference.

- The tests are executed with only 1 accelerometer and gyroscope. In the future all 4 devices should be combined.

12 RECOMMENDATIONS

This chapter will describe the future vision of the Move on.. and additional changes that need to be done in order to develop the concept even further.

FINAL CONCEPT

The final concept, especially the shape and connection to the user, has not been tested with the target group yet. One of the first steps for future improvements should be testing if the concept does fulfill the needs of the users. In particular the attachment to the wrist, ankle and checking if the shape of the concept is appealing enough for the users to buy. These tests should be conducted with a large group since we want the product to be bought and used by a large variety of adolescents.
The results of these tests should be implemented to the first iteration step. After this iteration step the first batch should be deployed.
A possible feature for any future developments could be to create a large variety of hardware casings, covers or bands. This enables the user to customize their product which enhance the user satisfaction.

KEY PARTNERS

Something which is still a bit uncertain with regard to the Move on concept, is the actual games or companies that are willing to partner up. After finalizing the concept with some user tests, looking for potential partners is the first next step in the elaboration. These partners need to be found, since the concept can not be functioning by itself. When partners are found, the rewarding system can be adjusted specifically for each game and in particular the motion rewards.

Of course, to arrange any partner deal, some possible rewarding systems could already be elaborated, but this will be done at a prototype level.

APP POSIBILITIES

Once the key partners are found, the engineering of the application (app) can also be executed. This app should be able to convert the performed physical activity to a particular reward for the user's desired game.
Some new features can be implemented in this app, such as:
- *Augmented reality integration.* When the smartphone is pointed at the Move on, the avatar of choice (could be different for each game) can be projected. It could be possible to literally see the physical input change the avatar when connecting. The legs can grow bigger, for instance.
- *Educational health.* It could be possible to educate the adolescents on the performed physical activity. They could for instance learn about different type of muscle groups working together when performing different type of motions, which can be seen as an intrinsic motivation to be more physically active.
- *Geo targeting.* A possible feature could be to integrate Geo targeting into the app. This implementation will also create an extra extrinsic motivation to start being more physically active. For instance, a user could run/walk to a specific location to gather a 'package' and receive some extra rewards.

PRICE ESTIMATION

Some estimations have been done with regard to the price estimation. Some of them need to be investigated further in order to set a determined price. Since the purchased parts are the highest expenses, these need to be investigated further. Instead of checking the prices at distributors, potential suppliers should be contacted with the aim for solid deals, while negotiating about bulk prices.
Shipping prices, packaging costs, and assembly costs should also be elaborated even more.

SECURITY OF DATA

The last couple of years, laws and regulations concerning data security has been considerately tightened. Data which is collected from users/ customers should be kept secure to prevent possible data leakage. That is why the Move on concept should be elaborated more on securing this data. A possibility could be to immediately convert the measured data to 'game points', when connected to the application. In this way no raw data will be stored.

PLAY TOGETHER

As mentioned in the Program of Requirements, adolescents/children like to play with others. The stimulation of physical activity could be enhanced even more, if the product allows for playing together. For instance the adolescents could achieve twice the amount of rewards when another Move on product is located in the area. It could also be possible to solve specific quests together, while wearing the Move on, in order to create a higher reward.

PERIPHERALS

The aim for the concept was to create a generic device to measure various type of motions. Nevertheless, the measurement system of the Move on has its boundaries when speaking of register motions.
A potential marketing feature could be seen in selling peripherals. Those peripherals could be measuring particular motions that are not able to be registered by the product. Peripherals like a small throwing rocket (like the Nerf: Vortex) or a soccer ball, to measure even more type of movements and obtain even higher rewards.

ALGORITHM

As mentioned in the previous chapter, the algorithm for recognizing motion also need to be elaborated.
- The time per 'training' session should be increased to obtain detailed data and a higher accuracy.
- More specific motions should be added to the training session in order to recognize more. Motions like swimming, climbing, kicking, punching, dancing, jumping, stretching, crawling, etc.
- The training sessions should be performed by multiple participants with a large variety of people, such as gender, length, BMI etc., to eventually create a substantial general set of data to be used as a reference.
- The tests are executed with only 1 accelerometer and gyroscope. Eventually all 4 devices should be incorporated within the algorithm.

SUSTAINABILITY

For now, the concept is not specifically designed for sustainability, although it has partly been taken into account. For instance, the components will be assembled without any adhesive, only screws and form interlocking parts, which also allows proper disassembling the product. Therefore, recycling of the specific components can be done quite easily.
If we want the product to be really sustainable, circular economy strategies should be taken into account. Also the chosen materials should be reconsidered.

POWER SOURCE

For now, the power for the concept will obtained by the small batteries integrated within the PCB. These batteries are charged by the USB-C connection in the master device. In the future, some other charging possibilities could be considered. You can think of possibilities like inductive(wireless) charging or charging by motion. These possibilities are too expensive or too big to fit within the devices for now. Nevertheless, future technologies could make this possible.

13 EVALUATION

In this chapter the evaluation will be addressed. This evaluation is divided into two parts: Project evaluation and personal evaluation.

13.1 PROJECT EVALUATION

In order to evaluate the project I want to look back at the initial set-up of the project, which can be considered as the graduation assignment supplemented with the design goal and the program of requirements.

GRADUATION ASSIGNMENT

If I compare the deliverables in the graduation assignment to the performed work in this thesis, I can say that in general the project worked out the way I intended it to be. I managed to build a physical model and a (partly) functional model. I unfortunately did not have enough time to actually test those models with the target group.
The approach on the other hand changed quite a bit in comparison to the graduation assignment. Especially phase 3, 4, and 5 have changed.
It can be said that the initial approach did not include any iteration steps. It was more or less based on a chronological approach for a simple product creation. Due to the complexity of this project, some iteration steps had to be made, which resulted in three smaller ideation phases.
This is possibly also the reason why I did not have enough time to validate the final concept with the target group.

DESIGN GOAL

At the end of the analysis phase I stated the design goal:

"I want to create a product that stimulates the physical activity of adolescents (12-17), in order to prevent health issues and maintain emotional well-being, while focusing on the advantages of screen time".

When comparing the final concept to this design goal, not a clear approval can be made. As discussed in the recommendations, further tests and research should be done in order to see if the product actually stimulates the physical activity.
As far as I can say, I think that if some of the bigger gaming companies will collaborate, the product will definitely have a positive impact on the user, both physically as mentally. If this product does reduce the actual screen time of adolescents, is hard to say. In my opinion, I think that the screen time of adolescents will remain the same, even with using the Move on.
But the physical and mental well-being of the adolescent will definitely be increased.

PROGRAM OF REQUIREMENTS

If I compare the final concept to the program of requirements, it is hard to clearly say that the final concept succeeds every requirement. The potential for the final concept is there to eventually fulfill every requirement. But elaborated research or tests have to be executed and the final concept have to be elaborated more to fulfill all of them.

13.2 PERSONAL EVALUATION

PROJECT DIRECTION

The project for me had a bit of a rough start. I knew I wanted to do something with online rewards for offline effort, but I had no actual direction to go for.
At the beginning I also did not know if I wanted to start the project for a company or for myself.
Due to these uncertainties, the first part of writing the graduation assignment therefore took more time then estimated.
At a certain moment I figured that it would be the best possible moment for me to create a product (company) for my own and therefore I choose not to initiate the project from a company, which would result in relinquish the intellectual property of the final concept.

MOTIVATION

Within the analysis part, I really had some difficulty with stimulating myself to convert the read literature to a piece of text of my own, but after some particular literature, I found out that some contemporary problems like, digitalization among children and their decreasing level of physical health could be perfectly integrated with the online/offline rewarding system.
This actually gave me the feeling that the product eventually could have a positive effect on modern society, which stimulated me to 'Move on' and finish the analysis phase of this thesis.

This lack of motivation could also found its origin in the fact that I worked a lot of the time at home when performing literature research. At the end of the analysis phase I noticed that the environment of the Industrial Design Engineering faculty really was a better place to work on my graduation than working at home.

After the analysis part, the more exciting phase of the design process started for me. The reason I chose the master Integrated Product Design is because I really like to create something feasible out of nothing.
So imagining ideas in your head and elaborate them further and further to finally have a (physical) product that solves the initially stated problem.

AUTONOMY

One thing I also noticed, in particular during ideation phase is that I really like to discuss about the ideas with other team members. Sometimes I missed the involvement of team members who keep you focused during one of the many discussions.
Since the finalization of my Bachelors degree, this was the first project that I executed completely on my own. Nevertheless I found enough people to discuss my ideas with and they gave me feedback when it was needed.

FUTURE PLANS

As mentioned before, the initial set-up for this graduation project was to eventually build a start-up, based on the project. When looking at this from the perspective I am now, I still have the same attitude as in the beginning of this project and my eagerness to actually move on with this topic grew even more.
After more than 8 years of studying I can say that I really look forward to this next step in my live as a person, but most importantly as an industrial designer and future entrepreneur.

14
ACKNOWLEDGEMENTS

First of all, an indescribable thanks to the never-ending support from my family and especially my parents and brother, the ones who made it possible for me to be where I am today.

I would also like to extend my gratitude to my supervisory team, Wilfred van der Vegte and Mathieu Gielen for their wisdom during every meeting and keeping my feet on the ground during the process. The fact that you always made time for me, when I unannounced walked by your offices, really felt like you were there for me.

I would like to acknowledge Frido Smulders and Vici Pavlic for giving me advice on the business perspective and guiding me into the right direction.

I would like to acknowledge Bradley de Leeuw for actually performing the machine learning implementation and advice how to get the data ready.

I would also like to thank:
- Jannes Nelissen for making my 3D printed flexible connections possible, for his time for giving me advice, even though I sometimes did not do anything with it.
- Ben Kromhout for help me out with the Arduino programming and advice.
- Jasper Barsingerhorn for proofreading this thesis.

Lastly, I would like to thank everyone who supported me along the way of delivering this master thesis.

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16
FIGURE LIST

MOVE ON