Hobble

stimulating physical play in children with cancer

Master thesis
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STIMULATING PHYSICAL PLAY IN CHILDREN WITH CANCER

graduation project by
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Delft, March 2018

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SPECIAL THANKS

Boudewijn Boon;
Marco Rozendaal;
Quiel Beekman and her research for POKO;
Janjaap van der Net, Patrick van der Torre, Peter Bekkering;
Jannie Dijkstra;
the children and staff of child care centres Merijn and Marie;
the children and families that participated in my research;
my proofreaders: Isabell Trinh, David Jiminez-Lluva, Midas Delnooz, Leisan Luu, Thomas van 't Groenewout, Paula Scheenloop, Dilara Hos and Thijs Schippers;

Chan Hung Luu, Tohoa Luu-Tran, Leisan Luu;
and all the friends that kept on believing in me.

EXECUTIVE SUMMARY

The aim of this project was to stimulate young children with cancer to engage in physical play to decrease the stagnation of their physical development. Children from the age of 2 to 5 are in the middle of their physical growth and development. This is also the age group with the highest risk of being diagnosed with acute lymphoblastic leukaemia (ALL). The disease and treatment cause stagnation in the children's physical development. The body focuses on fighting the disease and that stops the children from moving and playing because they feel weak and insecure. Therefore, the goal is to create a (home) situation in which young children with ALL can freely play, while doing therapeutically relevant movements without professional supervision. What is missing from the current solutions like exercise programs from physiotherapists is a solution that attune to children's natural way of engaging in physical activity, namely through physical play. Such solutions acknowledge the child as a child again, rather than a patient.

Therapeutically relevant movement

The threats of ALL should be dealt with to heighten the chances of recovery and to keep the delay in the child's physical development to a minimum. This is precisely the focus of physiotherapists during the treatment of the child. Because every child is different and every cancer affects children differently, physiotherapists state that it is impossible to create something that focuses on specific movements for all children with ALL. Instead, physiotherapists settle for focusing on broader muscles groups and movements. Therefore, the focus of this project will be on three important general movement categories: locomotion, torso and power. These areas are affected by the disease or treatment and are important for the recovery and development of the child.

Play as intervention

The mainly exercise-based solutions of most products are not very suitable for young children; their physical activity is generally more spontaneous and intermittent, characterized by short bouts of activity. Young children's physical activity is play. Hence, it is only natural and appropriate to allow children with ALL to play and elicit the physical activity that physiotherapists want to see through playing. How do we control play, an unstructured and self-directed instinct of the child, without structuring and regulating it? Through the variable that parents and designers do have control over: toys. The three Playscapes perspectives will be used as a guideline to design a toy that is bodily, dispersed and free in play (Boon, Rozendaal, van den Heuvel-Eibrink, van der Net, & Stappers, 2016).

At home

The home is the chosen context for this project because 90% of all the children with ALL will be sent home after their chemotherapy sessions. At home they do not have the physiotherapists' watch or professional control over their behaviour and movement, so there is a lack of (professional) guidance. However, the children should still be physically active to ensure their immune system recovers faster and they are strong enough to fight back the cancer. Making sure the toy stimulates the movements that physiotherapists recommend will give the parents confidence and consequently transfer that confidence to the children.

It is important to try and elicit the child to start playing as soon as possible after getting treatment. Even though the child might feel weak, the child should still be stimulated, but not forced, to start to play. Enhancing the ways the child can play within the normal home environment should give the child a feeling of

		FOCUS POINTS		
RQ1	Children with ALL	Locomotion	Torso	Power
RQ2	Playscapes	Bodily play	Dispersed play	Free play
RQ3	Home context	Safe and 'normal' environment	Elicit/Stimulate play that fits the energy level as soon as possible	Empowerment through a sense of control

Table 1: An overview of the focus points resulting from the research.

familiarity, safety and trust. Thus the layout of the home should stay mostly the same and the toy should fit in with the general furniture, like tables, chairs and coffee tables.

Lastly, the children should be empowered through a perceived sense of control. Keeping the home environment as close as possible to how it was when the child was not sick, 'normal', can do this. By giving children self-direction and allowing them to make decisions for themselves greatly increases the child's well-being and confidence.

All these insights were brought together into an overview of focus points for this project.

Hobble

Through iteration phases of prototyping and testing, the concept Hobble was created. The main intention was to hide therapeutically relevant exercises and movements in the toy, so the children could freely play. To test this, a simplification of the concept was build as a prototype. This version of Hobble can walk forward by means of two wheels that can be switched for others. Each set or combination of wheels changes Hobble's behaviour and walking pattern. It gained a different personality with different walk patterns and different wheels.

Testing with healthy children

According to the interviewed physiotherapists and the parent:

> *"..children with ALL are just like normal children except a little bald."*

This is true for the most part, but of course these children are sick. Their energy levels are lower and they feel nauseous, so the frequency and the intensity of their physical activity will be lower than healthy children. However, they should still be able to play as long as they feel confident and safe. Therefore, the focus for the user tests would be the same for children with ALL: does Hobble stimulate children to physically play? And does it elicit locomotion and using the torso during the play as intended?

Hobble was tested with fives families with healthy children between 2 to 5 years old (plus one extra 6 year old). The result are that Hobble's characteristics and role change, dependent on the child's interpretation of the wheels and its walk patterns. Hobble can walk, chase, follow, stunt and get stuck. Free play is very much stimulated because the child can interpret the toys characteristics.

Hobble has a hard time walking straight and is intentionally clumsy so it needs help often. This stimulates locomotion and gives children a sense of control that boosts their confidence and motivation to play more. Thus, Hobble elicits therapeutically relevant movement of locomotion

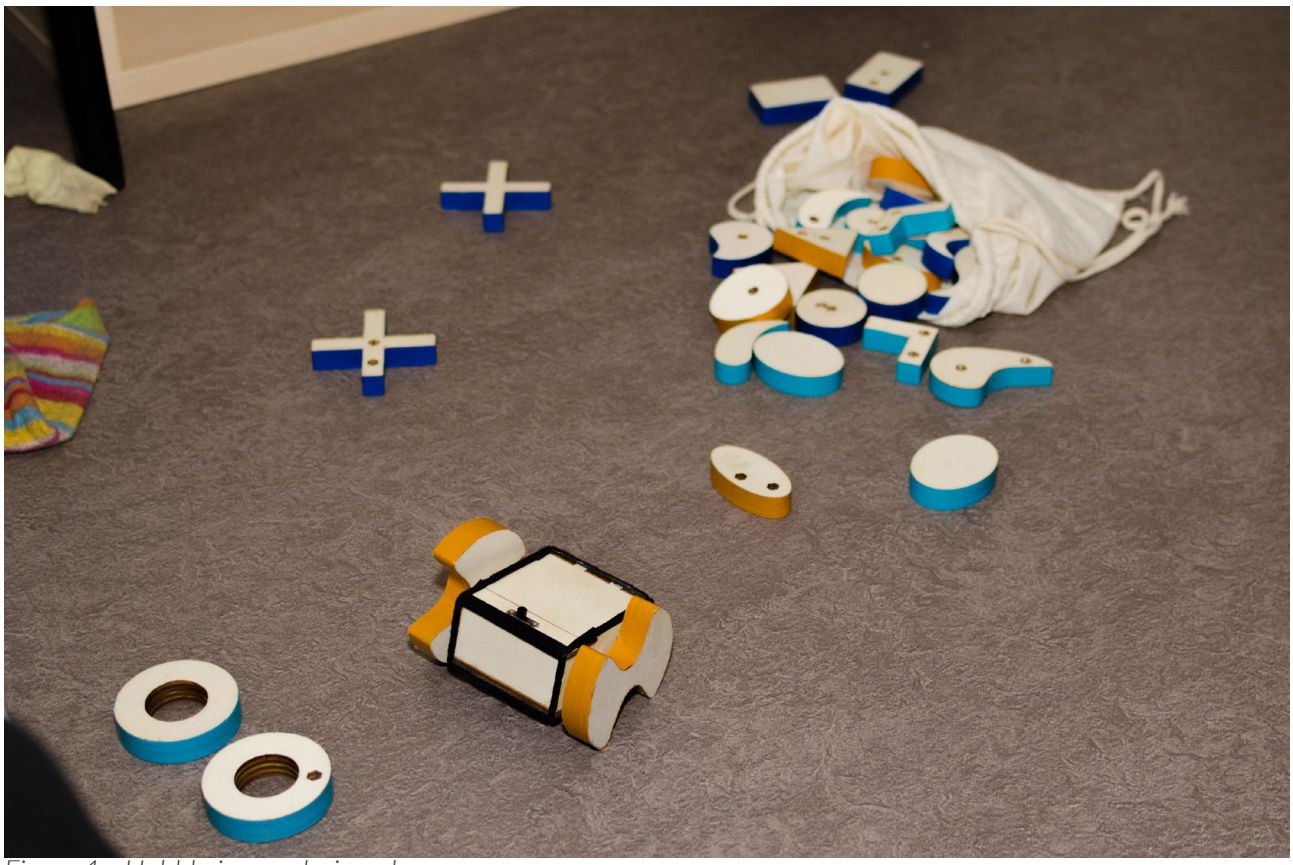

Figure 1: Hobble in use during play.

and using the torso that the physiotherapists want to stimulate. Ultimately letting the children play naturally like any other child while getting healthy. The helplessness of the toy can help in empowering the children: The toy is something they have control over and can help.

Validation

The initial idea was to create three walking toys that interacted with each other and Hobble was just a simplification of the idea for prototyping. However, after the results were analysed and evaluated through the Playscapes perspectives, a singular Hobble seemed to be enough. Hobble had shown that the intended bodily, dispersed and free play were already present in the play, It demonstrated it has the potential to fulfill the needs without the additional complexity of a three parts Hobble design. Although the results of this study with healthy children are representative for children with ALL, to properly validate the concept with certainty, a study with children with ALL should still be done.

Lastly, the insights made throughout this research were combined into the final concept, which should be further explored through additional prototyping and testing.

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1

INTRODUCTION

This graduation project is positioned within the 'Meedoen=Groeien!' project, a collaboration between the Dutch Rehabilitation fund, the Princess Maxima Centre for paediatric oncology, and the Delft University of Technology. This project's goal was to design something that would stimulate physical play in children with cancer. The introduction starts with some background information to illustrate the problem and the context of this project. Following this, the project goal and 4 research questions are stated. At the end, the design process that was followed is described.

Introduction project

The biggest cause of death of children between the ages of 2 and 11 years old is cancer. (CBS, 2016). Of all the cancers, leukaemia is the most diagnosed cancer with a percentage of 30-35% with children between 0-18 years old. Within leukaemia, 85% has acute lymphoblastic leukaemia (ALL), making ALL the most common cancer. Young children between the ages of 2 to 5 years old have the highest chance of getting diagnosed with ALL (Bekkering, Hartman, van der Torre, & Beishuizen, 2016). During these years children are in the middle of their physical development and growth, but ALL forces the body to redirect the focus completely towards dealing with the cancer. This usually results in their physical development stagnating. Physical development not only involves health-related fitness but also mastering a set of motor skills upon which children will rely on in later life (Caspersen, Powell, & Christensen, 1985). General movement categories recommended

by physiotherapists might be relevant during periods of hospitalization or rehabilitation (interview in appendix A). For example, squats to enhance the leg muscles for muscular endurance and strength (health-related fitness). Or running to enhance the leg muscles for balance (motor skills) (Strong et al., 2005). These mainly exercise-based solutions are not very suitable for young children; their physical activity is generally more spontaneous and intermittent, characterized by short bouts of activity, in other words young children play (Frost, Wortham, & Reifel, 2012). This is why the physiotherapy for ALL patients in the hospital focuses on games that incorporate these general movement categories. The downside is that about 90% of all ALL patients are part of the medium or low risk factor patient groups, making them outpatient (Kazak et al., 2007). For these groups there is no supervision or immediate help from the specialists in the hospital. The patients and their family have to deal with the treatment and recovery mostly by themselves at home.

The problem of the current home situation is that young children with cancer have little opportunity to engage in physical play that is unstructured and spontaneous. This can be because their physical state inhibits or limits their play and movement: children might feel weak, tired or in pain, due to the disease or due to the side effects of the treatment (interview in appendix B). Or because parents are worried and overprotective of their sick child, limiting their confidence and willingness to play (Beekman, 2016). Generally physiotherapists encourage families to try to keep children physically active through recommending everyday life activities or offering an exercise program (interview in appendix A). What is missing from these are solutions that attune to children's natural way of engaging in physical activity, namely through physical play (Boon, Rozendaal, & Stappers, 2015). Such solutions acknowledge the child as a child again, rather than a patient.

Project goal

The above discrepancies create research and design opportunities. The goal is to create a situation in which young children with ALL are stimulated and can engage in spontaneous and unstructured free play, while engaging in specific bodily movements that are controlled and therapeutically relevant and situated at home without professional supervision. This is an interesting challenge, as it seems paradoxical.

To tackle this challenge more knowledge was needed, especially on the different aspects mentioned in the project goal. However, first of all some background information is needed for a better understanding of the target group, namely children with ALL, before research can be done on how to help them (chapter 2.1). The following research questions were created and answered to get a clearer view of the context. These research questions will be discussed in the analysis section.

Research questions

RQ1 How does ALL threaten the physical activity of young children? (Chapter 2.2.)

RQ2 How to stimulate physical activity in young children with ALL in a playful manner with interactive toys? (Chapter 2.3.)

RQ3 What is specific for the home context when it comes to stimulating physical play through toys? (Chapter 2.4.)

Project process

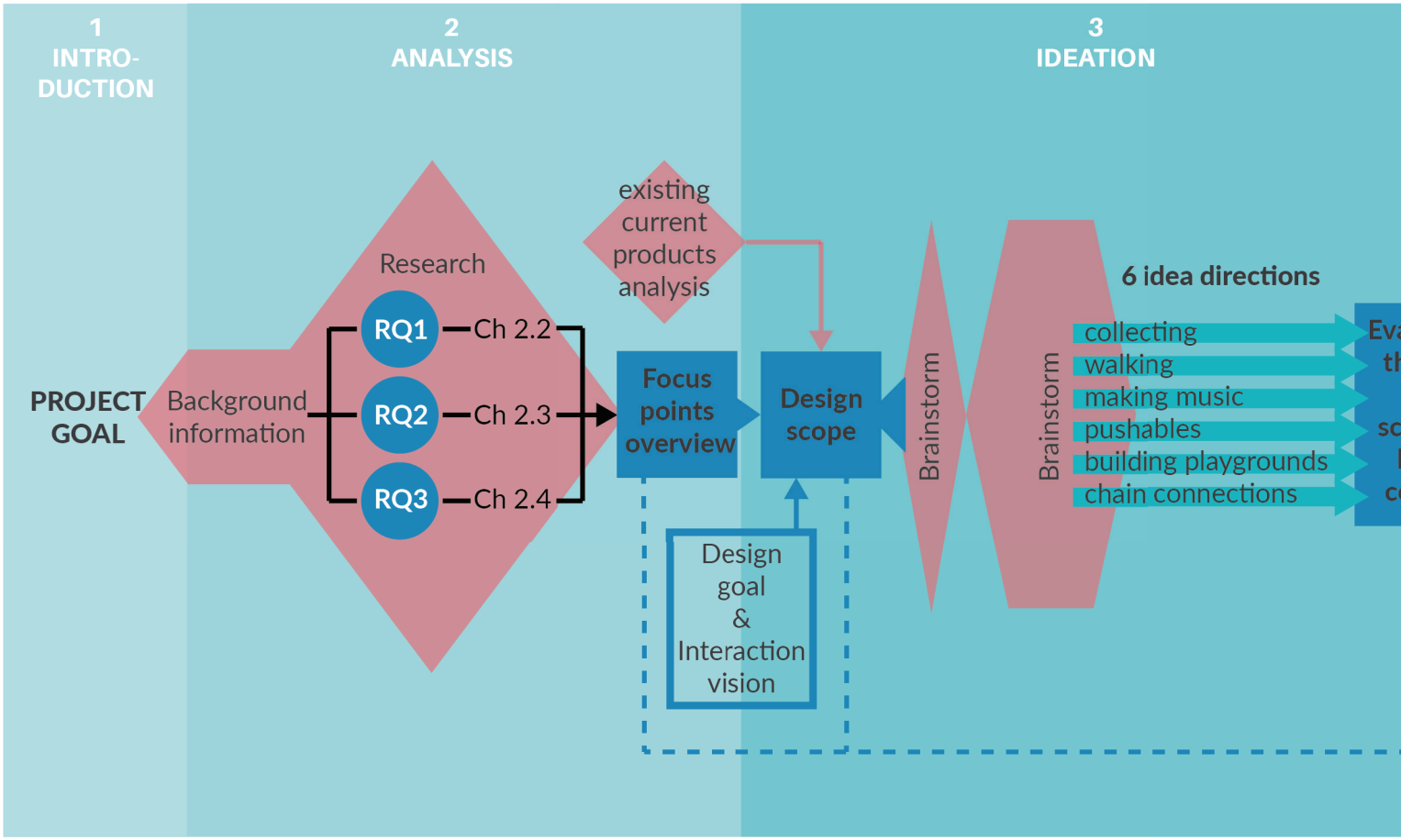
In the figure below, the project is visualized.

Following this introduction section, the project continues with the analysis phase. The analysis starts with getting familiar with the background information for this project. Then the three research questions are explored and discussed, each in a separate chapter. The goal was to get clear view and understanding of the target group, their problems, their environment and how to potentially solve the problems. A compact overview of the main focus points resulting from answering the research questions concludes this section.

The ideation phase follows the analysis phase. With the focus points a design scope is made that consists of a design goal and interaction vision. Before starting generating ideas a short analysis of the current existing products was done to check what is already available on the market. This analysis together with the design goal and interaction vision is used to create a framework to generate ideas in. From the idea generation process 6 idea directions were created. These directions were explored until a representative idea per direction was chosen. These ideas were then evaluated through Playscapes and home context lenses to end up with a final chosen idea.

The chosen idea was then conceptualised, in this project the focus was on prototyping and testing as fast as possible to get tangible feedback. This is why the idea was then simplified to be able to create a first prototype, a proof of concept. Then a second prototype was build where the focus was on the wheels of the concept. The wheels were tested for the behaviour and character of the design, resulting in the third iteration and final concept: Hobble.

This iteration was ready for user testing, which starts the evaluation chapter. The tests gave a lot of data that was analysed in different ways. The observations and interviews were used for general insight and the home context. While the



test results were analysed with the Playscapes' perspectives to get insight into how children play and how they move. The results then gave conclusions that could be evaluated with the focus points and design scope to improve the design.

The last chapter describing the process is the recommendation chapter. This section describes an overarching idea of which this toy is part of and gives an indication of a redesign of Hobble as well as the recommendations for the future of this project.

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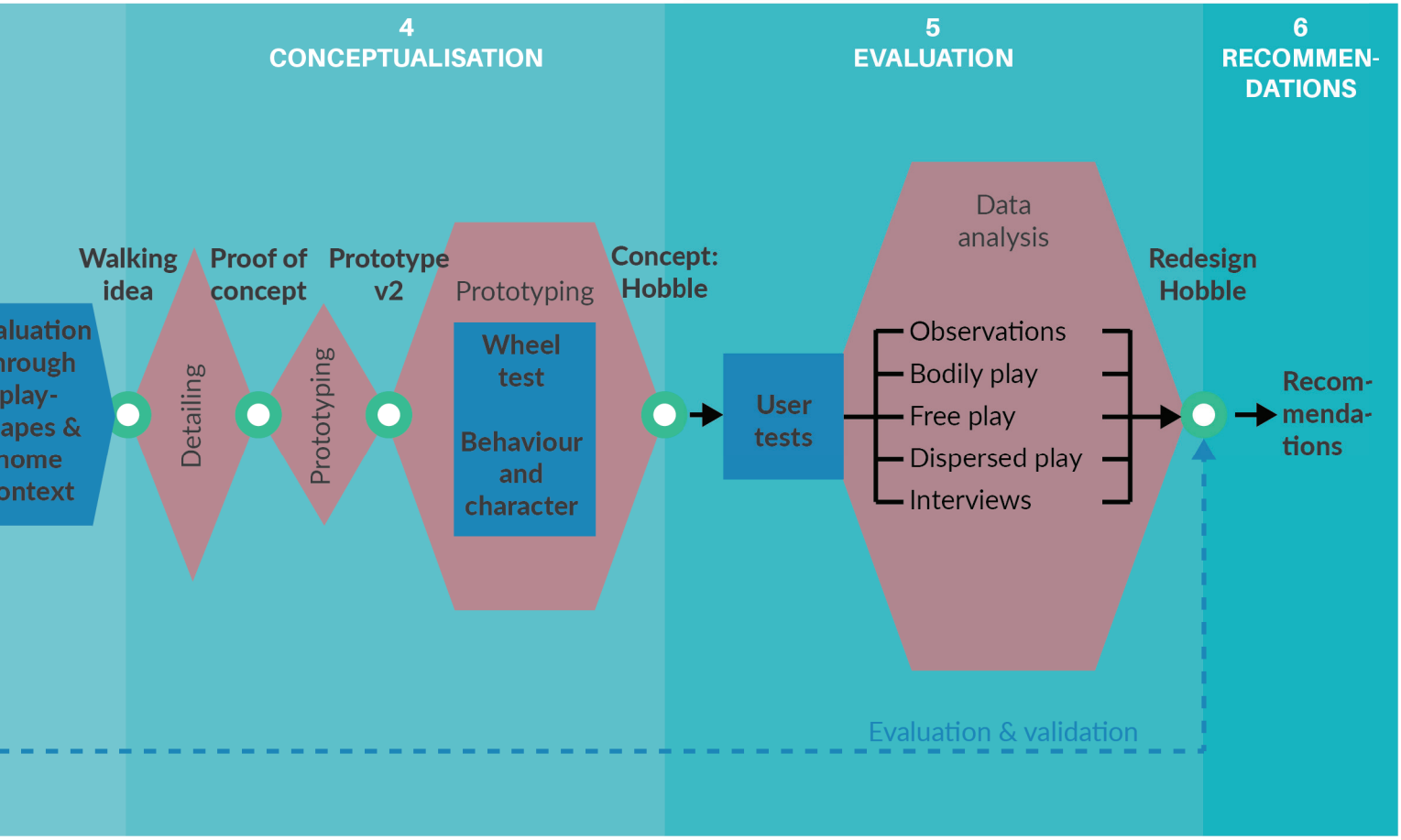
Conclusion box

Throughout this report, these orange boxes are used to highlight the most important information of this project. They will mostly appear as the final paragraph in chapters to display the conclusions, but will also be used for insights, results and decisions made that are important for the project.

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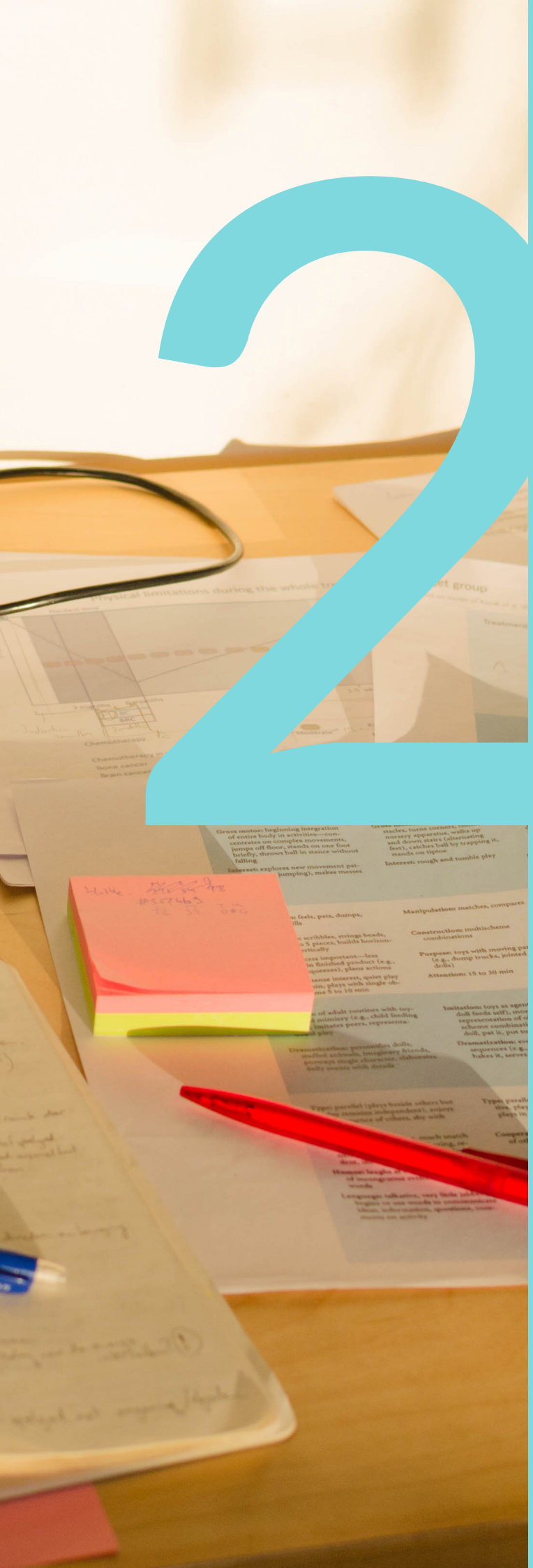


2 ANALYSIS

In this section the results of the research done in this project will be discussed. First background information of the target group is given. Then each section afterwards will be focused on discussing one of the research questions. The goal was to get clear view and understanding of the target group, their problems, their environment and how to potentially solve the problems. This section will conclude with an overview of focus points that were the most significant results of the research.

2.1 Background information: Children with ALL

In this chapter information is given about the chosen target group: Children with ALL. Specifically about why ALL was chosen, why the target group is 2 to 5 year old children and what the effects of ALL and the treatment of ALL are on children. The goal is to get a general understanding of what children with ALL go through.

2.1.1 Childhood cancer

Cancer is an autonomous growth of abnormal cells that derails the normal cell division process. The biggest cause of death of children between the ages of 2 and 11 years old is cancer (CBS, 2016). The curing percentage of cancer is around 75% (KiKa, n.d.), while the curing chance of children with ALL has increased to around 80% (SKION, n.d.-b). However, after being cured, these children are often behind in their physical development. Among the many research efforts, there is 'Meedoen=Groeien!' (Participation is Growth), this project is trying to help children with cancer with their development. The development is divided into physical development and psychosocial development. In this project the focus is mostly on the physical development, this is to make up for the abovementioned delay that ALL causes.

2.1.2 Acute lymphoblastic leukaemia (ALL)

There are over hundred different types of cancer. However, out of all of them, leukaemia is the most diagnosed cancer with a percentage of 30-35% with children between 0-18 years old. Within leukaemia, 85% has acute lymphoblastic leukaemia (ALL), making ALL the most common cancer (Bekkering et al., 2016).

Leukaemia is the official term for blood cancer. Acute lymphoblastic leukaemia causes quick noticeable issues and complaints and is extremely dangerous and life threatening. ALL originates in a certain type of white blood cell called the lymphocyte. The cancer cells quickly overtake the blood cell production and spread through the body using the lymphoblastic system and blood. There is also the danger of the leukaemia spreading through the spinal cord to the central nervous system or brain (Bekkering et al., 2016; SKION, n.d.-b). This makes it very dangerous and life threatening.

Target group

Children in the age group of 2 to 5 years old have the highest chance of getting diagnosed with ALL (Bekkering et al., 2016). This is why this age group is chosen as the target group. These children are also in the middle of their physical growth and their development of motor skills. This means that these years are very important for the child, because he or she is learning the fundamentals of moving (Frost et al., 2012). The cancer and the treatment both have detrimental effects on the development and growth of the child. The younger the child when the disease manifests, the bigger the consequences on the development are.

2.1.3 Effects of disease and treatment

Cancer brings a lot of symptoms with it. In general all children with cancer suffer from an overall malaise, in combination with decreased stamina and/or loss of weight. At the onset of leukaemia the symptoms can vary, a lot of children have difficulties recovering from colds and the flu. More symptoms surface after a while, symptoms like being tired, bleeding, nosebleeds, pale skin, swollen lymph nodes in neck, armpits and groin and easy bruising. Almost half of the diagnosed children with leukaemia experience balance problems, pain in the bones, pain the legs and difficulties with walking. These symptoms have a lot of consequences for the child and need to be taken into account. The child will mostly feel very sick, weak and in pain most of the time. Besides that the leg and bone problems make it difficult for the child to move. And lastly the easy bruising and bleeding require the child to be careful. Playing normally can be very dangerous for the child if safety and hygiene is not taken into account. The blood problems cause the child's immune system to be a lot more vulnerable and more susceptible to infections and sickness. (Bekkering et al., 2016; appendix A, appendix B)

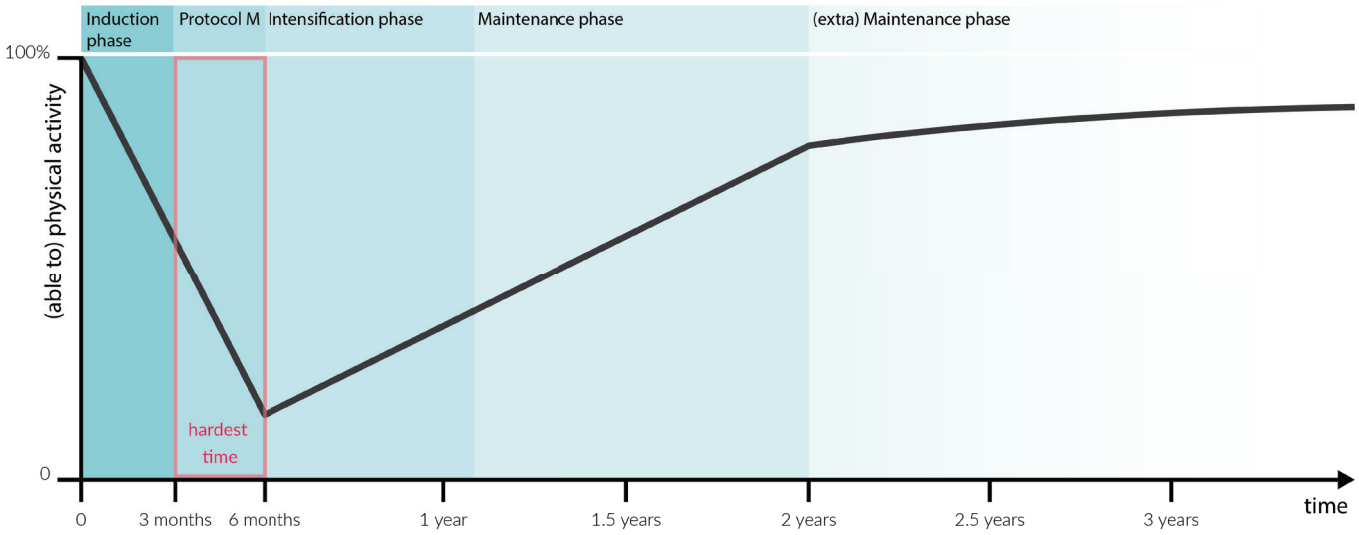


Figure 2: An average 2-year ALL chemotherapy treatment with extra maintenance time that can push the treatment time to 5 years if remission is hard to achieve.

Chemotherapy

The current treatment of ALL has significantly The current treatment of ALL has significantly increased the chances of the child surviving this cancer. The treatment usually consists of chemotherapy, which has four stages spanning over a two-year treatment plan. The treatment for leukaemia in The Netherlands follows ALL-protocol: ALL-11 (SKION, n.d.-b). It starts with induction chemotherapy, which is meant to bring the disease into remission. Remission means having no more cancerous cells in bone marrow samples, having the normal marrow cells return and having the blood count return to normal.

In The Netherlands the second step in the chemotherapy treatment process is called Protocol M. In this phase the focus is on the prevention of the spreading of the leukaemia to the central nervous system. Followed by an intensification phase and lastly the maintenance phase. In the last phase the goal is to prevent the cancer from recurring after the remission. This phase consists of outpatient care and the patient is usually most of the time at home. This phase might take up to three years after the two-year chemotherapy treatment. As is visualized in the figure Figure 2 above (more information in section 2.4). In some cases chemotherapy is not enough and stem cell transplantation is needed.

The chemotherapy sessions are more intensive in the first two stages. In the first month it is possible to have chemotherapy for multiple days a week, every week. A chemo session every 3 weeks is average after the first month. These sessions make children feel very weak and sick. The two weeks at home, after chemotherapy, are difficult, because the children will have to deal with the harsh effects of the treatment. After that they will usually start to feel better, but the next chemotherapy session will already be planned in that week or the following week. Effectively making the children not want to be physically active two out of the three weeks that they are at home in between the chemotherapy sessions. More about this in section 2.4.2. (American Cancer Society, n.d.; Bekkering et al., 2016; SKION, n.d.-b)

Medicine	Function	Side effects	Limitation for physical activity
Prednisone/ Dexamethasone	Inhibit inflammation and oversensitivity reactions	Bone decalcification	Falling and bumping can cause bone fractures
		Delay growth	Changes in sensibility of muscle use
		Weak muscles	Lowered power
			Problems with walking, foot drop, lessened gait cycle
		Increase in weight (specifically a big belly)	Difficulties in movements
Vincristine	Inhibit cell growth and multiplication	Lowered (white) blood cells	Fatigue/less energy
			Higher chance of bleeding
		Lowered immune system	Higher susceptibility to infections
		Irritation of nerves	Tingling sensation in fingers and toes
			Loss of muscle power in legs and hands
L-asparaginase	Break down amino acid asparagine	Nausea and vomiting	Fatigue/less energy
		Overall malaise	
		Central neurotoxicity	Behaviour changes, excessive sleepiness, depression, hallucinations, agitation, disorientation or seizure. Less commonly seen stupor, confusion and/or coma.

Table 2: The medicine's functions, side effects and limitations to the physical activity of children.

The children with standard-risk ALL get treated by three types of medicine at least. These antibiotics and their effects are shown in the table (SKION, n.d.-a). For this project the effects (mostly the limitations) they have on the physical activity of the children is important.

Prednisone and Dexamethasone are corticosteroids that are used to inhibit inflammation and oversensitivity reactions. However, they are also responsible for the difficulties in the movements of the whole body, lowered power and changes in sensibility of muscle use. The body does not respond or react like it used to, making it difficult for the children to use their own body. This in turn causes the children to lose confidence in their own movement and body. For ALL a common symptom is foot drop, which causes a lessened gait cycle, problems with walking. Moving becomes a tedious and sometimes painful task and usually results in less physical activity of the child. (Farmacotherapeutisch Kompas, n.d.-b)

Vincristine is used to inhibit the cell growth and multiplication. However, it does not only direct itself to the cancer cells, but it also affects the healthy cells. It lowers the production of blood cells, especially white blood cells. As consequence there is a higher chance of bleeding, higher risk of infection and a lowered immune system. This means that children on Vincristine should avoid falling and bumping into things as much as possible to avoid bleeding and infections. (Farmacotherapeutisch Kompas, n.d.)

L-asparaginase is used to break down the amino acid asparagine, without it cancer cells cannot make DNA, thus they cannot grow. It also causes overall malaise, nausea and vomiting, making it hard for the child to feel like moving. Neurotoxicity is also an issue that brings changes in behaviour and mood swings that need to be taken into account when designing something that stimulates physical activity. (Farmacotherapeutisch Kompas, n.d.-a)

2.1.4 Main insights: Children with ALL

Acute lymphoblastic leukaemia (ALL) is the most common cancer. **Young children between the ages of 2 to 5 years old** exhibit the **highest chance of being diagnosed with ALL**. During these years, children are in the middle of their physical development and growth, but ALL forces the body to redirect the focus completely towards dealing with the cancer. This usually results in the **stagnation of their physical development.**

ALL will make the child feel very sick, weak and in pain most of the time. When chemotherapy is employed more problems arise: **difficulties in the movements of the whole body, diminished strength and changes in sensibility of muscle use.** This effectively makes the children not want to be physically active two out of the three weeks that they are at home in between the chemotherapy sessions. The body does not respond or react like it used to, making it difficult for the children to use their own body and causing them to **lose their confidence.** Additionally, ALL can cause **leg and bone problems**. A common symptom is **foot drop, which causes a lessened gait cycle and problems with walking.** Moving becomes a tedious and sometimes painful task and usually results in less physical activity of the child. There is a **higher chance of easy bruising and bleeding, as well as a higher risk of infection** and lowered immune system. Playing normally can be very dangerous for the child if **safety and hygiene** are not taken into account. This means that children during treatment should avoid falling and bumping into things as much as possible.

2.2 Threats in the physical development

The last chapter explained that the cancer and the treatment have effects on the physical activity of young children. In this part the first research question (RQ1) is discussed: "How does ALL threaten the physical activity and development of young children?"

2.2.1 Child's physical developments

One of the main subjects of this project is movement, specifically the movement of young children while they are growing and developing. Frost describes children's developmental progression in acquisition of motor skills.

Gross- and fine-motor skills

Motor skills are the movements and actions of the muscles. Children develop their motor skills in the earlier years of their lives. There is a distinction between gross-motor skills and fine-motor skills. Gross-motor skills are the movements of large body parts and the whole body, while fine-motor skills are the smaller and more precise movements in the extremities. Children develop gross-motor skills first and slowly grow towards more and more finer motor skills.

As the table below shows, children in the ages of 2 to 5 are in the middle of their development of fundamental movements. This table was derived from the Knox Preschool Play Scale (Appendix D) and Frost's development of movements per age tables. These children are in an important

Physical abilities	2 years old	3 years old	4 years old	5 years old
Gross-motor skills	Stands on one foot briefly	Smoother walking	Stunts	Hops in a straight line
	Jumping	Climbing	Stands on one foot and balances briefly	Gallop, skips and hops
	Runs around obstacles	Runs freely with little stumbling or falling	Kicks a ball while walking	Somersaults
	Can run with better coordination, although the stance may still be wide	Accelerates/ decelerates	Climbs ladders	Lifts self off ground
	Throws ball in stance without falling	Jumps distances	Rough and tumble play	
	Can pick up objects while standing, without losing balance		Quick movements	
Fine-motor skills	Can build a tower of 6 to 7 cubes	Fine motor manipulation of play materials	Uses scissors	Builds with small construction toys
		Builds a tower with 9 or 10 blocks	Strings beads	Brushes own teeth and cares for own needs

Table 3: A healthy child's average development of physical abilities per age.

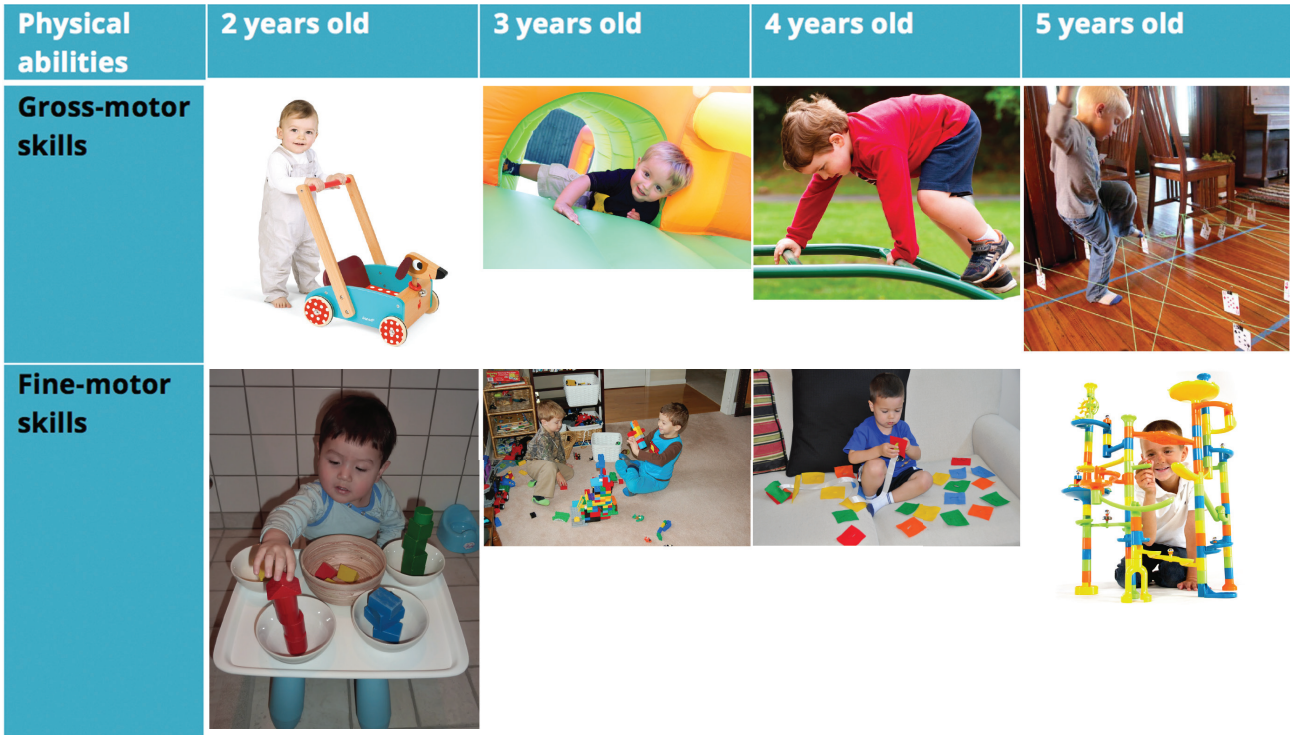


Figure 3: A healthy child's average development of physical abilities per age visualized.

phase of their lives where they learn to use and move their bodies. It is the progress from initial and elementary stages of movement to mature stages of movement. There is a big difference between how a 2-year-old moves compared to how a 5 year old moves. In the visualization above can be seen that the range is from barely walking to pretty precise control of the body. Both the gross-motor skills and the fine-motor skills are developing and improving. This makes this age group so crucial, because with the interruption of the cancer, the children's development is delayed. The disease demands all the energy and power of the children's bodies and halts or delays their growth. The consequences are that most survivors still have to deal with a lot of delay in their development compared to their healthy peers (Frost et al., 2012; Knox, 2008). [insert physical abilities of children with ALL]

Below is a physical ability scale based on examples given by physiotherapist Van der Torre. It is a guide for recommending what physical ability children should work towards next. The scale starts with sitting (sedentary physical ability) and moves to higher intensity physical activities that require motor skills. During treatment, the children's maximum physical ability is placed somewhere on this scale and then the physiotherapist can recommend a more intense physical ability that they should try and reach. Getting to standing and walking is a challenge as

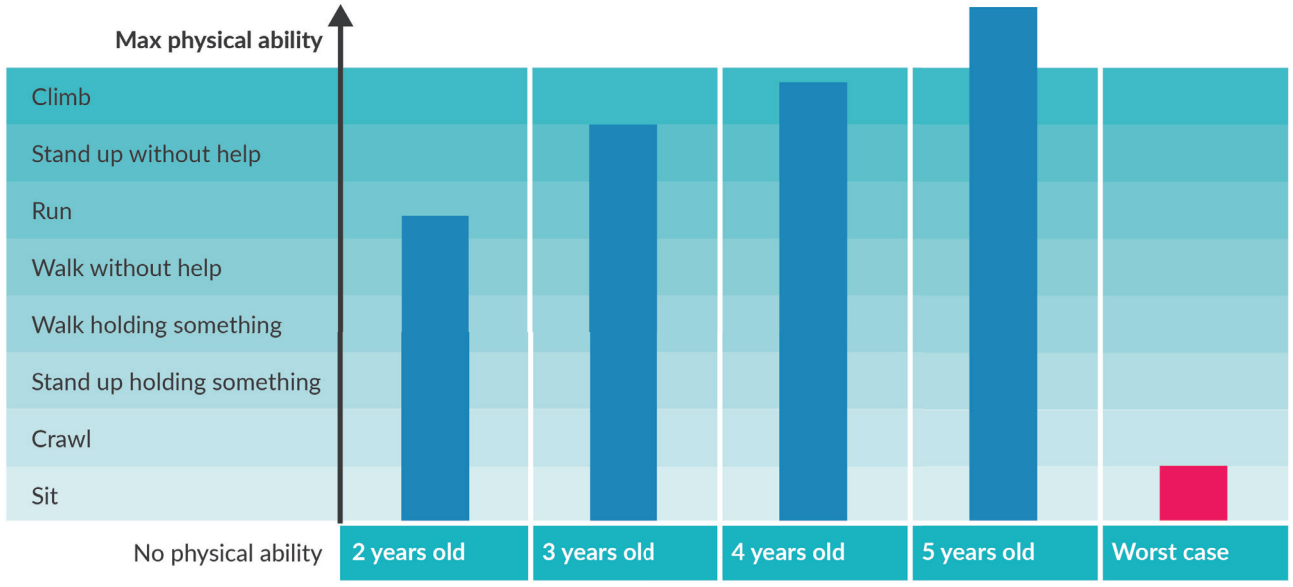


Figure 4: Physical ability growth steps that physiotherapists focus on with children with ALL against healthy children's average physical ability per age and the worst case for children with ALL.

these abilities are affected during the treatment. Standing up without help is difficult for children between 2 and 5, because around these ages gravity is still an issue. Strength in muscles and bones is needed, but they are affected during the treatment. This makes standing up without help harder than walking and running. Worst-case scenario for children with ALL is being completely sedentary (Van der Torre's physical ability scale as cited by: E. Sollenby a, L. van den Berg a, E. Polat a, M. Echavarria a, 2015).

2.2.2 Physical activity

To stimulate the development of motor skills the child needs to be physically active. The World Health Organization defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure" (WHO, 2018). In this project the focus is on the physical activity of young children, in other words the bodily movement of young children. The physical activity that will be discussed is mainly physical play. This is the way young children develop and grow, the physical activity of children is primarily for play (Boon et al., 2015). In the next section 2.3 play will be discussed.

2.2.3 Physical fitness

Physical fitness, different from physical activity, is a list of measurable physical attributes that people have or achieve. These attributes can be divided into skill and health related fitness and can be seen in the Figure 5 (Caspersen et al., 1985). Both consist of attributes that people

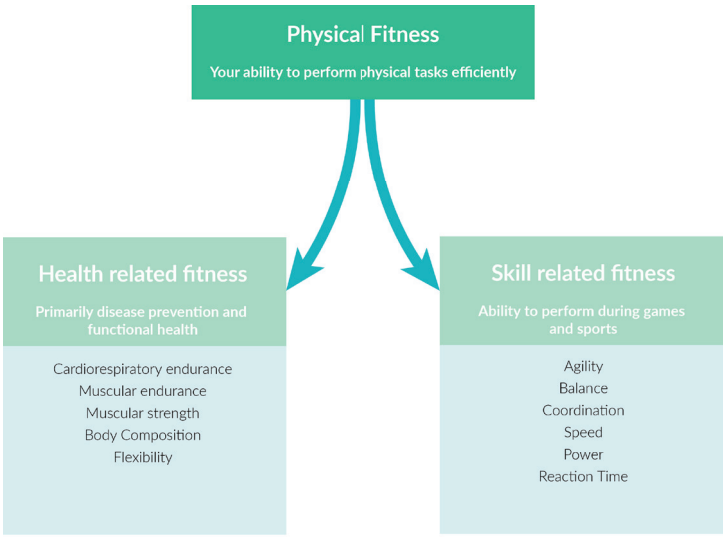


Figure 5: Physical fitness consists of health and skill related fitness.

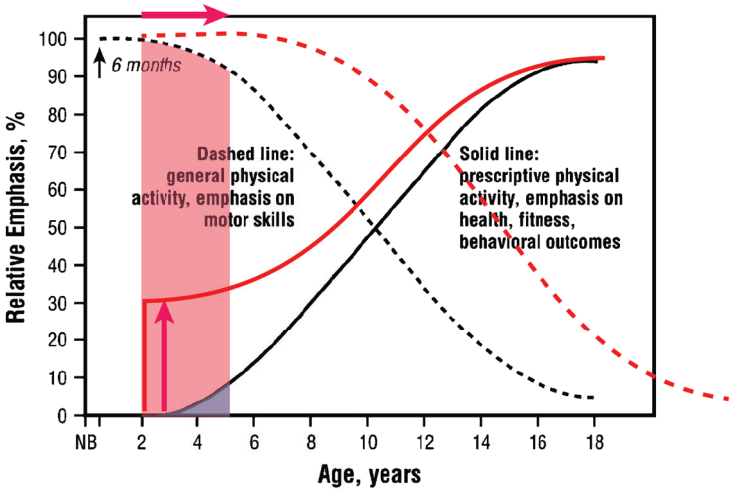


Figure 6: The relative emphasis of physical fitness over the years when growing up.

cultivate over time. Young children learn and develop these attributes through their physical activity. Through the years the physical activity starts to shift from an emphasis on the motor skills (skill related fitness) to an emphasis on health, fitness and behavioural outcomes (health related fitness). This can be seen in black in Figure 6. When a child is diagnosed with cancer the treatment creates a delay or even a stop in the development and this skews the graph lines, which is indicated by red lines in Figure 6.

This shows that the cancer creates an immediate need of emphasis on health related fitness and because of that the emphasis on developing motor skills is delayed. The aim is to make the delay in development and growth as small as possible.

2.2.4 Exercise, exergames or free play to fight back cancer

Exercise is a commonly used way to maintain physical fitness and wellbeing for adults and older children. A way to get children to be more active is to make exercise more fun. A clear example of this is a sort of in between form where exercises are offered through play, these are called 'exergames' and can be found in the field of human-computer interaction. Exergames are games that require a certain level of exertion and involve structured and repetitive movement. This is accomplished through gamification or simply by adding a play element to exercises, through which physiotherapists are able to target specific areas of the body. However, such exercise-based solutions are not very suitable for young children (2-5 years old); their physical activity is generally more spontaneous and intermittent, characterized by short bouts of activity. In other

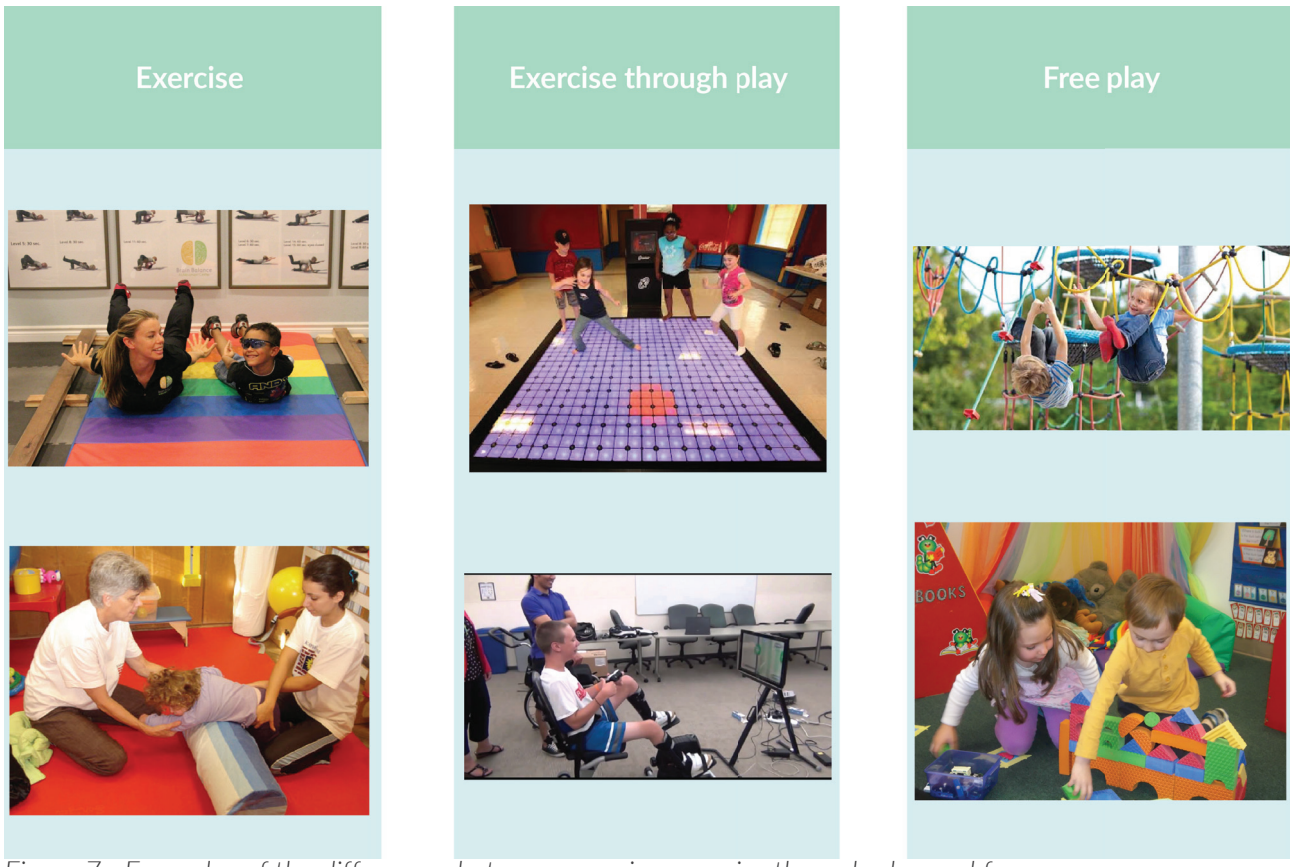


Figure 7: Examples of the differences between exercise, exercise through play and free

words children's physical activity is play (Boon et al., 2016). However, when the cancer shows up, it obstructs the possibility for the children to be normally physically active. The treatment of the cancer adds extra obstructions to the child's movement that affect specific areas of the body. The children then ideally need exercises that target these areas to fight back the cancer and the side effects of the treatment. However, 2-5 year old children are not able to understand the concept of exercises yet according to physiotherapists (appendix A). This discrepancy is the starting point, namely the need for them to keep growing, developing and fighting the cancer through structured and specific physical activity against the natural instincts of the child to play freely. More in section 2.4.2.

2.2.5 Movement focus of physiotherapists

Physiotherapists specialized in children were interviewed to get their expertise on what movements are important for children with ALL in practice. The main answer to that question was that every child is different and needs a different treatment. There is no specific bodily movement that can be targeted to fight cancer. However, there are general movement categories that physiotherapists would like to see more in children with ALL. These movement categories are focused on muscles groups that the disease or the treatment affects. For children with ALL there are three most common problem areas that need to be addressed: locomotion, torso and power (See appendix A). They are explained on the next page.

LOCOMOTION

Locomotion is moving forward. In this case it is any variety of bodily movement that children make to move from one place to another. According to the physiotherapists this is one of the most important physical activities children with ALL should do. As explained in section 2.2.1 children are growing and developing their bodies, one of the most essential movements they need to learn in this age group is walking. Another problem is that chemotherapy upsets the balance and sensibility in the muscles of the legs, so moving the legs to train them is very important. Next to that locomotion helps the children to work on their cardiorespiratory problems and stamina. For a child to learn and train to move from A to B, he or she needs to train both power and flexibility as well. (Whitehead, 2010)

TORSO

The torso of the child during chemotherapy is important, because there are antibiotics for ALL that causes the stomach to swell a lot. To counteract this, the torso needs to be trained. Ideally the child should do sit-ups, but this is not possible with 2 to 5 year olds. What is possible and very natural for children of this age group to do is falling and getting back up. Only falling is not very safe for children with ALL. In this case the focus should be on sitting down and getting back up to train the torso. While doing this the children will both keep their bellies smaller and keep training their muscles for growth as their peers would.

POWER

Power is always important in growth and development of a child. Especially in the case of cancer and chemotherapy, which make the child very weak. So in general it is important to keep the power of the child as high as possible. The biggest problem is that the power and energy of the child is completely redirected to fighting the cancer and handling the treatments instead of to their growth and development. And as the treatment intensifies the child should not just get weaker and weaker. To be able to fight back, the child needs to have stamina and work on its cardiorespiratory system. And to be able to do that, the child needs power, the power to move its body. (Appendix A and B)

RQ1 How does ALL threaten the physical activity of young children?

The first threats of ALL on the physical activity of children are the limitations imposed by the disease and its treatment. It affects the **strength of the muscles**; there is **pain in the legs, balance problems, difficulties with walking, changes in the sensibility of muscle use and decreased stamina**. This combination threatens the development of the child as well, because the child is **less inclined to be physically active**. This has two big consequences: the child is **less fit to fight back the disease and treatment**, and the **child's physical development is delayed**.

These threats should be dealt with to heighten the chances of recovery and to keep the delay in the child's physical development to a minimum. This is precisely the focus of physiotherapists during the treatment of the child. Because every child is different and every cancer affects children differently, physiotherapists state that it is impossible to create something that focuses on specific movements for all children with ALL. Instead, physiotherapists settle for focusing on broader muscles groups and movements. Therefore, the focus of this project will be on three important general movement categories: **locomotion, torso and power.** These areas are affected by the disease or treatment and are important for the recovery and development of the child.

2.3 Play (as intervention)

Physical activity is very important to young children as the last part showed. The next question to explore in this part is RQ2: "How to stimulate physical activity in young children with ALL in a playful manner with interactive toys?"

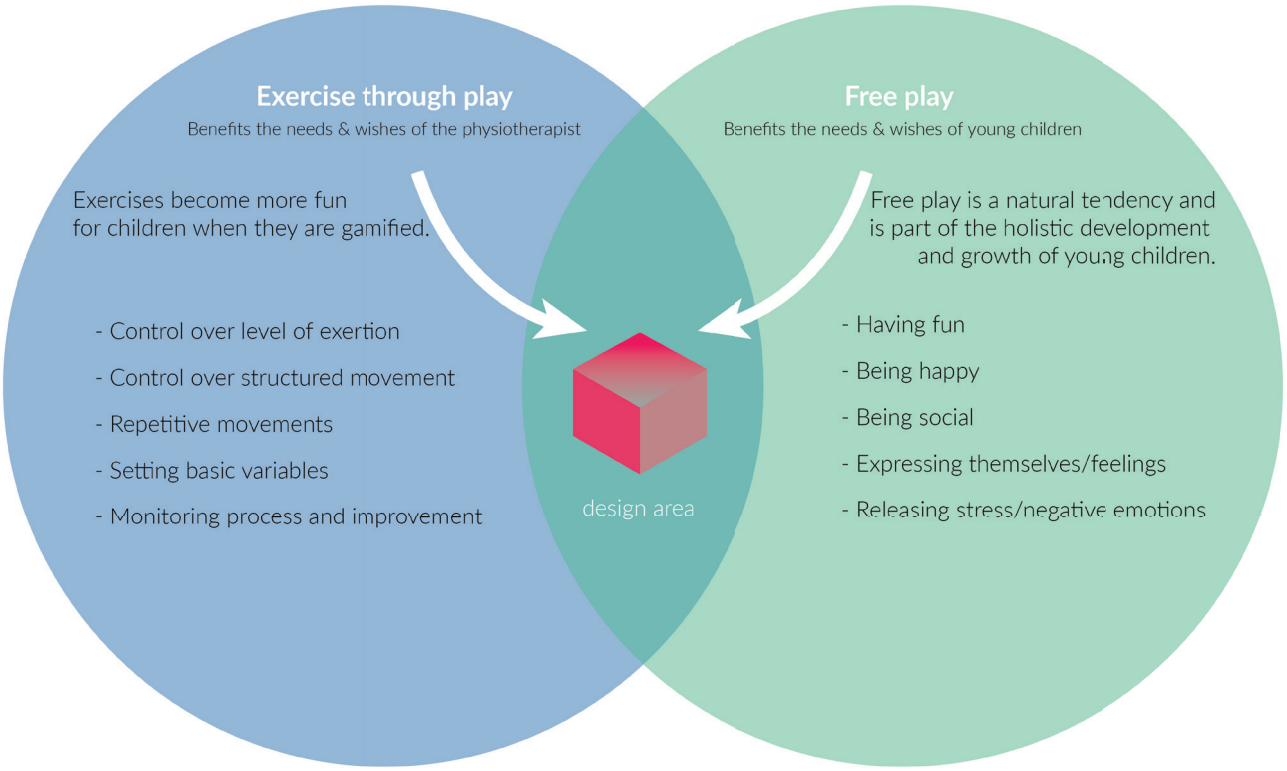


Figure 8: This project's design area is lies in the intersection of exercise through play and free play.

2.3.1 Define play

It was already mentioned in the last section, that play is the main physical activity children have. However, what is play? Play is defined in the Oxford Dictionary as (English Oxford Dictionaries, n.d.):

> **play**
> /pleɪ/
>
> *verb*
>
> **1** *[no object]* Engage in activity for enjoyment and recreation rather than a serious or practical purpose.

This definition is very broad and makes it difficult to grasp what play exactly is. There are many other definitions for play as well, but for this project the focus will be on young children and their play as a physical activity. The way children play can take many shapes and forms, but most importantly most of young children's physical activity occurs in the form of play (Burdette & Whitaker, 2005; Pellegrini & Smith, 1998; Timmons, Naylor, & Pfeiffer, 2007). Play is the leading source of development in the ages between 2 and 6 according to Vygotsky (as cited in Whitehead, 2010). When possible they spend their days at play. They develop their bodies and minds through play while they are inventing games and dramatizing fantasies. Free play helps develop well-being by enabling children to pay attention and teaching them to affiliate with other children. Most of all, play makes kids happy (Burdette & Whitaker, 2005; Pellegrini & Smith, 1998; Timmons et al., 2007).

To children play is not just a means to get to a goal, but it is also the goal itself. Play is for play. This is also the case in this project, where play

is used to stimulate physical activity, but is also a goal.

2.3.2 Playscapes

This project is continuing the research on design for play and exercise. A new perspective is offered by Boon, Rozendaal & Stappers named 'Playscapes', where the focus is on providing children with a meaningful environment that invites physical play. This perspective is situated in the intersection of exercise through play and free play. This area is the design space to search for how specific therapeutically relevant bodily movement, as prescribed by physiotherapists and human movement researchers, might be elicited in free play through the design and use of open-ended play objects. See figure previous page.

Quite some research has been done on how to design for free (or 'open-ended') play (e.g. work by Tilde Bekker and Linda de Valk). Also, another body of research has focused on so-called 'exergames'; i.e. games that require a certain level of exertion. Such games offer control on the type and intensity of movements that are required to achieve the goals of the game. In combining the benefits of exergames (i.e. control over therapeutically relevant movements) and open-ended play (i.e. allowing children to naturally engage in physical activity), this addresses a relevant research gap currently unaddressed as can be seen in the figure above. These interactions need to be explored in the complex social contexts where different actors (both human and non-human) influence children's play potential at a given time and place. To get more insight into this two day care centres were

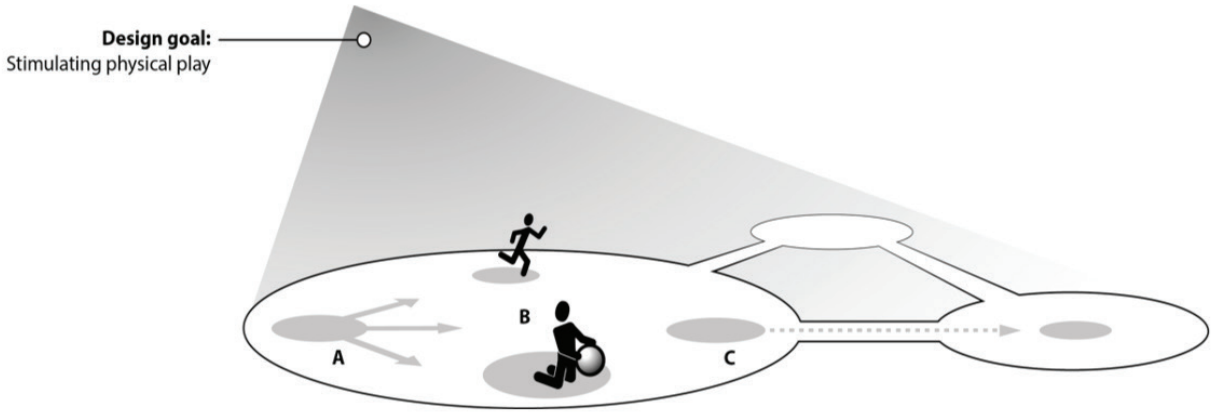


Figure 9: The design perspective of Playscapes accounts for three key qualities: free play (A), bodily play (B) and dispersed play (C).

Bodily play (full body movements)

Bodily play concerns full body movements where the child makes use of the large muscles. These are relevant for the development of motor skills. This quality takes the child's balance, locomotion, flight, manipulation, projection, construction and communication into account when designing.

Dispersed play (beyond boundaries of single dedicated area)

Dispersed play concerns play that goes beyond the boundaries of a single dedicated area or play area. This is relevant for locomotion and spatial directional awareness. Moving away from the play area helps children expand their play narratives and gives them opportunities to explore. Thinking of destinations and pathways or loose parts helps stimulate dispersed play.

Free play (unstructured, spontaneous and self-directed)

Free play concerns play that is unstructured, spontaneous and self-directed. The relevance is not as straight forward as the other two qualities. Free play is dependent on what the child decides to do. To design for free play there are several points that help: ambiguity, unpredictability, variety, manipulability, open-endedness.

visited for observations (see appendix C).

Playscapes is a design perspective divided into three qualities: how to design for bodily play, dispersed play and free play. See Figure 9 (Boon et al., 2016).

2.3.3 Bodily play in this project

In the previous chapter three movement categories, locomotion, torso and power, were defined on which this project would focus on. In Playscapes bodily play is the quality that concerns full body movement, but for children with ALL the above three movements are the focus points. It is however difficult to focus purely on power in the physical activity of young children. This is because to train power it usually involves exercises (see section 2.2.4) or many repetitions of the same movement to train the muscles. This is not a natural way for young children to move. There are differences between what children can handle in power depending on how old they are. This is very dependent on their growth and development of their motor skills. Naturally young children's power grows simultaneously with their development of motor skills. This means that power can be trained by stimulating children with ALL to lessen their delay of their growth and development of motor skills as much as possible. For this project the decision was made to focus less specifically on power. The focus would be mostly on locomotion and torso. The most important parts of using power in children with ALL should still be addressed in locomotion and torso. This can be done by stimulating the child to move around his or her body weight and by lifting up toys and themselves. This is why in this project bodily play will be considered locomotion and using the torso. As is illustrated in Figure 10.

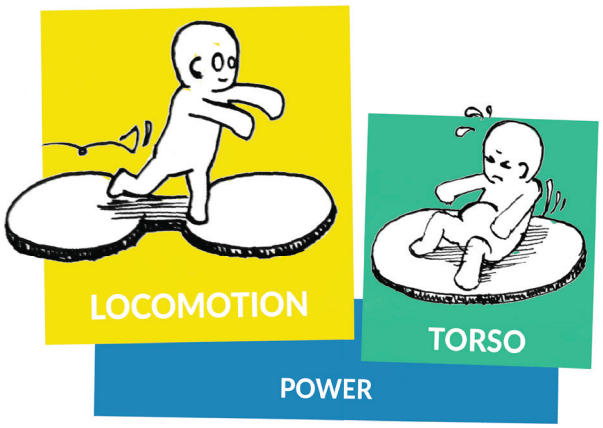


Figure 10: With young children the use of power is part of their locomotion and using their torsos.

RQ2 **How to stimulate physical activity in young children with ALL in a playful manner with interactive toys?**

The mainly exercise-based solutions of most products are not very suitable for young children; their physical activity is generally more s**pontaneous and intermittent,** characterized by **short bouts of activity. Young children's physical activity is play**. So it is only natural and appropriate to allow children with ALL to play and **elicit the physical activity that physiotherapists want to see** through playing. So how do we control play, an unstructured and self-directed instinct of the child, without structuring and regulating it? Through the variable that parents and designers do have control over: **toys.** The three **Playscapes** perspectives will be used as a guideline to design a toy that is **bodily, dispersed and free in play.**

2.4 Physical play in the home context

The last part to be considered is where the physical activity can be stimulated, namely the location. This will be discussed in this part with the third research question (RQ3): "What is specific for the home context when it comes to stimulating physical play through toys?"

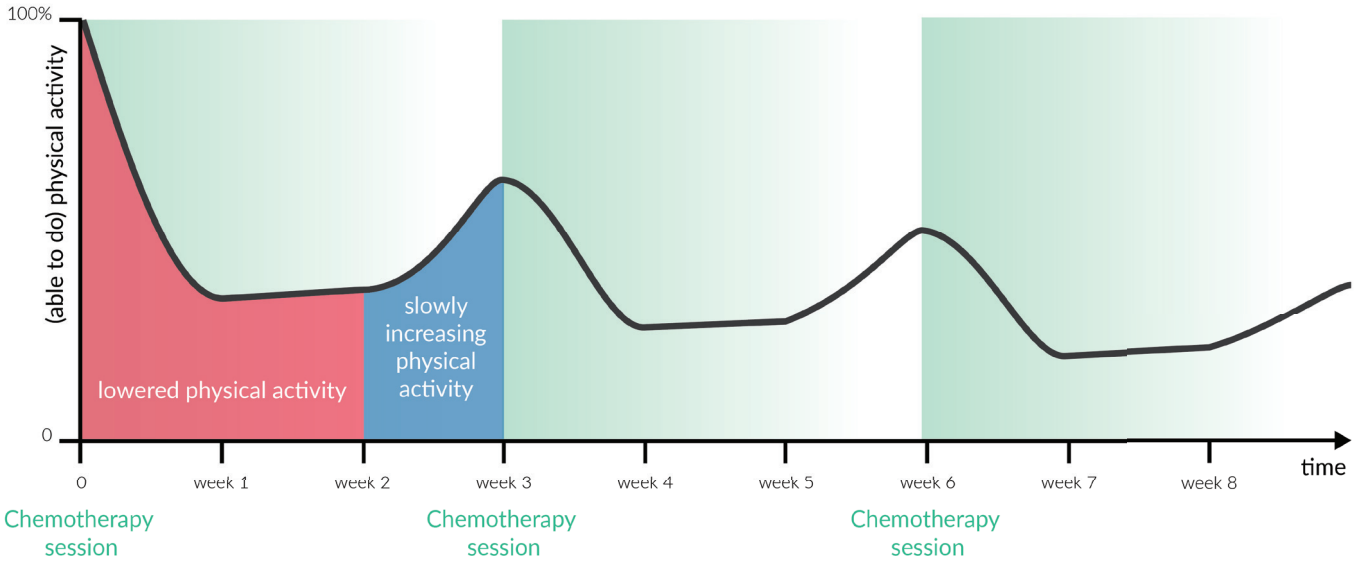


Figure 11: The lowered physical activity through 3-weekly chemotherapy sessions.

2.4.1 Medium and low risk factor patient groups

Most cancer research has a focus on cases of leukaemia with higher risk factors. This generally means the children that are in need of hospitalization and clinical treatment. This group amounts to around 10% of all ALL patients. However, there are also the other patient groups that have medium or low risk factors. These are the patients that usually do not stay hospitalized, but go home after their treatment (Kazak et al., 2007). These patient groups spend most of their treatment and recovery time at home. And the treatment usually takes up to 2 years, with potentially 3 years of recovery afterwards. There is no supervision or immediate help from the specialists in the hospital for this group of patients. The patients and their family have to deal with the treatment and recovery by themselves. This is the group of patients that this project will focus on. (Beekman, 2016; Appendix A and B)

2.4.2 Children with ALL at home & Child's energy fluctuations

Children are sent home after their chemotherapy treatment, they usually feel very low in energy and overall bad. With the usual prescribed chemotherapy for young children with ALL, the children will feel sicker the week after chemotherapy. With certain antibiotics, like dexamethasone/prednisone or vincristine, they will keep feeling sick for 10 or 14 days and will only start to feel better in the middle of the second week or even at the end of the second week. In the third week the child will start to slowly feel better, but this is also the week that a new chemotherapy session will be planned. This results in an on-going fluctuation of the child's energy, as can be seen in the Figure 11. The vertical axis represents the children with ALL their ability to do physical activity like their healthier peers. This will on average drop to around 40% of what healthier kids can do. (Appendix A)

The fluctuation is directly correlated to when and how children will play at home. The first week children will play significantly less and when they play, it will be for a lot shorter duration. The child will spend a lot of time in bed or on the couch, this is the when the child should be stimulated to try and start moving. Nowadays there are many sedentary ways of playing or spending the time: playing with computers, smartphones, tablets and watching television are very common. These ways of spending time can keep the child sedentary, while it is much healthier for the child to start moving. If children start their physical activity again after chemotherapy, their immune system will restore quicker and their delay in growth and development will be smaller (Appendix A and B). To achieve this a toy should be designed that elicits the child to start being physically active and stimulates bodily play. The child does not need to be forced to play through the pain, but the child should ideally play when it feels like it can play.

"Sick children can also play very well, they know their limits very well. You really do not have to tell them, you can not do this."
– P. Bekkering (physiotherapist)

In the second and third week, the child will start to feel better and better, making play more frequent. Children know their own limits and will move and play as long as they feel all right and when they are confident (Appendix A).

"Most of the time the problem is not with the child, if the child feels well he will play."
– J. Dijkstra (mother)

Playing during the day is not much different from healthy children, especially when there are siblings. Meaning children with ALL will want to play all day just like healthy children. The only difference is that the child needs more breaks, and hygiene and safety have become very important. The chemotherapy and the antibiotics lower the immune system of the child tremendously and that is why the hygiene of the toys and of the home environment are paramount. Next to the hygiene, the safety of the home environment is also important. This all is in relation with giving the child enough confidence to move and the confidence that he is able to move. (Appendix B)

2.4.3 Confidence and trust of parents

The people that are most affected by the child's disease and treatment, next to the child, are of course the parents and the possible sibling(s). The whole family goes through the disease and treatment process with the child. This radically changes the lives of all people involved, as all focus of the family will be pointed towards the sick child. The consequences of these changes bring changes to the family rituals and relations. The cancer takes much more time away from the family, while other things in their lives are forced or pushed to the background. Most of the times it is:

"What goes for the child, goes for everyone in the house."
- J. Dijkstra (mother)

What this family and home situation involved was part of the research of "Participatief Ontwerpen voor KinderOncologie" (POKO), translated to English: Participatory Design for Child Oncology. The insights and results of this research were used in this project to get a clearer understanding of the home and family situation of children with cancer. (Beekman, 2016)

When a child gets really sick, there is a dilemma every parent faces:

"How do you prevent being too worried as a parent and despite that offer the child the facilities to play safely?"
- J. Dijkstra (mother)

As stated before there are several risks, like higher vulnerability to infections and less blood clotting, that pose a challenge to parents, especially when they want to constrain their children as little as possible. One of the most common reactions is that parents become overprotective of their children. It is very difficult to find the balance between responsible and safe physical activity and when it is dangerous. The biggest issue here is that by being overprotective it is possible to talk your child sick. In contrast children themselves very much live in the here and now, if they feel

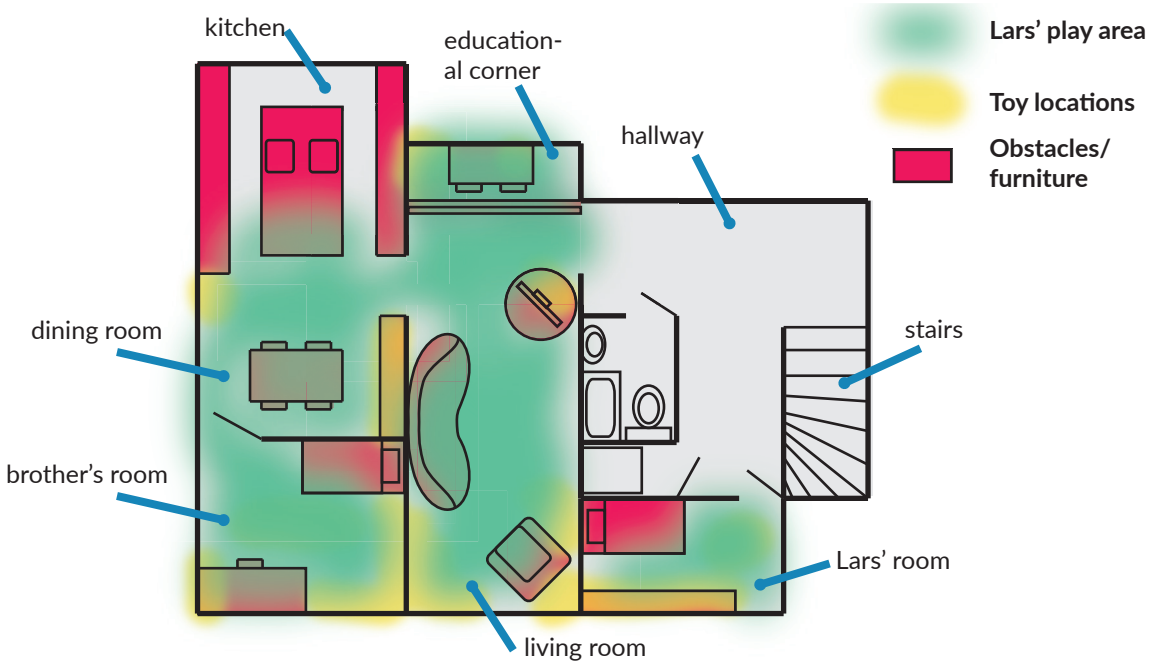


Figure 12: Lars' home layout of the second floor as an example. Green shows where he usually plays, yellow is where his toys are stored and red are the obstacles and furniture he comes in contact with during play.

well enough they will play. It is important as a parent to make sure the child gets the confidence and trust that he or she can be safely physically active. (Beekman, 2016; Appendix B)

To achieve this, the parents themselves need to trust and be confident in the child's situation first. This is solved by making sure the physical activity is in line with what the physiotherapists wants to see in children with ALL. In this way parents know the movements and play elicited from the toy is recommended by experts. (Appendix A and B)

2.4.4 Home environment

To start developing something for the children to play with at home, the home environment needs to be explored. First of all, this means the layout of the home. There is no standard home layout. Every home is different. Although, there are some commonalities between the homes of families with children. Children tend to play everywhere, but mostly either in their rooms or in the social places of the house, like the living room and kitchen. Because the children's play brings them everywhere, the toys they play with also end up everywhere in the house . See the example in Figure 12 (see interviews Appendix K). To try and control this, a lot of parents try to create a central point where all the toys are stored. This usually takes the shape of a playroom, play corner in the living room or simply a closet or boxes with all the toys in them. In some cases the playroom is also the bedroom of the child or the room of a sibling (see observations Appendix J)

Next to the most frequent places where the children play at home, it is also important to take into account how these areas look. What type of floor is in the play area, how much furniture or obstacles are there and how much space does the child have to play in? In general family homes do not have a lot of space and the space is even smaller because of the furniture or obstacles in the house. However, children are creative and imaginative and use the space and furniture they have in their play. That does not take away that the toy should not be too big and should still fit in the home environment. It is important to remember there are different types of flooring and surfaces where it should function on, such as smooth laminate or coarse high carpet.

After chemotherapy the children are usually found in bed in their bedroom or parents' bed, or on the couch of the living room. They usually try to stay close to the others in the house. The task at hand is to try and elicit these children to get out of bed and off the couch. Eliciting is important, because if the child feels well he or she will play, but if he or she does not feel well they should be able to make the decision to not play. The issue here is to make the child feel confident and well enough to start getting up and start playing physically active. (Beekman, 2016)

How to elicit movement and play in the home environment?

Children with ALL at home will already have regained some feeling of safety and confidence, simply by returning home from the hospital. However, the challenge is in the environment to give the child enough confidence to be physically active when they feel sick and their sensibility of their body is changed. The effect a hospital room with four beds with sick children in them, lots of medical staff and no room to play, has on a child is not one that should be brought home. Every home is different, it is very difficult, and usually very expensive, to try and change the environment to make the child physically active through a design. Besides the child and the family still want their home to feel familiar and stay relatively close to what the child and the family consider their home. So the toy designed should not aim to change the home environment, but instead it should help enhance it by aiming to provide both the parents and the child the confidence to start being physically active within the space that they trust and feel safe in: their home environment.

In the hospital the physiotherapist's watch and the professional control translate to trust in the parent, that what is happening is good for their sick child. The obvious problem at home is that there is no physiotherapist's watch or professional control. A solution is to create a toy that the physiotherapist supports or recommends. This will instil confidence in the parents that the play and movement stimulated by this product are beneficial to their child. (Beekman, 2016; Appendix A and B)

RQ3 What is specific for the home context when it comes to stimulating physical play through toys?

The home is the chosen context for this project because **90% of all the children with ALL will be sent home after their chemotherapy sessions**. At home they do not have the physiotherapists' watch or professional control over their behaviour and movement, so there is a **lack of (professional) guidance.** However, the children should still be physically active to ensure their immune system recovers faster and they are strong enough to fight back the cancer. The problem is that the chemotherapy and antibiotics make the child very weak and vulnerable. This in turn makes it harder for the child to move, but in general **as long as children feel safe and confident, they will want to play,** as it is their **natural instinct of being physically active.**

To make sure the child feels confident, the **parents should feel confident in their child's ability to play and move.** Hence, it becomes really important to make sure the design makes parents feel confident in the movements it elicits in the child, **removing any doubt or overprotectiveness.** Making sure the **toy stimulates the movements that physiotherapists recommend will give the parents confidence.**

It is important to try and elicit the child to start playing as soon as possible after getting treatment. Even though the child might feel weak, the child should still be stimulated, but not forced, to start to play. **Enhancing the ways the child can play within the normal home environment** should give the child a feeling of **familiarity, safety and trust.** Thus the layout of the home should stay mostly the same and the toy should fit in with the general furniture, like tables, chairs and coffee tables.

Lastly, the **children should be empowered through a perceived sense of control.** Keeping the home environment as close as possible to how it was when the child was not sick, 'normal', can do this. Giving children self-direction and allowing them to make decisions for themselves greatly increases the child's well-being and confidence.

2.5 Focus points overview

After gathering the background information and exploring all the research questions, all the insights were combined to get a clear overview of what the focus points are of this project.

With the main insights of the research an overview of focus points can be made that will help guide this project. See Table 4, on the left, the research sources are given and the three most important insights are listed in the same row. These nine insights are the focus points that represent the aim of this project and the qualities it is trying to achieve. The table will be used as guideline throughout the project as well as an evaluation tool at the end to check the final concept and design.

		FOCUS POINTS		
RQ1	**Children with ALL**	Locomotion	Torso	Power
RQ2	**Playscapes**	Bodily play	Dispersed play	Free play
RQ3	**Home context**	Safe and 'normal' environment	Elicit/Stimulate play that fits the energy level as soon as possible	Empowerment through a sense of control

Table 4: An overview of the focus points resulting from the research questions.


PUSH & COLLECT.
PUSH&COLLECT & SHOOT
mier bewegen
afzonderlijke bewegingen
onderdelen.

3 IDEATION

In this part the idea generation process will be explained. The research results were used to create the design scope that consists of the design goal, interaction vision, design implications and an analysis of the current products. Using this scope as a framework, and together with the focus points as starting point, ideas were generated and categorized resulting in six idea directions. After exploring these idea directions, one main idea was selected for each. These six ideas were then evaluated by using Playscapes and the expected interactions as qualitative evaluation lenses to decide on the final chosen idea.

3.1 Design scope

The design scope is the framework in which this project will design a new toy. The design goal, interaction vision, design implications and the current products on the market shape the scope.

3.1.1 Design goal

In the introduction the project goal was given. This goal can now be specified with the insights of the research:

Eliciting physical activity, *and consequently growth and development, in* ***children with ALL cancer*** *in the* ***age group of 2 to 5 years old*** *through* ***interactive toys*** *in a* ***playful*** *manner in their* ***home context****.*

Adding the resulting focus points of the analysis can create a more detailed design goal. The terms that are made in bold are specified below:

Physical activity: At the start of the project the goal was to stimulate specific bodily movements that are therapeutically relevant. Stimulating children to play and be physically active turned out to be unnecessary. Children will naturally be active and their natural activity is play, as long as they feel safe, confident and well enough to move. (Appendix A and B) That is why the problem is to elicit children to feel safe, confident and well enough to start moving within their own capacity. Focusing on specific bodily movements turned out to be very difficult to do with young children, so the specific was changed to general movements that help lessen the delay in development and growth: locomotion and using the torso (and the power to move).

Children with ALL cancer: The age group of 2-5 years old was already fixed by focusing on leukaemia. For this project the context for these children would be the home context, meaning the children that are in the mid to low risk factor group, that are polyclinic and spend most of their treatment time at home.

Playful interactive toys: To make the toys playful, the toys need to be designed by using the Playscapes perspectives, by using the qualities of bodily, dispersed and free play. This should result in a toy that fits with the natural way children play without rules or assignments. By giving the children this freedom they gain back a sense of control in their lives. This will empower the children and help with increasing their confidence.

Home context: The toy should fit in the current home situation. The toy should not create more changes than the children (and family) are already experiencing caused by the disease and treatment. By keeping the home familiar, the children will feel safe and confident while at home. The toy should instead enrich the current environment, making the child more inclined to start playing.

By incorporating all these points the following design goal was created:

Eliciting physical activity *focused on* ***locomotion and using the torso*** *in* ***children with ALL*** *cancer in the* ***age group of 2 to 5 years old*** *through* ***interactive toys that encourage bodily, dispersed and free play.*** *The toy should* ***empower*** *the children to* ***play naturally*** *and give them* ***a sense of control****. To do this the design needs to* ***fit in and enrich the home context*** *for the children to feel* ***confident and safe*** *to play.*

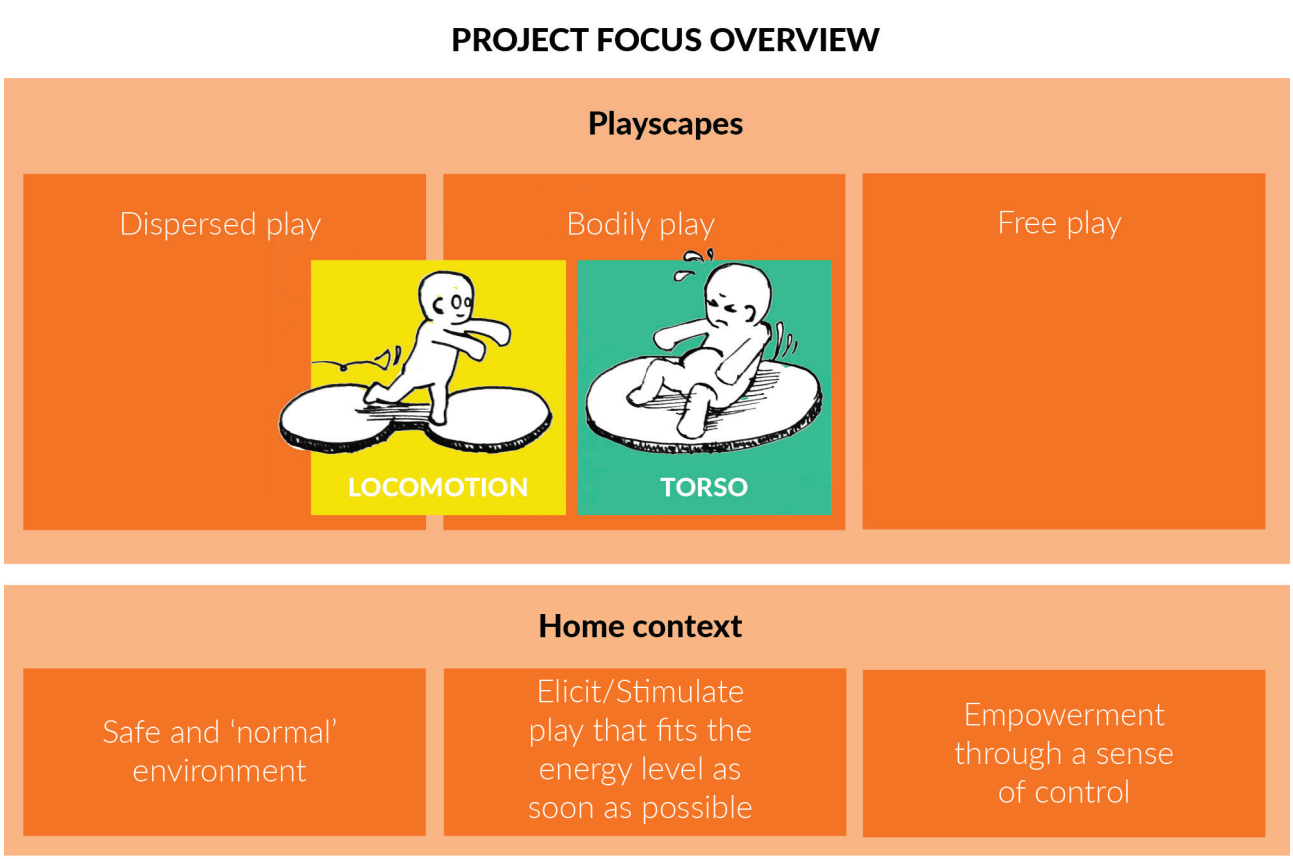


Figure 13: The final overview of the focus points resulting from the research questions that shows the project's focus.

With this specification and also as discussed in section 2.3.3 the three movement categories threats can be brought back to just locomotion and torso. These two are the focus of bodily play, although locomotion is also connected to dispersed play. This makes the focus points overview look like Figure 13 above. This overview represents the focus of the design goals and will be used as a starting point for ideation.

3.1.2 Interaction vision

The next step is to envision how the children should play, what should the interaction be between the toy and the child to achieve the design goal. The intended interaction is expressed in an interaction vision that consists of interaction qualities. The interaction vision for this design is:

The core interaction qualities of the toy are free, empowering and inviting. Playing should feel like a treat, very attractive to start playing and satisfying and rewarding for the child while playing.

Children with ALL should not feel like patients, but they should feel like normal children. They should be able to play however they want and whenever they feel like it. Playing with the toy should empower children to play more and move. And the toy itself should be inviting to children to play and to keep playing with.

Free: The interaction of children with the toy should be natural. The children should play like their healthy peers would play and decide on their own how to play. To do this the toy needs to be ambiguous and flexible. This also means that their play should be balanced to how they feel. Children themselves know best what their limits are and can decide their own maximum pace and vigour in their physical activity.

Empowering: Ideally the toy should empower the children to feel more confident in their ability to be physically active. The toy should help in the self-assurance of the children feeling sick does not need to stop them from playing. To do this the toy should also empower the parents by giving them the knowledge the toy is safe and helps the children fight the disease.

Inviting: Lastly the toy should be inviting, to make children more inclined to start playing. The toy should elicit controlled movements and make being physically active rewarding.

3.1.3 Design implications

The main insights from the analysis can be turned into design implications. The following were used as starting points to generate ideas and to evaluating the ideas.

Children with ALL
- The design does not strain the child physically continuously (pain in the legs and bones)
- The design does not create (extra) risks for the child to fall (bleeding and balance problems, Port-A-Cath)
- The design should be hygienic.
- The design challenges the child's sensibility of muscle use.
- The design does not force the child to move fast (foot drop, lowered strength, lower confidence in their own movement and body)

Threats in development
- The design does not force the child to be continuously physically active.
- The design does not focus on exercise, but allows the child to play like their (healthy) peers would.
- The design focuses more on the health-related fitness than the skill-related fitness. Although the two should not be separated.
- The design stimulates the movement categories for the motor skill developments for appropriate age group.
- The design focuses on locomotion, torso and/or power to lower the effects of ALL and the treatment.

Playscapes
- The toy should incorporate bodily (full body movements) play (Playscapes)
- The toy should incorporate dispersed (beyond boundaries of single dedicated area) play (Playscapes)
- The toy should incorporate free (spontaneous and unstructured) play (Playscapes)

Home context
- The toy should not get stuck under furniture.
- The toy should be usable in the social locations of the home (living room)
- The toy allows break times and should not cry for attention continuously.
- The toy needs to work on various surfaces and floors.
- The toy needs to work on its own and should not require help from parents or guardians to function.
- The toy should be recommended or supported by physiotherapists to ensure confidence of the parents in the toy's value.
- It should be clear what the expected effects of the toy will be on the child.
- The toy should elicit play and movement in a sedentary child with ALL.
- The toy should enhance the play in the home environment.

3.1.4 Existing current products

The next step was to generate ideas that were inspired by the research. But first a short analysis of existing products that stimulate children to move was needed to see what is already available. The goal was to get a clearer view and insights into what the current solutions are, but also to see what solutions would be suitable for the home context. After the insights, the idea generation started with using the Playscapes' perspectives and the insights as focus points to generate ideas from.

First was analysing existing toys and products that stimulate physical activity and see what their appeal was. So a search was done on current products that stimulate children to move. To get a clear overview of the current market, the products were put in a scheme, see Figure 14, and ordered by two ranges: the vertical axis contains the range of stimulating sedentary to vigorous physical activity products. And the horizontal axis contains the range of size, from small toys to large products that require a completely dedicated room. In Figure 15 the results of the scheme are explained. The biggest insight was that a lot of products that stimulate children to move are quite large. Especially the products that stimulate a lot of gross-motor skills and stimulate full body movements, like playing outside, interactive walls, etc. The smaller products tend to stimulate smaller movements and even sedentary play. In the figure these are the two yellow marked areas. The area of sedentary physical activity and large products is something to avoid. However, the area that is most interesting for this project is the vigorous physical activity and small products. A toy in this area would fit the design goal the best.

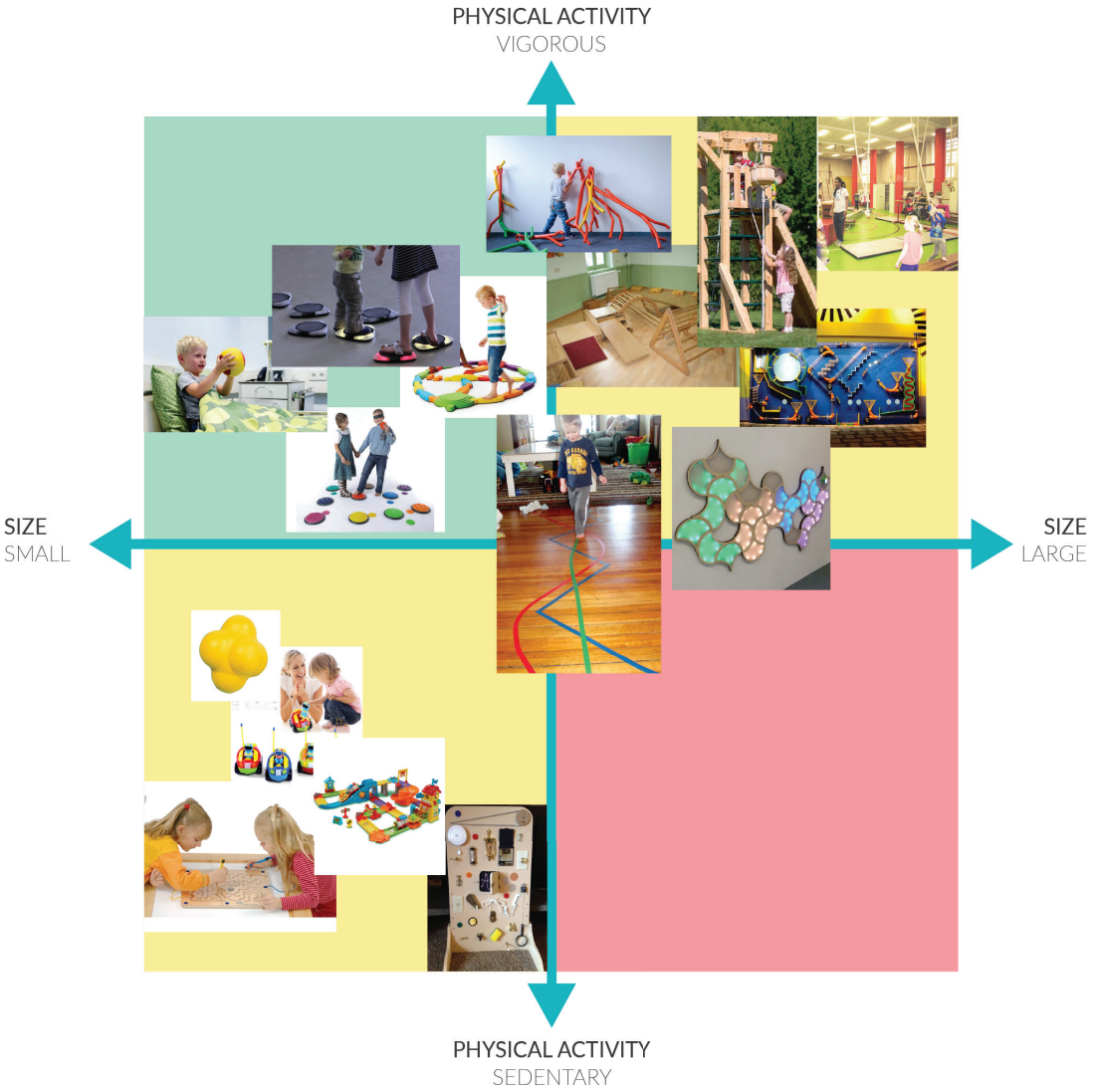


Figure 14: Scheme of existing products ordened by size from small to large and by physical activity from sedentary to vigorous.

PHYSICAL ACTIVITY VIGOROUS + SIZE SMALL

These products are the most interesting for this project. They stimulate a lot of physical activity, but are small in size so they still fit in the home context. The toy design should fall into this category.

PHYSICAL ACTIVITY VIGOROUS + SIZE LARGE

These products are not suited for this project, because they are large in size and usually do not fit in the home context. But they do stimulate vigorous full body movements. The element that stimulates children and what makes these product interesting to them has value.

PHYSICAL ACTIVITY SEDENTARY + SIZE SMALL

These products are not suited for this project, because they are small in size and do not stimulate vigorous full body movements. But they still stimulate play and movement in children eventhough it is more sedentary. The element that stimulates children and that makes these product interesting to them has value.

PHYSICAL ACTIVITY SEDENTARY + SIZE LARGE

These products are completely not suited for this project, because they are large in size and do not stimulate vigorous full body movements. They do not fit in the home context nor do they stimulate physical activity. In general this is not an area for toy designs, but an example of a product would be a television.

Figure 15: Scheme of existing products ordened by size from small to large and by physical activity from sedentary to vigorous.

3.2 Six idea directions

After setting the design scope ideas could be generated. This was done through brainstorming, creative sessions and using how-to's (see appendix F) based on the different aspects of the design goal, interaction vision and focus points overview. The current products were also used as inspiration, especially to figure out why certain toys were more appealing to children (see appendix E). The next step was to find the commonalities of all these ideas and create design directions. In the end six design directions were created: collecting, walking, making music, pushables, building playgrounds and chain connections. (Appendix G)

Evaluation through playscapes

In all six directions ideas were created and finally a main idea for each direction was selected. To be able to measure what the value of these ideas actually was, a method was needed to judge the toys. To do this Playscapes' perspectives were used to create a qualitative evaluation method. Playscapes was used as a base to create a method on which the idea directions could be compared. A scale division of 1 to 7 was created for each of the Playscapes' qualities, so the ideas could be evaluated on how well the product stimulated each quality. This division can be found in Figure 16. Part of the evaluation was the expected interaction of both negative and positive interactions between the toy and the child, parent and home context as well. More details can be found in the template on the next page. All six main ideas were then evaluated, these can be found on the pages following the template page.

Figure 16: The playscapes' design perspectives scale division to grade and evaluate idea directions and ideas.

[TITLE IDEA DIRECTION]

Description of the idea direction here.

A short description of what this idea direction is and what the potential ideas could do. The way of playing and what the important aspects are of this direction will be explained here.

Picture representation of the idea direction here.

A representation of what an idea from this idea direction could look like.

EXPECTED INTERACTION

+ Positive expected interactions are listed here. *These will contain the expected interactions from the product with the child. with the parents and with the home context.*	CHILD	- Negative expected interactions are listed here. *These will contain the expected interactions from the product with the child. with the parents and with the home context.*
+	PARENTS	-
+	HOME	-

BODILY PLAY

Description of what the intended locomotion is.

Bodily play will be evaluated by focusing on locomotion and torso.

DISPERSED PLAY

Description of what the predicted dispersed play is.

Description of what the intended use of torso is.

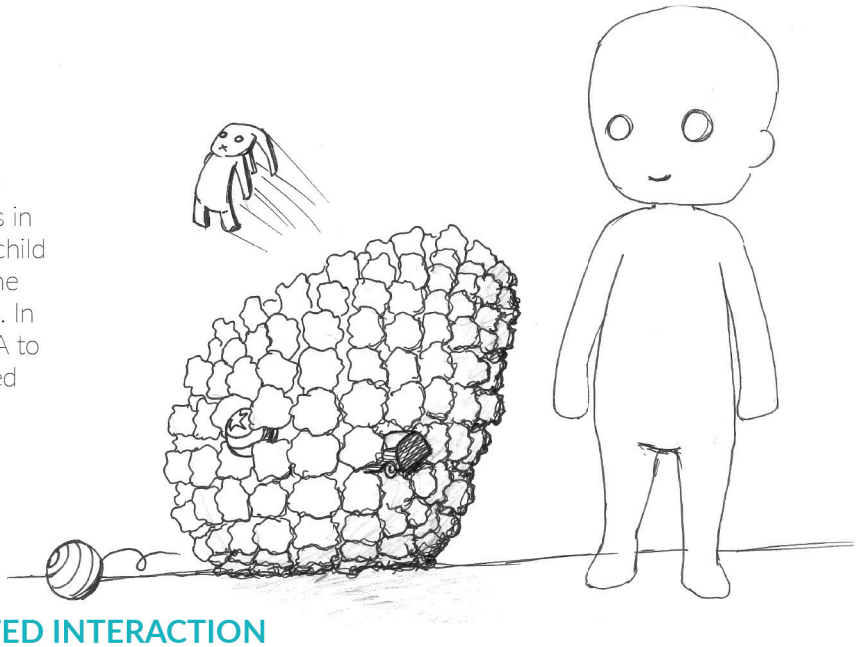
Bodily play will be evaluated by focusing on locomotion and torso.

FREE PLAY

Description of what the predicted free play is.

COLLECTING

The core idea was to have a central point or centerpiece where objects are collected and then spread out. This toy should invite children to store and potentially hide objects in it. The toy itself can be moved and placed anywhere the child wants it. Ideally the toy will be triggered by proximity of the child and irregularly/reactively shoot out/drop stored toys. In this way the toy focuses on stimulating locomotion from A to B back to A. This toy does possibly need to have dedicated related toys that match the collective centerpiece.



EXPECTED INTERACTION

+ Product itself attracts interaction because of irregular shape, material and texture. + Interaction is elicited by shooting out/dropping toys. + Locomotion is stimulated by bringing toys to the collective core. + Stimulates the torso by eliciting picking toys up and placing them in the collector.	CHILD	- Mostly interesting to younger children. - Does not directly elicits locomotion.
+ Toy will be easy to store (it is its own container).	PARENTS	- Will actively make a mess and that will not be appreciated by the parents. - Parts might get lost because of all the separate parts.
+ Fits in and can be combined with the current toys. + Toy can be moved to any area in the house. + Toy keeps children in the same area.	HOME	- Shooting toys out might not be the safest thing to do in the house.

BODILY PLAY

The spreading of the loose parts and collecting them and then putting them back in the centerpiece is what makes the children go from A to B and back to A. By picking up and placing the core locomotion is also part of the play.

DISPERSED PLAY

The play will mostly be limited to the playing area and reach of the shooting distance of the collective core, but this might increase or decrease depending on which toys and the initial placement of these toys that the child adds to the collective core. Locomotion is not directly stimulated with this idea.

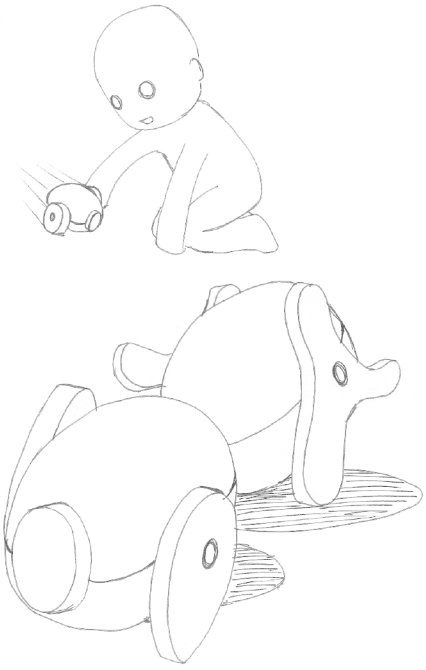
The collecting of the loose parts also stimulates picking products up and placing or removing them from the centerpiece. This makes the children move up and down and bend over during their play.

FREE PLAY

The play is ambiguous because of the irregular shape and materials. The shooting off of toys is slightly unpredictable, but the product does not allow for much variety. The unclear purpose or functionality of the idea might not be logical or understood by the children.

WALKING

The core idea was to have a toy that walks away from the child and makes him or her chase it. The toy should invite children to experiment with making it walk in different and interesting ways. To do this there should be different wheels/legs that can be attached. Potentially there could be multiple of these toys moving simultaneously and interacting with one another by for example combining. This toy focuses on locomotion by making the child run or walk after the toy.



EXPECTED INTERACTION

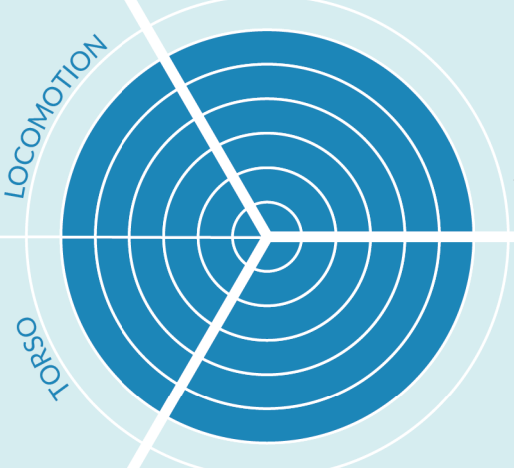
+ Interaction is elicited by autonomous walking toys. + Locomotion is stimulated by the toys 'running away'. + Multiple toys stimulate dispersed play and locomotion between toys.	CHILD	- Might keep children stationary seated down and just playing on the spot.
+ Small and easy to maintain product.	PARENTS	- Parts might get lost because of all the separate parts.
+ Toy can be moved to any area in the house. + Toy makes children walk/run around the floor.	HOME	- Might get caught under furniture or get stuck.

BODILY PLAY

The toy stimulates chasing it and trying on new wheels. This means a lot of walking and running after the toy. There is also a lot of moving back and forth between the collection of wheels and where the toy is walking.

DISPERSED PLAY

The various 'loose parts' wheels will start moving or be moved in several directions, increasing the play area of the child. The spatial directional awareness becomes more important to keep track of all toys. If the toys interact when they meet, the direction also becomes purposeful. Locomotion is needed to chase and retrieve the toy.



The toy stimulates the torso by eliciting bending down, sitting down and getting up. This needs to be done to catch the toy, change the wheels and to change directions.

FREE PLAY

The interpretation of the toys is left up to the child, the toys are a little unpredictable as they move on their own and the wheels/legs keep the behavior varied. There is freedom to create their own walker variation.

MAKING MUSIC

The core idea is to make sounds that are dependent on the movements of the child. The toy should stimulate movement by music and sounds. Potentially the toy could scan and react to different colors and textures, creating more sounds. By trying to link these sounds together the child could make music. Locomotion should be stimulated by for example making bigger movements create louder sounds. Dancing would be a very good way of playing with this toy.

EXPECTED INTERACTION

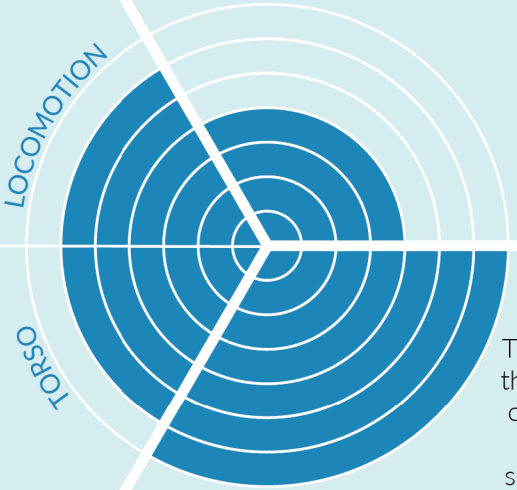
+ Experimentally starts moving more to test the limits of the toy. + Product only does something when movement is detected. + Locomotion in the form of dancing.	CHILD	- Toy could be used stationary. - Child could become very hyperactive and start swinging the toy wildly and dangerously.
+ Can be very easily be used to play together. + Educational games could be created together.	PARENTS	- All the sounds and music could be very annoying. Potentially also really loud.
+ Uses the house as part of the play. + Toy can be moved to any area in the house.	HOME	- Child might start banging the toy against everything in the house.

BODILY PLAY

The movements needed to create sounds will stimulate locomotion, but it will not directly push the child to move from A to B. The main purpose is to make big movements, having big movements make better sounds and music will stimulate the child to move from A to B.

DISPERSED PLAY

There is no set destination or pathway for this type of play. Exploration is encouraged through how the product reacts to the child's movement leading to spatial directional awareness.



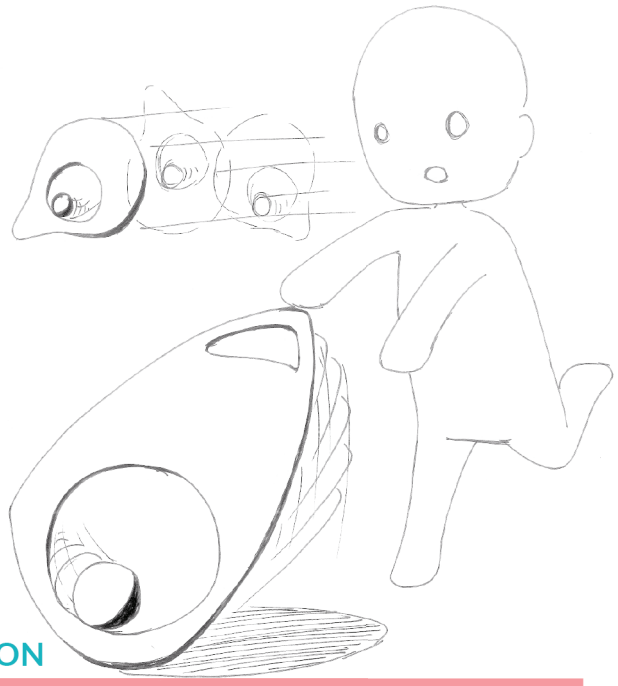
Best case scenario is that the music starts making the child dance, dancing uses a lot of muscles in the torso.

FREE PLAY

The undefined way of play is what keeps this product very ambiguous. The variety of play is completely dependent on how the child chooses to interpret the sounds, leaving a lot of open-endedness for the child's play.

PUSHABLES

The core idea of the toy is that the toy is easily brought out of balance and will start to irregularly move around, stimulating the child to follow it. The toy will stimulate movement and the use of power, where the child tries to move the toy around, chase it and tries to figure out how the product works. The round like objects will keep moving because of a free moving sphere weight inside of the product that keeps the product off balance. This makes the movement erratic and unpredictable.



EXPECTED INTERACTION

+ Interest and play elicited through the irregular shape of the product and the size. + After the toy is set off balance, play is stimulated because the toy does not move as one would expect. + Child is stimulated to try and move and then try and stop the toy. + The size stimulates full body movement like outside play.	CHILD	- Might keep children stationary seated down and just playing on the spot. - The play might be limited to making the toy stay in balance and on one spot. - Might not elicit play if not set off balance.
+ Easy to put away.	PARENTS	- Because of the size it might always be in the way/an obstacle. - Might be dangerous because of the erratic movement of a pretty big object through the house
	HOME	- Might be too big for some households to store or place. - Might damage furniture because of size and erratic movements. - Might be too big to play with in smaller rooms

BODILY PLAY

Locomotion is stimulated by the irregular motion after the toy is set off balance. The child is challenged to follow and stop the toy and try and control the toy or the direction the toy is going in.

DISPERSED PLAY

The toy does not directly stimulate a lot of dispersed play, but it does encourage it by keeping on moving. The toy will move in unpredictable ways, making exploration part of the play. There is no clear destination, but the product will create interesting pathways for the child to follow. The toy will most likely not move far away.

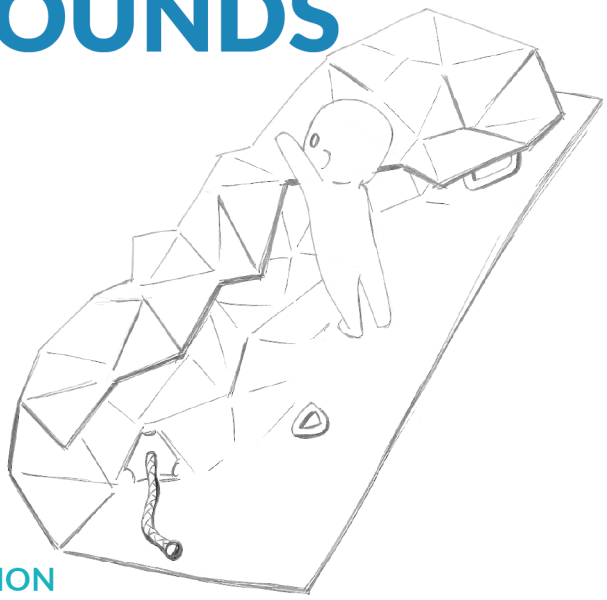
Power and torso are stimulated by interaction with the product to keep it in balance. Carrying the big objects and moving them around will also require the torso to pick the toy up and place it down.

FREE PLAY

The toy is quite ambiguous because of its irregular shape and unpredictable because it is off balance. But the variation is limited to the shape of the toy. It might become predictable over time. There is al most no manipulability except for the different ways of placing the product.

BUILDING PLAYGROUNDS

The core idea is that the child's play corner carpet is the toy. The play corner itself is part of the play and stimulates the child to use power and locomotion to manipulate it into different shapes. Power is stimulated by addition of multiple elements attached to the carpet that can be interacted with. Locomotion is stimulated through the use of those elements and by playing with the shapes and forms the carpet will take after manipulation.



EXPECTED INTERACTION

+ Interaction is stimulated through how easily the carpet is manipulated into different shapes. + Power is directly stimulated. + It facilitates the possibility for a lot of free play.	CHILD	- The carpet might just be used as a carpet. - During play the carpet might keep the child seated. - Locomotion is not directly stimulated.
+ Easy to set up the toy in a new way	PARENTS	- Might cause concern because of the big size. - There might be a lot of big parts of the toy dispersed over the floor.
+ Can be used in combination with already existing toys and play corner.	HOME	- The toy is quite big and might not fit in the home. - Might have a lot of big loose parts that need to be kept together.

BODILY PLAY

Locomotion is not directly stimulated, only slightly stimulated because it is needed to manipulate the carpet. But once the playground is build it will give space to free play where locomotion around and on the playground is stimulated.

DISPERSED PLAY

The product is not very dispersed. There are no real destinations or pathways. But within the boundaries of the reach of the carpet, it can be quite dispersed. Building this playground stimulates spatial directional awareness. But all in all the carpet will most likely stay in the same spot.

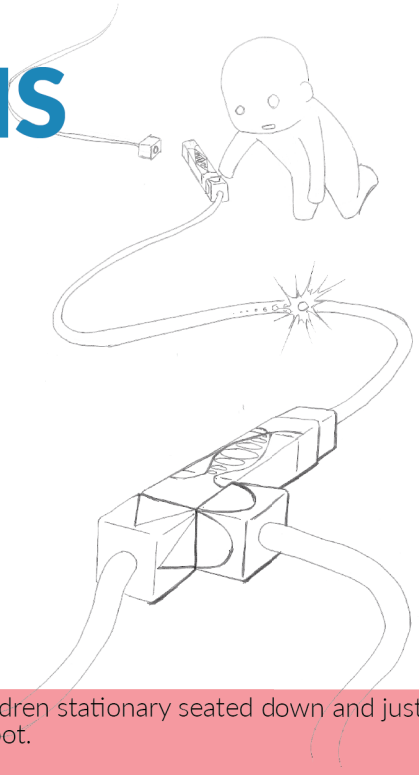
Mostly power is directly stimulated through this product. The manipulation will require balance and the use of the torso from the child. Afterwards the playground will be open for climbing, uneven floors and crawling.

FREE PLAY

Depending on how the carpet is manipulated, the ambiguity can be quite high. The manipulability is quite high allowing for quite some variety and open-endedness to the play. The play is not very unpredictable, the child will figure out how the carpet tends to move when manipulated by a certain element.

CHAIN CONNECTIONS

The core idea is to stimulate locomotion by making the child chase a light that moves around a track. The child needs to help the light to continue travelling by adding new stations and tracks. Potentially the light will respond to the proximity of the child, trying to stimulate the child to chase and/or help the light travel further. The play invites building the connection further to see what happens. In this way the toy should stimulate locomotion further by every track or station.



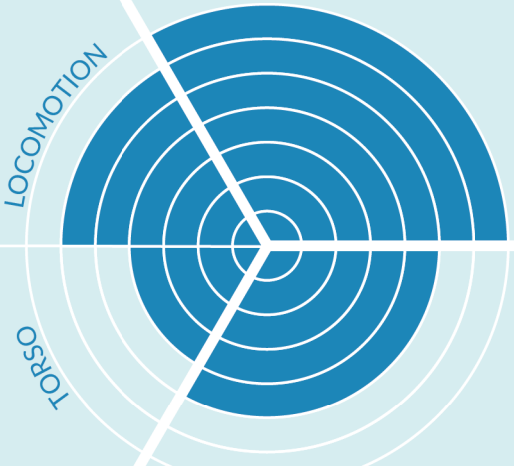
EXPECTED INTERACTION

+ Eliciting the child to chase stimulates play and movement. + Locomotion is needed for the play on multiple levels: laying the track, continuing the track by building stations and more tracks, chasing the light, etc. + Power and torso are also stimulated through the building of the track.	CHILD	- Might keep children stationary seated down and just playing on the spot.
+ Big pieces are easy to collect and put away.	PARENTS	- Trying to keep the toy in the play area and not all over the house. - There might be the danger of tripping over the long pieces.
+ Toy can be used to play with the house layout and the furniture.	HOME	- Might have a lot of big loose parts that need to be kept together.

BODILY PLAY

Locomotion is dependent on eliciting the child to chase after the light. If the light reacts to the child this will make the child much more interested. Locomotion is also needed to build the connection further. The locomotion also has a play purpose, namely to help the light move further.

The construction part of the play is where the torso comes into play the most. The child needs to pick up and carry the track pieces to be able to build the chain connection.



DISPERSED PLAY

A big part of the play of this toy is to create pathways and destinations. There loose parts that child can build with and arrange in different ways. The long tracks and how to use them in the house environment creates spatial awareness for the child, stimulating the child to play outside the play area.

FREE PLAY

The play is not very ambiguous. The behavior of the light is open for interpretation, but the parts are quite defined. The play is unpredictable and varies depending on how the light reacts on the child and how the tracks are build. There is quite some manipulability in how to create the tracks and stations. The child can decide on his or her own what the purpose of the play is.

3.3 Chosen idea: Walking

The walking idea was chosen after the evaluation through Playscapes. This idea scored the highest and most evenly in all the Playscapes design perspectives. In bodily play it scored well on locomotion and using the torso. The focus lies in having the child walking or running after the walking toy. Therefore, the main physical activity and movement the toy focuses on is locomotion. Besides locomotion, the toy will have many loose parts, which evokes dispersed play. However, the small size of these loose parts also indicates that the child will frequently have to pick up and carry the parts, which is done by sitting down and standing up. Hence, the torso will also be activated while playing with this type of toy.

The toy needs to stimulate movement in the child. This ideally will be achieved through a toy that reacts to the child. Thus the toy probably should have some intelligence to run away from the child or get closer to the child to tease him or her into playing. The child is also elicited into playing because of the way the toy will move forward. It will walk differently depending on the type of wheels used. And also the children will be stimulated to catch the walking toy as it will try and move away from them.

Following Playscapes, we only have free play left. The toy needs to stay ambiguous and simple to keep the interpretation of the toy open. With the different wheels the toy can change as well, allowing the children to create their own walking toy versions.

Lastly, it is also important that the idea will fit within the home context. The walker idea direction in general consists of relatively small parts that will easily fit in all households. The walking toy direction seems to be the least intrusive into the home environment. The building playgrounds and pushables directions are potentially too big. The making music direction is probably too noisy and possibly a nuisance to the parents. The collecting direction does not directly stimulate locomotion, but is a more passive play idea. That leaves the chain connections and the walking directions. The small size and way of playing fits the home environment without being too disruptive. That makes these two better suited for the home context.

All in all, the walking direction came out as having the most potential, so this direction was chosen to continue with (more detailing of the concept in appendix H).

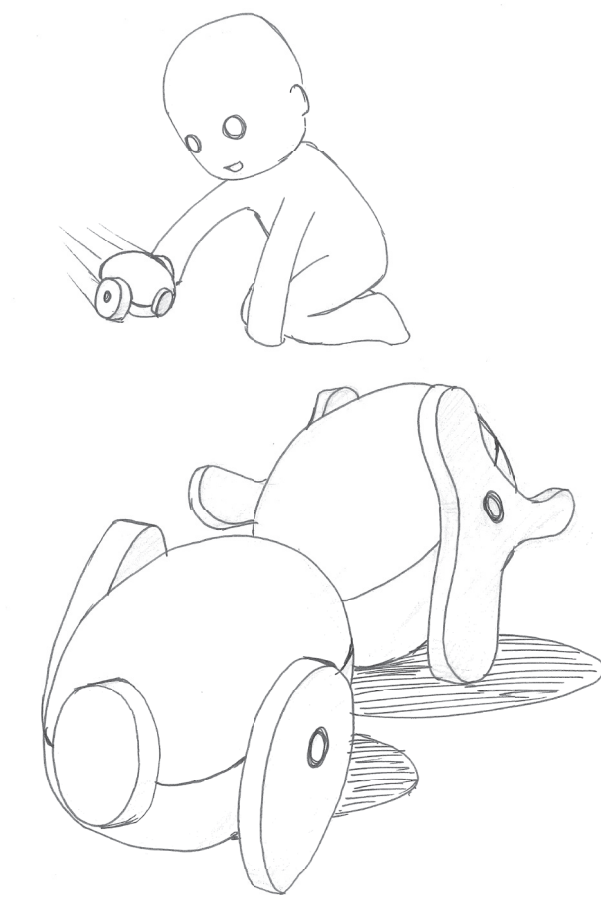


Figure 17: Initial idea sketch for the walking idea.

BODILY PLAY

The toy stimulates chasing it and trying on new wheels. This means a lot of walking and running after the toy. There is also a lot of moving back and forth between the collection of wheels and where the toy is walking.

DISPERSED PLAY

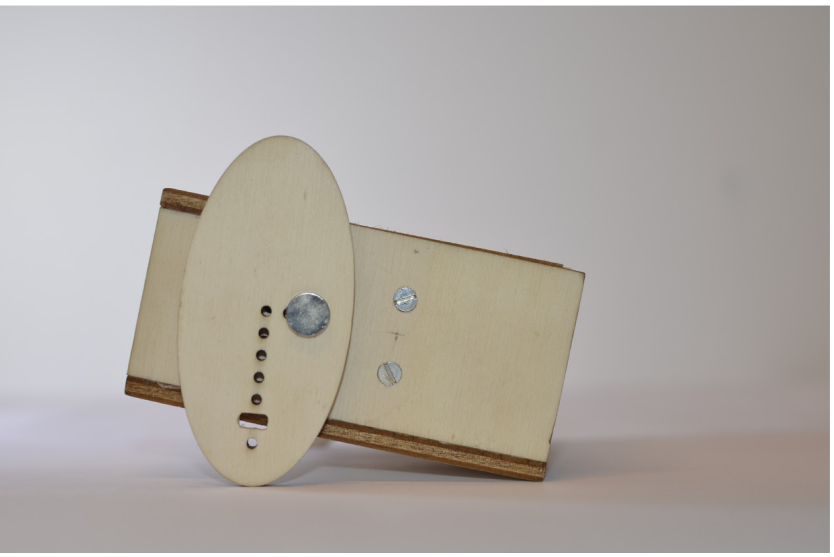
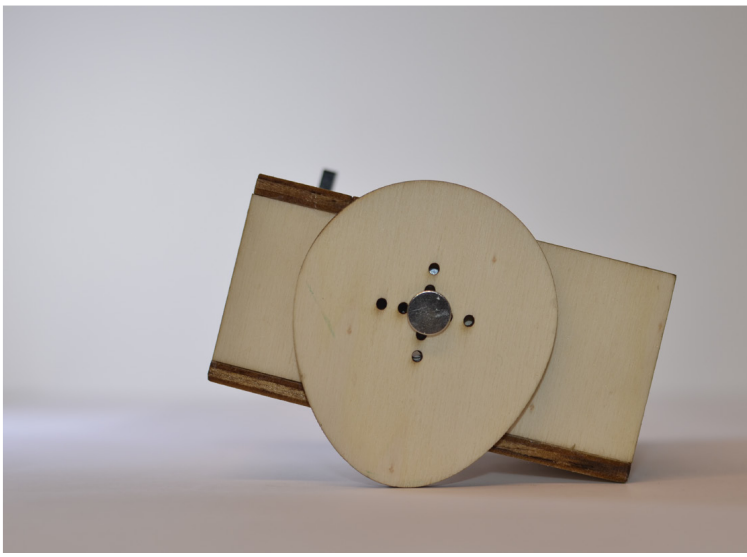
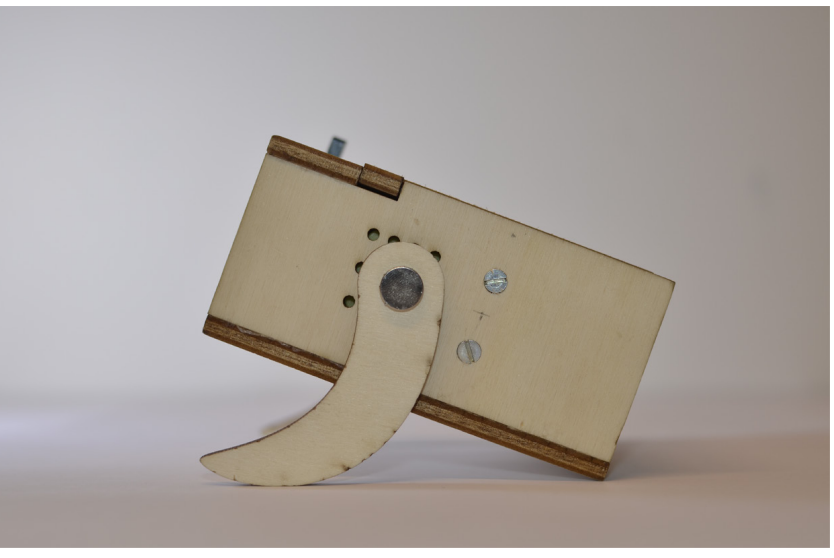
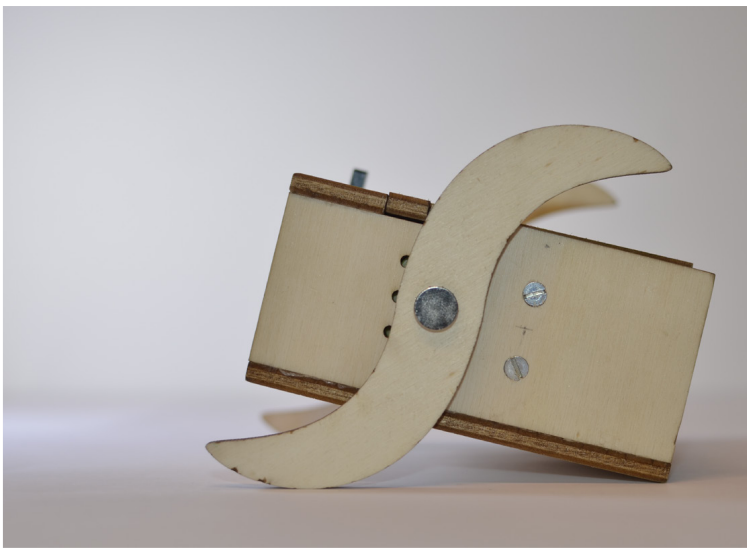
The various 'loose parts' wheels will start moving or be moved in several directions, increasing the play area of the child. The spatial directional awareness becomes more important to keep track of all toys. If the toys interact when they meet, the direction also becomes purposeful. Locomotion is needed to chase and retrieve the toy.

The toy stimulates the torso by eliciting bending down, sitting down and getting up. This needs to be done to catch the toy, change the wheels and to change directions.

FREE PLAY

The interpretation of the toys is left up to the child, the toys are a little unpredictable as they move on their own and the wheels/legs keep the behavior varied. There is freedom to create their own walker variation.



4

CONCEPT-UALISATION

In this part the conceptualisation process will be explained. The chosen idea 'walking' will be detailed into a concrete concept with a list of requirements. In this project the focus was on prototyping and thus the decision was made to conceptualise the idea through prototyping and testing. Insights were gathered through creating several iterations of the idea. Each iteration was used to detail and test certain aspects of the concept until the final version, the concept called Hobble. The final step is to make the concept a user test ready prototype, so it can be tested with children.

4.1 Prototyping

To start prototyping the walking idea was simplified. Then a simple proof of concept was made to test the fundamental functionalities of the idea. After the validation the idea was detailed through building and making iterations until a version was made that was ready for testing.

Detailing idea to concept

The next step in the process was to detail the chosen 'walking' idea. The core of the idea was a toy that walks away from the child, focusing mostly on locomotion. The toy would try and elicit the child to follow after it and play with it. The biggest obstacle was how to elicit locomotion from the child. To answer this question several aspects of the design need to be addressed: Size, intended interaction, behaviour and intelligence of the toy and how to elicit bodily, dispersed and free play. These aspects will be tested through prototyping and user tests.

The initial idea was to create three walking toys that interact with each other. The front and back of the toys would have magnets and would make it possible for the toys to combine into one longer toy. The toy would then be able to walk like a caterpillar. Social play with others could be stimulated more as well, as more people would be able to join in.

To start the prototyping, the decision was made to start with one walking toy and not three. This was done as a proof of concept and afterwards to research the potential of play with just a singular base. Only the bare essentials of the walking idea were kept in the simplification. A single base and its wheels. The magnets and sensors were left out for now. See Figure 18.

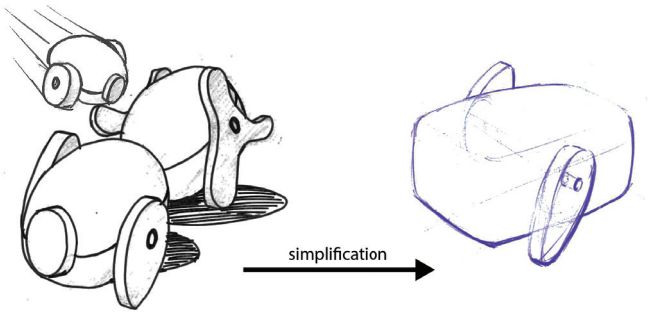


Figure 18: Simplification of the walking idea into a buildable prototype.

1st Iteration: Proof of concept

Goal

The first prototype was made to validate the concept. It was created to make the idea more concrete and three-dimensional. The main goal was to see if the design would actually walk as it was supposed to, to check if all components would fit in the toy, if all the dimensions fit young children and the home, and if building the idea was feasible.

Approach

To decide on the shape and form several try-outs where made with cardboard. To keep the ambiguity in the toy the decision was made to keep the base simple. As a start a box shape in which all the electrical components would fit was created for the base. A simple system was made to make the toy able to walk. See Figure 19.

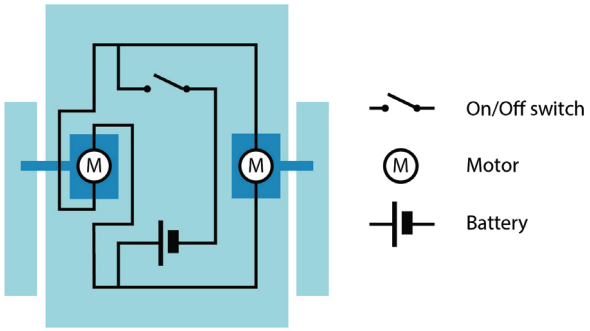


Figure 19: Electrical scheme connecting the battery, the switch and the two motors parallel.

After installing the components in the base, a test wheel was created that was connected to the motor. After assembling everything the motor was turned on to see how the toy would move. See the figures of the cardboard prototype.

Results

By building the prototype the ideal shape and size could be determined, based on sizes of existing toys, the electronics inside and it being big enough for children to play physically with.

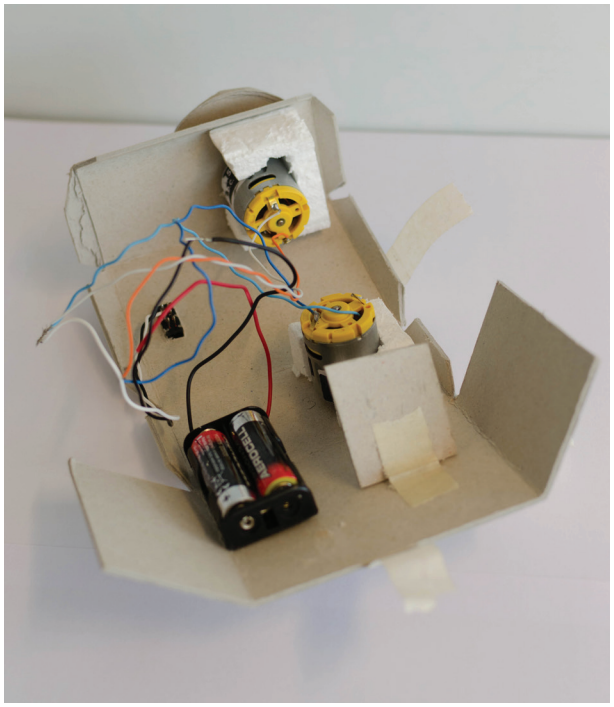


Figure 20: Electrical components in the proof of concept

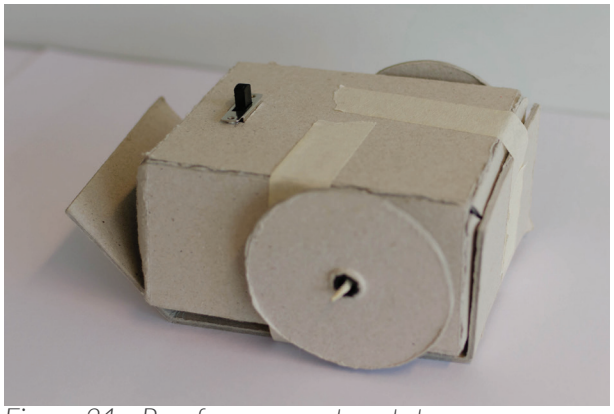


Figure 21: Proof on concept prototype

This was important for both the sizes of the base and the wheels.

Another insight was that the button to turn the toy on needed to be placed in a position that did not hinder it from walking. The bottom and the sides were not suitable, because it hindered the walking. The button plays a part in what is perceived as the front side of the toy. It was decided that the button on the front part of the top was the most logical placement, because the button was percieved as part of the 'face' of the toy. The toy was 'facing' or 'looking in' that direction. In the next iteration, what the front and 'face' of the toy is, is explored further.

2nd iteration: Building the design

Goal

The next step was to make a prototype to test how the toy would function. The goal was to figure out how the toy would move with various wheel designs. As well as figuring out where the wheel placement should be.

Approach

The first thing to design was the base of the toy. As stated earlier the shape was kept in a simple rectangular shape. This shape was kept as neutral as possible to put the focus on the wheels.

Plywood was chosen as the material to build the toy out of. The toy had to be sturdy and not too light to be able to physically play (roughly) with.

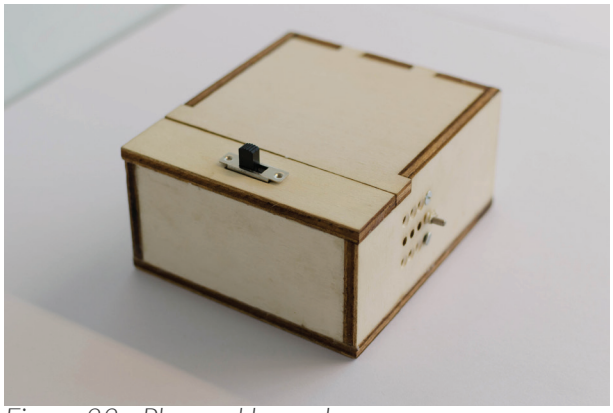


Figure 22: Plywood base shape.

Several wheel shapes were made to test what it would do to the walk pattern of the base. The wheels were made with several axis holes for extra variety in what the wheels could do.

With all the weight of the wood in the base and wheels added to the weight of the electrical components, it was necessary to test again if the motors were strong enough to carry the weight of the toy itself.

Figure 23: Plywood base shape with plywood wheels.

Results

One of the biggest problems was the motor for the toy. The motor had to be strong enough to carry the base and the wheels, and still be able to move forward. This is why initially quite strong motors were used in this prototype. However, these motors were mainly focused on speed. So the wheels were turning frighteningly fast. See video at Figure 25.

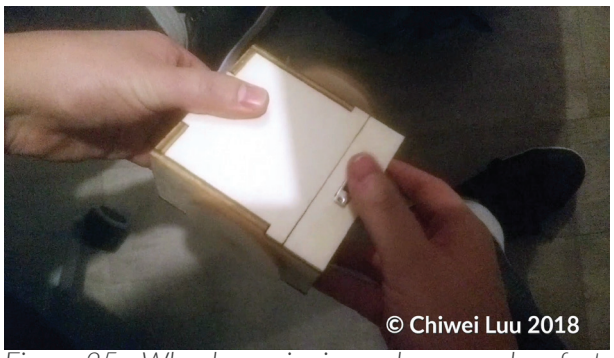
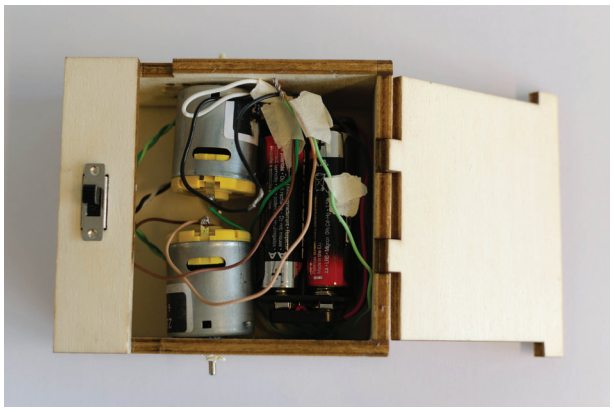


Figure 25: Wheels spinning dangerously fast. Video URL: https://youtu.be/Ds42Hn1pJDk

The motor had to turn a lot slower to make the toy safe to be played with. But it had to be strong enough to keep moving forward, especially because the wheels were not optimally shaped to move with. So new motors were added with a lower speed (rounds per minute) and a higher torque to carry the weight. See Figure 24.



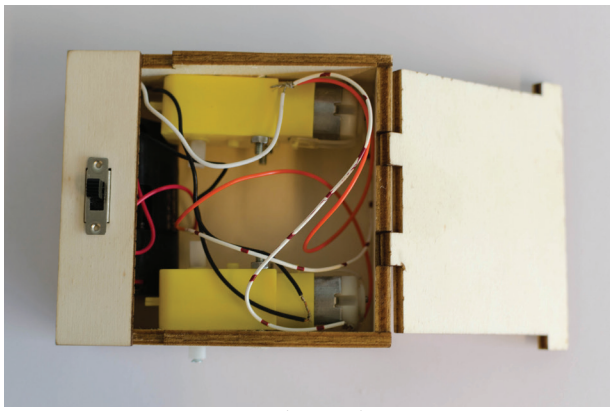


Figure 24: Old motors (above) replaced with newer higher torque and lower speed motors (below).

A new insight was that the wheel placement on the base was very important. A different placement would make the movement and the way the toy walked completely different.

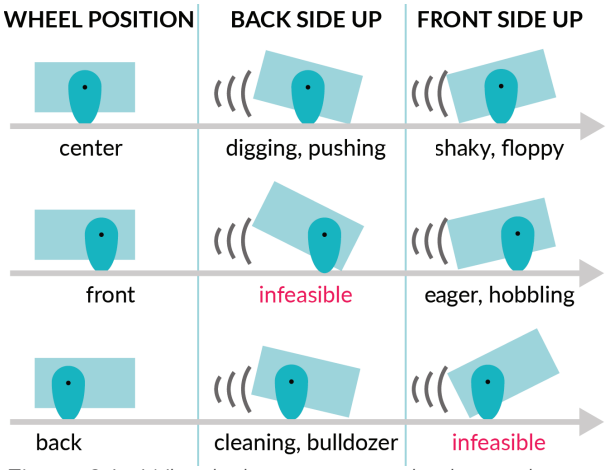


Figure 26: Wheel placement on the base changes the perception of the front of the toy and of the character.

See Figure 26. One side of the base would be lifted from the ground, while the other side would be still on the ground because of the weight. This created a clear difference between the front and the back of the design. The decision was made to have the side that was lifted off the ground to be the front, because it looked most natural. Most living beings have an elevated head in the front. The wheels look like 'arms' and are touching the ground keeping the 'head' up. See Figure 27.

What became clear was that next to the placement of the wheel, the wheels themselves changed the perception of the toy quite drastically. Therefore, to explore what the potential was of the wheels on the toy, they were researched more in-depth.

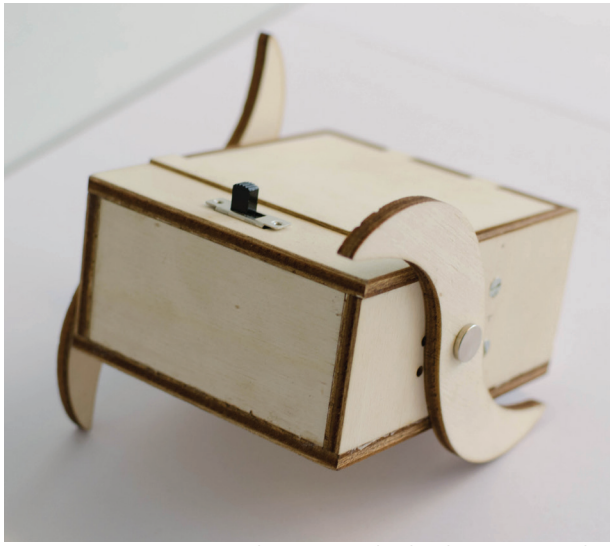


Figure 27: Front of the toy with the button on the top front part and the legs at the front side

Wheel tests: Characteristics and behaviour

Goal

After creating a suitable and testable version of the toy the next step was to focus on creating the intended interactions. The goal was to create interesting walk patterns with the different wheels. This was done to keep variety and unpredictability.

The goal was split up into the following questions:
- How does the toy walk? What/how is the locomotion?
- What kind of gait/walk pattern does the toy have?
- What is the projected emotion/mood/trait?
- What is the expected response of the child?

Approach

The next thing to verify was how the toy would walk. This started with an exploration into different shapes and forms of wheels.

Exploration of wheels

Finally, the decision was made to start prototyping with relatively simple shapes. In this way the focus of the test would be on the movement of the wheels and of the base. The wheels shown in Figure 28 were chosen and laser cut, so they could be tested.

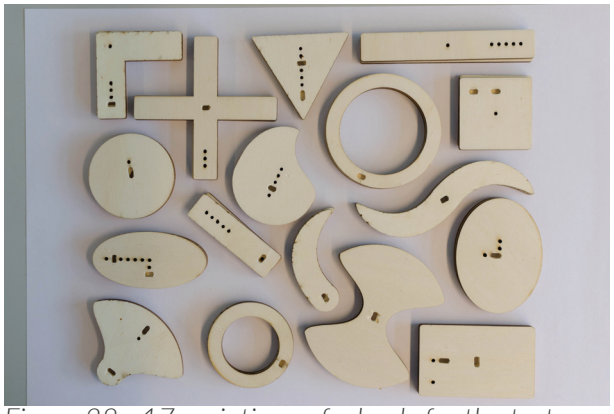


Figure 28: 17 variations of wheels for the test.

Test setup

A test setup was made to test the wheels in a controlled environment to be able to see what the effects of the wheels are on the motion of the base. A flat smooth surface was used, in this case a whiteboard, with a straight line drawn on it as a route indication. To record the movements two cameras were used to get both a side view and a three-quarter view. Every set of wheels was then attached to the base and then the whole toy was placed on the same start point. It was turned on and the movement were recorded. The test was done multiple times with the same wheels and also repeated with the motor axis in different attachment points on the wheels. See the two pictures at Figure 29.

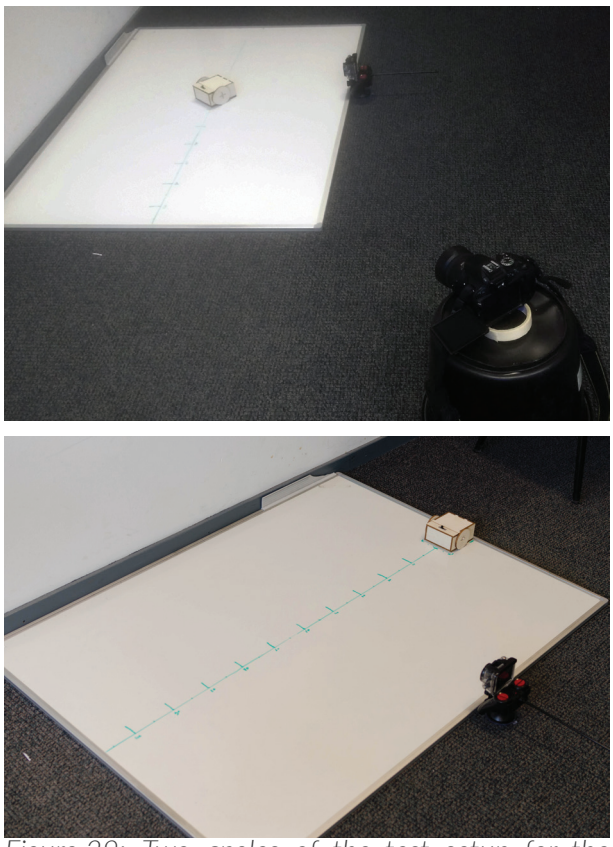


Figure 29: Two angles of the test setup for the wheel tests. Flat surface guide track, two cameras (side and 3/4 view).

Results

The results of the locomotion and gait/walk pattern are displayed in Figure 30 and Table 5. The wheel shapes are displayed in the figure with a number. That number is used to reference the wheel in the table. The wheels' walk patterns were recorded and are organised by wheel number in a video playlist. They can be seen by following the URL provided on the next pages.

The wheel shapes 01, 08B, 11 and 13 were considered to be less interesting and inferior to the other wheels, especially when compared to eliciting physical play. These wheels were consequently removed. The wheel test also gave more general insights into Hobble.

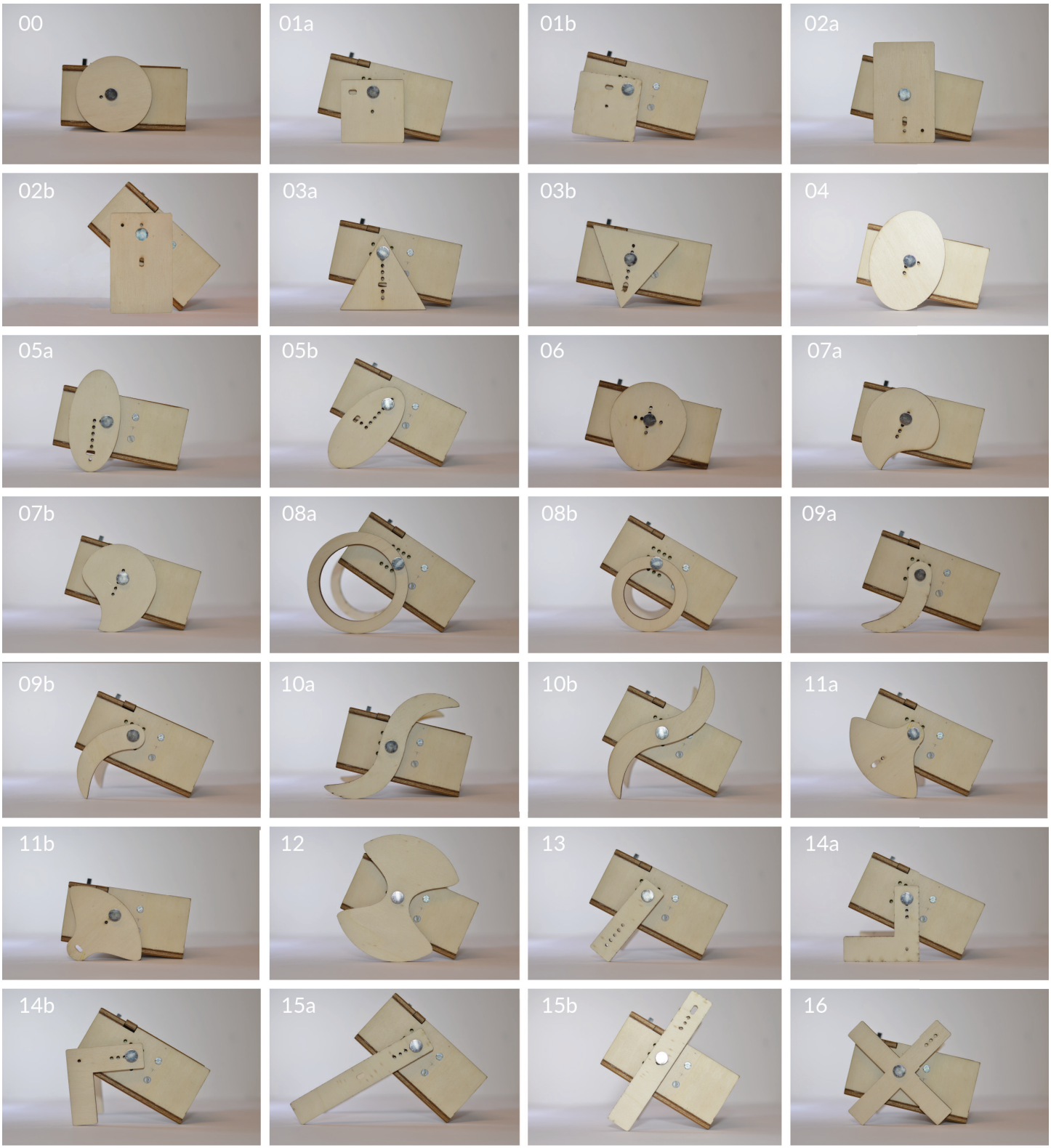


Figure 30: Wheel analysis of the variations of wheels. The walk patterns' effect on the behaviour and characteristics of Hobble, the locomotion and the expected response of the children. Video playlist URL: https://www.youtube.com/playlist?list=PLLnTNwodSiyTLA4CsxLiGG0pNLRTwRLCB

VIDEO PLAYLIST OF ALL WHEELS URL:

https://www.youtube.com/playlist?list=PLLnTNwodSiyTLA4CsxLiGG0pNLRTwRLCB

Wheel	Walk pattern	Behaviour/ Characteristics	What kind of locomotion?	Expected response
00	Fast smooth direct steady drive	Car-like, steady	Straight-ish locomotion	Play like it is a regular car toy
01	A: Bumpy crawling or falling up and down	Slow walk or seal-like, aggressive belly flops	Straying locomotion or almost stationary	Too stationary or too slow moving forward, mostly sedentary play.
	B: Bumpy swimming or falling up and down	Slow swim or seal-like, aggressive belly flops	Straying locomotion or almost stationary	
02	A: Bumpy walking with head bob or skittish walk	Bouncy happy or desperate walk forward	Slow forward locomotion	Mostly watching the movement
	B: Crazy rolling of base and wheels	Clumsy, desperately crawling forward or unpredictable crazy stuntman	Stunting, moving and flipping in all directions	Excitedly following or moving away to give space
03	A: Dragging short distance forward in intervals	Sadly dragging/clawing itself forward, wounded or amputated	Curved slow interval, slow locomotion	Watching movement, trying to help it forward
	B: Fast small falling of base	Snapping down, Pac-man	Fast interval, but slow locomotion	Walking away to not get caught
04	Fast smooth driving while bobbling up and down	Cartoony car, happy	Straight-ish locomotion	Walking or running after it
05	A: Swaying walk	Sassy, strutting, shaking butt	Straight locomotion	Walking after it
	B: Up and down	Climbing, reaching for the sky	Very little locomotion	Trying to make it climb over obstacles
06	Irregular fast small steps	Jittery, spastic, nervous	Shaky forward locomotion	Walk away from it
07	A: Fast crawler	Butterfly stroke, swimming, steady	Fast wavy locomotion	Walking after it
	B: Slow hopping waddle	Sad, waddling, disappointed	Fast wavy locomotion	Watching it maybe walk after it.
08	A: Swinging base OR Fixed wheels and turning base driving backwards	Strolling, leisurely OR tumbling around, fun	Slow curved locomotion OR straight-ish locomotion	Walking after it, surprised by it and following it closely
	B: A, but smaller, cuter movements.	Waggle	Almost no locomotion	Too stationary or too slow moving forward, mostly sedentary play.
09	A: Seal belly flop or push forward	Sad, powerless, struggling forward or slicing forward	Almost no locomotion or slow wavy locomotion	Trying to help it or walking away from it
	B: Belly flop or crawling forward	Determined ploughing forward	Almost no locomotion or slow wavy locomotion	Trying to help it or walking away from it
10	A: Fast waddling	Happy, enthusiastic, clumsy	Slow locomotion	Follow and help it along
	B: Fast waddling	Angry, aggressive, clumsy	Slow locomotion	Walk away from it
11	A: Waddle step by step	Leisurely, smooth, relaxed, steady	Straying locomotion	Walking after it
	B: Shivering forward	Boring, broken	Almost no locomotion	Too stationary or too slow moving forward, not interesting
12	Smooth regular forward motion	Noble, proud, elegant, like a dressage horse	Fast straying locomotion	Making space for it and following it
13	Swimming arm by arm	Regular, rigid, machine like, robotic	Straying locomotion	Watching it, not very interesting
14	A: Crawling waddle OR Crazy rolling base and fixed wheels OR arms like wheels on stationary upright base	Enthusiastic, determined, struggling to go forward	Slow wavy locomotion or backwards straight-ish locomotion or stationary	Surprised by the different movements, follow it and make space for it.
	B: Belly flop or crawling forward OR arms like wheels on fixed base	Determined ploughing forward	Slow wavy locomotion or backwards straight-ish locomotion or stationary	Surprised by the different movements, follow it and make space for it.
15	A: Fixed arms, backwards rolling base	Goofy, sluggish, dragging arms	Straight-ish locomotion	Walking away from it, giving it space
	B: Fast falling down and little forward	Aggressive, angry, destructive	Almost no locomotion	Walking away from it, giving it space
16	Fast small tapping walk	Noble, fearless	Straying locomotion	Walking after it, surprised by it and following it closely

Table 5: Wheel analysis of the variation of wheels. The walk patterns' effect on the behaviour and characteristics of Hobble, the locomotion and the expected response of the children.

Wheel test insights

- The shape of the wheels and the walk pattern create a certain behavior that gives character to the toy.
- Not being able to walk perfectly gives the need to help the robot.
- The walk pattern and characteristics can change drastically dependent on whether the wheels are attached to the base completely parallel symmetrical or asymmetrical.
- The ambiguity of the shapes together with the created personality.
- The loose wheel parts feel less interesting. Clear distinction between wheels and should spark interest to play with.
  - These loose parts should have extra functionality to stay interesting.
  - Example: wheels as building blocks for obstacles and clear color codes between wheels
- The base shape can determine the way of playing with the robot.
  - Add different base shapes?
- The material of the surface the robot is walking on is very important to determine the locomotion capabilities of the robot.
- The robot walks easier if the front part is lifted from the ground instead of the back part.
- The walking makes a lot of noise. The wheels (maybe even the base shape) need to be covered in a soft material to lessen the noise
- The wheels fall off really easily, there should be a better attachment system.
  - Axis needs better attachments and easier way of positioning and switching of the wheels.
- The shape of the wheels allow the robot to climb over obstacles.

Main wheel insights

One of the biggest insights was that the different wheels not just changed the walk pattern of the toy, but also changed the perception of the toy. The movements got interpreted as a certain behaviour that in turn is interpreted as characteristics of the toy. It gained personality with different walk patterns and different wheels. This helps to keep the variety and unpredictability in the toy, but more importantly it helps to elicit the child to play more with the toy and play differently with the toy. Free play is very much stimulated because the child can interpret the toys characteristics. And **the characteristics can be designed by selecting the most interesting wheels for physical play.**

Another big insight was that not being able to walk perfectly was a good quality. It elicited the need in people to help the 'poor' toy. This was a very potent way to elicit action from the user. As a bonus the helplessness of the toy can also help in empowering the children. **As the toy is something they have control over and also can help.** This could make the children feel less helpless and more in control.

Attaching the wheels to the base

The axis is what connects the base and the wheels, and also converts the motor's rotation to the wheels. This connection is important because the wheels, the base, but especially the connection between these two should be easy to handle by children. The wheels have to be easily attachable and stay attached during walking, but also easily removable.

The biggest challenge was to keep the wheel attached during walking. To do this a locking system was created to attach the wheels to the axis, see Figure 31 and Figure 32.

One of the reasons the wheels were made thicker was to create this locking system. The other reasons were to make the wheels easy to grab and hold, and to have the wheels become more prominent loose parts. The wheels should not just be seen as wheels, but they should be the attention drawing focus point of the toy. The main function of the concept is to play with different wheels after all.

The final design of the axis was made thicker to strengthen it, but also to make attaching wheels to the base easier. The fine-motor skills of sick children would have a hard time attaching wheels to a very small axis. The axis was designed to have a hexagonal shape that connects with the hexagonal holes in the wheels. This allows the wheels to easily be attached to the axis, because there is only 60 degrees maximum rotation needed for the axis to fit in the hole of the wheel.

The axis was made longer to have the wheels further away from the base. This made sure the wheels would not be able to get stuck to the base when turned on. However, this also provides space for the child to grab the wheel more easily and remove it from the axis.

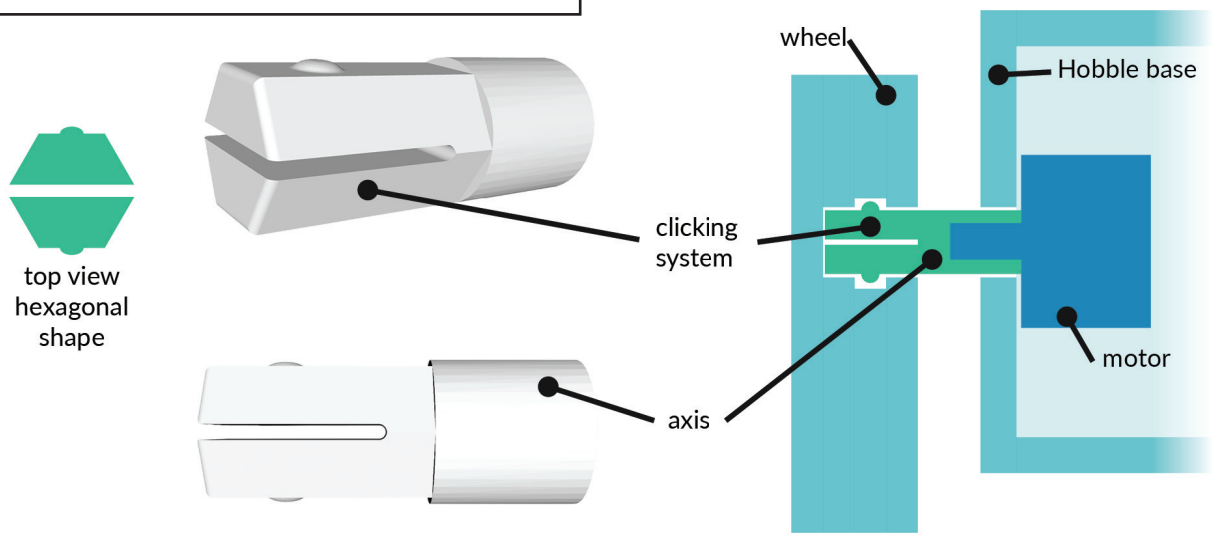


Figure 31: Clicking system with two rounded extrusions that fit in gap inside the wheel.

Figure 32: Multiple iterations of axes to create one that is attachable, keeps attached to and is removable from the wheel. Oldest to newest iterations from left to right.

4.2 Concept: Hobble

Figure 33: User tests ready prototype version 3 of concept Hobble.

The final walking concept is called Hobble. This is because the purpose of the toy is to walk around in different ways with different wheels. The different shaped wheels can also be seen as legs, creating different walk patterns for the toy. It became apparent during the wheel tests (see prototyping chapter 4.1) that these wheels resulted in a clumsy way of walking. Or in other words: hobbling.

The initial idea was to create three walking toys that interact with each other. The front and back of the toys would have magnets. This would make it possible for the toys to combine into one longer toy. The toy would then be able to walk like a caterpillar. Social play with others could be stimulated more as well, as more people would be able to join in. See Figure 18.

To continue, the decision was made to start making one Hobble and not three and see how much could be achieved with a singular Hobble toy. The following version has been selected as the final concept. This version will be further explored through prototyping.

User test friendly version

To be able to test the prototype with children more improvements were needed besides the functionality improvements. To be able to test with children the toy needed to be kid-safe, childproof, playable and testable.

The last prototyping step before user testing was to recreate Hobble but with more focus on safety, sturdiness and usability. A sturdy base was made from wood to protect electronics inside. A new attachment and detachment mechanism was created for the wheels. The wheels should be removable from the base by a child without tools. This is also one of the reasons why the wheels were made thicker. Partially for creating the locking mechanism with the axis and partially to make the wheels individual loose parts that can stand on their own, in other words more than just the accessories of the Hobble base.

The last addition to the prototype is the bag. The bag was used to store and easily transport Hobble. See Figure 33.

Hobble detailing

As stated in the beginning of this section, the biggest obstacle was how to elicit locomotion from the child. To answer this question several aspects of the design need to be addressed: size, intended interaction, behaviour and intelligence of the toy and how to stimulate bodily, dispersed and free play. The prototypes were tested to gather insights into these aspects, which in turn were used to create the next iteration. After consideration the following properties were decided upon for the concept.

Interaction

The end goal of the interaction is physical activity, specifically locomotion. The walking concept has several ways of eliciting locomotion integrated into the concept. First and foremost, the core functionality of the toy: walking away. To make this interaction elicit locomotion, the qualities of dispersed play can be used to create and keep interest in the toy. The wheels of the walking concept need to make the toy create interesting pathways, this is to keep how the toy walks interesting to the child and not repetitive. To keep the interest, there are various wheels for the toy. This simultaneously hits another quality, namely loose parts. By having many loose parts, in this case the different wheels, dispersed play is elicited. This makes it more likely for the children to move around the more the loose parts are played with and consequently spread out.

The wheels also help keep the toy interesting with a balance between the child's control over the toy and the unpredictability of the toy for the child. Control over what wheels are on the toy is completely for the child, while how the toy walks with the wheels is unpredictable. Every time the children want to try out new wheels, they will have to retrieve the toy and go back to where the other wheels are. The loose parts also make it so children will have to bend down or sit down to grab the parts, making sure they have to use their torsos and power to lift themselves. To draw the attention towards the variety of wheels, the edges of the wheels are coloured. This was also done to increase the dispersed play by putting the emphasis more on the loose parts.

Size

This brings us to the next design decision: the size. In section 3.1.4 the choice was made to focus on small size and vigorous physical activity. However, too small is a problem for this target group, these children are developing their gross-motor skills and are starting to develop more fine-motor skills. Therefore it is of importance that the children are able to hold and play with the toy and the wheels without the need of very fine-motor skills. Too big is a problem as well. The toy needs to be small enough for a child to be able to pick it up and carry it. Besides it needs to fit in the home environment.

Intelligence

To enhance how the toy elicits play, intelligence was deemed needed in the toy. The idea was that the toy 'knows' when the child is moving or not moving, for example like the Braitenberg vehicles that create intelligence in the vehicles with simple motors and motion sensors. Beckoning the child like a puppy that wants to play if the child is sedentary and challenging the children by being fast enough to walk away from them without it being stopped in their vicinity. It is important for the toy to not push the children over their limits. If the toy is too pushy, it will become annoying. This will make children lose confidence, because they will not be able to play like they would like to (or like their healthy peers would be able to). Therefore the toy should either elicit play that matches the child's energy and state or the toy should be flexible enough to allow different levels of physical play.

Free

Lastly the decision was made to keep the toy ambiguous as free play suggests. This is useful as an ambiguous toy allows for the children their imagination to be projected on the toy. This means children will have their own interpretations of what the toy is, or does or means to them.

List of requirements

The design implications can be put together to form a list of criteria, requirements and wishes. Criteria are mandatory for the design, requirements are measurable and should fit as much as possible and wishes are wanted, but optional.

Criteria

1) The toy's functions should not put the child or the rest of the family in danger.
a. The toy does not create (extra) possibilities for the child to fall (bleeding and balance problems, Port-A-Cath)
2) The toy should be hygienic to avoid infections, bacteria and viruses.
3) It should be clear what the expected effects of the toy are on the child.
4) The toy should elicit play and movement in a sedentary child with ALL.
5) The toy does not strain the child physically continuously and allows for breaks in the play (pain in the legs and bones).
6) The toy does not force the child to move fast (foot drop, lowered strength, lower confidence in their own movement and body).
7) The toy should not be too big and fit in the home environment.
8) The toy should not damage the furniture or the rest of the home environment.
9) The toy should not be obnoxiously noisy.
10) The toy needs to work on its own and should not require help from parents or guardians to function.

Requirements

1) The toy focuses on locomotion, torso and/or power to lower the effects of ALL and the treatment.
a. The toy focuses more on the health-related fitness (mostly gross motor skills) than the skill-related fitness. Although the two should not be separated.
2) The toy should incorporate playscapes as much as possible.
a. The toy should incorporate bodily (full body movements) play.
b. The toy should incorporate dispersed (beyond boundaries of single dedicated area) play.
c. The toy should incorporate free (spontaneous and unstructured) play.
3) The toy should enhance the play in the home environment.
4) The toy does not focus on exercise, but allows the child to play like their (healthy) peers would.
5) The toy needs to work on various surfaces and floors.

Wishes

1) The toy should be recommended or supported by physiotherapists to ensure confidence of the parents in the toy's value.
2) The toy challenges the child's sensibility of muscle use.
3) The toy stimulates the movement categories for the motor skill developments for appropriate age group.
4) The toy should stay interesting over time and should be reusable.
5) The toy should be usable in the social locations of the home (living room).
6) The toy should not be too small and get stuck under furniture.

5

EVALUATION

In this part the evaluation of Hobble will be explained. To test the idea, a user test friendly prototype was made that was safe for children to play with. User tests were done to evaluate the concept Hobble through four research questions. Five families with children between the ages of 2 to 5 years old participated in the tests. The goal, approach, results and conclusions and discussion will be covered in this section.

5.1 User testing

The user tests will be covered in this chapter. The tests were done with four research questions in mind that were based on the focus points: home context, free, bodily and dispersed play.

To be able to test with children with ALL the test needed to be approved by an acknowledged Medisch-Ethische Toetsings-Commissie (METC), loosely translated medical ethics review committee. This is an independent administrative body of experts that judges whether or not your research is ethical, legal and appropriate. Since getting approval would not fit within the planned time for this project, the decision was made to approach families with healthy children. The goal was to test whether children in general are interested in and will play the intended way with Hobble.

Testing with healthy children

In part 2.4.2 it was touched upon, that children with ALL do want to play all day just like healthy children. According to the physiotherapists and the parent:

"..children with ALL are just like normal children except a little bald."

This is true for the most part, but of course these children are sick. Their energy levels are lower and they can feel nauseous, so the frequency and the intensity of their physical activity will be lower than healthy children. They should however still be able to play as long as they feel confident and safe. While their energy fluctuates during chemotherapy, there will be moments where they play almost the same as others. This means that tests with healthy children can nonetheless provide valuable information on the types of play generated by Hobble.

The results of the tests help understanding how children play with Hobble. They represent what children with ALL should approximately be able to do when they are feeling well with the biggest difference being that they need more breaks.

Goal

The goal of the user tests was to observe what the interactions are between the child and the toy. The tests mainly focused on the physical play in children elicited by Hobble and its accordance with the focus points of this project. (see chapter 2.5). The three main focus points of physical play, free, dispersed and bodily play, were studied. As stated before, the movement categories of locomotion and torso were most important in bodily play. For the last focus point, the home environment was analysed to assess how Hobble would fit in. This included getting the parents' opinion on Hobble and getting a clear view of where children play at home. Finally, the focus points were used to create research questions for the user tests:

1. Home context - Does Hobble fit in the home context (family, environment, energy)?
2. Free play - Which kinds of play activities arise with Hobble?
3. Bodily play - What are the children's movements during their play, specifically concerning locomotion and using the torso?
4. Dispersed play - Does Hobble stimulate dispersed play?

Approach

The user test consisted of two parts: an The user test consisted of an observation of the user test (see appendix J) and an interview with both the children and the parent(s) afterwards (seen appendix K). In total, five families with healthy young children between the ages of 2 to 5 years old were visited. In the first three families visited a single child participated, while two siblings played together in the fourth family. In the final, fifth family two siblings and a friend of theirs, so three children in total, participated. Since the fifth family was visited at a later stage of the project, the focus was instead on how multiple children would interact with Hobble. For this reason, the

	Family	1	2	3	4	*5 (extra)*
	No. children	1	1	1	2	*3*
	Name(s) + age(s)	Lars (4)	Brian (2,5)	Billy (3)	Amber (5), Ommo (3)	*Ivana (5), Emma (4), Juul (6,5)*
ANALYSIS	**Home context**					
	Bodily play					
	Free play					
	Dispersed play					

Table 6: Overview of all the five user tests including the amount of children that participated and showing what has been analysed.

family's test results were not included in the bodily play analysis. All the names of the children have been changed to protect their privacy as displayed in the Table 6.

Test setup

It was crucial to the user tests to allow the children to play in a natural way without any external interference out of the normal home context. In this case, to be as close to free play as possible, there were no explanations, no rules and no examples provided. This also meant that the child was allowed to play and use or even abuse the toy to reasonable extent. In this case throwing and smashing as part of the play was permitted, but explicitly trying to destroy Hobble, by for example pouring water over it or trying to jump on Hobble, would be reasons for intervention. This was decided to study what kind of free play emerged from just providing Hobble to the children in their home context.

To achieve this the presentation of the toy was crucial. The toy by itself has to be clear to the children; they need to be able to figure out the functions and ways of play by themselves. In all tests, the toy was presented in a dedicated bag. The wheels were stored inside and the base of Hobble was placed on top of the wheels, with just one wheel attached. The intention for this setup was to visually trigger the children that the wheels could be removed or added without explaining it to them. The base was put on top to be sure the children would find the switch to turn Hobble on quickly. The design decisions were made to guide the children towards the intended play with Hobble as much as possible. Another reason was to streamline the study to achieve the most insight in the interactions while playing with Hobble and spend less time on figuring out how to play with Hobble. This reduces the possibility that the children lose interest in case they mistake the wheels in the bag as 'normal' wooden blocks.

Figure 34: Prototype starting setup

To not interfere with the child's natural play, the researcher observed and took notes from a distance. To be able to analyse the interactions in detail, two cameras were set up to film the tests from two different angles. With this setup the researcher could stay out of the play area as much as possible during the test.

After the children indicated that they were done playing or had lost interest in the toy, the test would continue with an interview. The children were asked simple questions to get their thoughts on the toy. Because of their age the questions and the interview were not forced. Then the interview shifted to the parents to see what their opinion was and to get more insights into the home context. See appendix K for the interview questions.

Physical activity level	Measure
Vigorous intensity (v)	>40 gcs/minute
Moderate intensity (m)	21-40 gcs/minute
Light intensity (l)	1-20 gcs/minute
Sedentary intensity	<1 gcs/minute

Table 7: Ovearview of physical activity intensity levels categorized by the amount of gait cycles, by Winter et al.

Analysis setup

To answer the research questions the following analysis setups and methods were used.

1. **Home context - Does Hobble fit in the home context (family, environment, energy)?**

The home context was analysed by interviewing the parents after the tests, using the observations during the test and analysing the videos of the tests. Questions about the play areas at home, the family situation, the social play and the children's average play were asked to answer the 'Safe and 'normal' home environment' focus point. The interviews can be found in appendix K.

The 'empowerment through a sense of control' focus point was hard to test, because this could only be tested with children with ALL. There was no way to see if these children were empowered or gained a sense of control through Hobble. However during the tests the play was analysed to observe if these children showed a general sense of control and empowerment during their play. As this focus point involved analysing the control over play activities, the results were found after analysing the free play. The results can be found in the free play results.

To get insight into the focus point of whether Hobble elicits play that fits the fluctuating energy as soon as possible, it was necessary to see how children play at home and what their physical activity is during play. Therefore, to be able to discuss whether the energy fits the children during the play, the activities and the needed physical intensity during the play had to be identified. The activities that arise during the play are defined in the free play question. Afterwards the intensity level of these activities can be determined in the bodily play analysis. With those results this focus point is answered.

2. **Free play - Which kinds of play activities arise with Hobble?**

A movement analysis was performed to determine the way children move during play with Hobble. All interactions were described in movements done by the child while playing with Hobble. They were then categorized as activities that consisted of combinations and follow-ups of movements, see Figure 35 at the results. These activities will be referenced as play activities from here onward.

In the conceptualisation section, the different behaviours of the wheels were explored. The effects of the different wheels and how they influenced the free play were observed and analysed.

Lastly, playing socially, with peers or parents, changes the free play. This was observed and analysed as well.

3. **Bodily play - What are the children's movements during their play, specifically concerning locomotion and using the torso?**

Generally physical activity is described in steps or gait cycles (gcs), where one gait cycle consists of two steps. Winter et al. describe intensity of physical activity in gait cycles per minute. The intensity is divided over a scale making a distinction between sedentary, light, moderate and vigorous intensity, as shown in Table 7. This scale was used in the analysis to indicate the physical activity level of the play activities. However, the play activities frequently lasted less than a minute, so the steps counted in the activity over time were extrapolated to one minute. (Winter et al., 2009)

With this approach the intensity of all the play activities was made into a graph for comparison and analysis. This gave an indication of how children play with Hobble and what play activities stimulated more physical play than others. It also showed the fluctuations of their play with

Hobble over time and whether it fits with the normal intermittent and fluctuating natural play. This is where the 'elicit play that fits the energy as soon as possible' focus point is discussed.

The next step was to analyse the bodily play, specifically the locomotion and the use of the torso. The physical activity graphs and play activities were combined to create an overview with play activities linked to intensity levels.

As the bodily play for this project is focused on locomotion and using the torso, the play activities were labelled with whether they induced locomotion or torso usage. Then, two lists of play activities that were either vigorous or light/sedentary in intensity were made. The lists represent which play activities elicited the most bodily play and which the least.

4. Dispersed play - Does Hobble stimulate dispersed play?

LLastly, the dispersed play was analysed by studying the dispersion in the videos and by creating dispersion maps. These maps are a visualisation of the dispersion of the child over time. The videos of the user tests were used and screenshots were made in a fixed interval, 1 minute per screenshot, creating a time-lapse of the dispersion of the child during the play. The time-lapse pictures will be used as an approximation to what was seen in the videos. The effects of the loose parts and the bag (central point) will also be analysed.

Expected outcome

In general the expectation was that children would explore the different wheels, turn Hobble on and follow it. The product would move away from the child and at some point most likely crash into an obstacle or not walk the way the child intended, stimulating the child to get up and move towards Hobble to help it. Depending on the wheels and their attached behaviour and characteristics, the physical play will change. The specific expectations for the wheels can be seen in the Figure 30 and Table 5 in the wheel tests part. The children will probably change the wheels and try them out. More specific expectations are shown below categorized per Playscapes quality in Table 8.

Free play	Bodily play	Dispersed play
The children's **interest will fluctuate** depending on the wheels they put on Hobble. This gives them **freedom to interpret** Hobble any way they want.	Hobble will elicit a lot of - **walking** - **crawling** - **sitting down** - **bending the knees** - **picking the product up and transporting it** - **Using the torso** - **Getting up and sitting down**	The loose parts, the wheels, in the bag will be a **central returning point** for the child, while Hobble will be moving away. This will give the children the space to move with Hobble through the play area however they want, but eventually they will **return to the bag with the other wheels.** The children will **follow Hobble** when it moves away.

Table 8: Expected outcome for the playscapes perspectives.

Results

1. Home context - Does Hobble fit in the home context (family, environment, energy)?

Focus point: Safe and 'normal' environment
Home layout and play locations

In general children are allowed to play almost everywhere in the house. Most families have a corner or a room where most of the toys are stored, which tends to be the child's bedroom or a play corner in the living room. Children usually like to play around the other family members, meaning they tend to generally play in the living room.
More information has been covered in analysis section part 2.4.4.

Family situation

On average children play 5 minutes with a certain toy before switching. Unless it is 'the toy of the week', in which case the play can be infinitely long with the same toy. (Appendix B). The interviewed parents try to keep their children busy with physical play and are quite conscious of how much they allow their children to be seated in front of televisions, laptops, tablets, smartphones and computers or other electronics. Most parents believe that playing physically is healthier and there are strict rules for when the children are allowed to watch or play with these 'screens'. The overall consensus was that children should be playing with toys and moving, preferably outside.

Family moments where children and parents really take time to play together happen rarely. Most parents do not have enough time to play together with their children frequently, so they try and keep 2-3 real contact moments a week that are more spontaneous and requested by the kids themselves. Usually the parents try to involve the children into the daily or weekly normal tasks. These are the main contact moments of the families. Playing together is usually only initiated when the child spontaneously requests to play something together, this then will be planned with the parent for a later time. However, all of the other times, parents prefer their children to be able to play by themselves. The toy and the play should not be dependent on the parent for the child to start playing.

Although multiple parents did mention that some control over the toys would be nice. If it were possible to guide the children in which toys to play with, they would want that. Especially when the children are younger they sometimes need to be motivated to start playing with different things, they are still very dependent and clingy to the parents. Hence, in the earlier years, parents try to stimulate and control which toys the children will play with by for example putting these toys more to the foreground. The parents would then not give in to the complaints and requests of the children.

"Children need to learn to be bored. By being bored the child needs to choose something to do and will usually start playing by themselves."
- Billy's mom.

Allow children to be bored so they have to choose something to not be bored. Older children usually do not need to be motivated to play as they start playing on their own.

There were a couple concerns that some parents had, mostly about the safety and hygiene of the Hobble. They wanted the materials and the production to be safe and hygienic, so for example children could safely put Hobble in their mouths. And one parent was afraid that children would throw with the parts. Nonetheless, the parents found the toy interesting and fun, and stated Hobble was welcome in their homes.

2. Free play - Which kinds of play activities arise with Hobble?

Through a movement analysis (Appendix L), the movements registered could be grouped together into activities that the children created during the play with Hobble. The diversity of play activities was used as an indicator for the possibilities that Hobble can provide. The observed play activities were categorized and put into Figure 35.

The table starts with the column 'Exploring & Trying', these activities are part of the introduction to Hobble. The three columns of play activities in the middle are divided by familiarity with Hobble. The left column contains activities that were present mostly in the beginning when the children were still playing in a simple way with Hobble. As the familiarity with Hobble

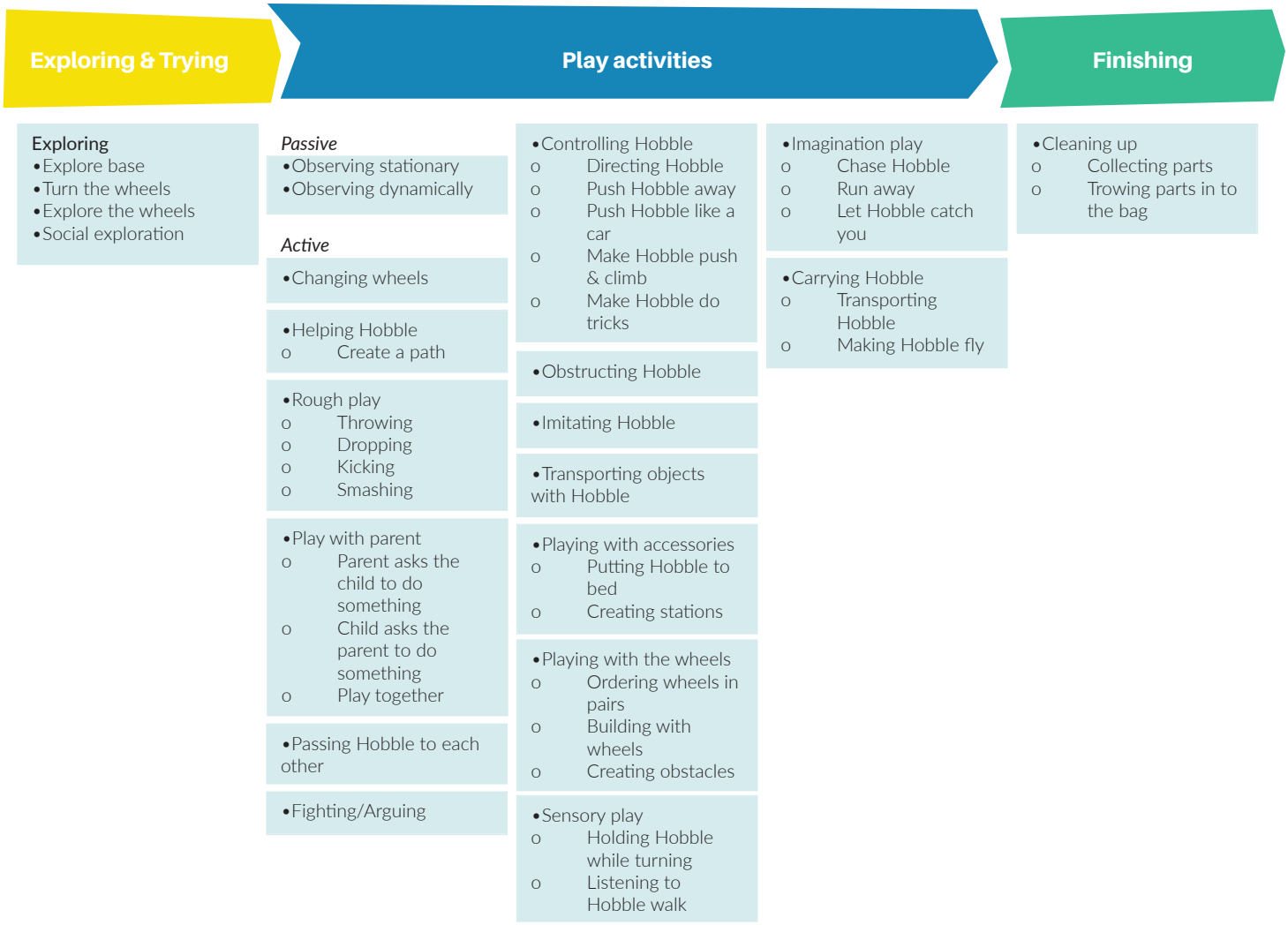


Figure 35: Overview of play activities with an increase of familiarity with Hobble from left to right.

and its properties rose, so does the complexity of the play. The middle column contains play activities that are more than just playing with the basic functionalities of Hobble, they start to manipulate the toy. The last column contains play activities where the children have a sense of complete familiarity with Hobble and start to play outside the functionalities of Hobble. The last column is about finishing the play, where the activities are cleaning up and stopping the play with Hobble.

Exploring and cleaning up turned out to be very large play activities that took a lot of time. Exploring was mostly sedentary, where children were exploring the parts of Hobble separately. Starting with the base and figuring out the on/off-button, then the wheels were explored. The exploration was done alone, but most of the time the children tried to involve a parent or their peers in their discovery. The cleaning up consisted of collecting all the parts, bringing them back to bag and throwing them back into the bag. The following play activities were most prominent. Observing Hobble by staying stationary and just observe in one spot or by dynamically following Hobble to observe. In general there was way more walking away and running away from Hobble than expected instead of following Hobble. Changing wheels and trying them out and testing the limits of Hobble through rough play by throwing, dropping, kicking and smashing Hobble. Controlling Hobble by trying to direct hobble through pushing, pulling. Obstructing Hobble by placing objects and furniture on the path of Hobble. Carrying Hobble by bringing Hobble to new places or back to the bag or simply playing with Hobble in hand. Imitating Hobble by copying the movements Hobble makes and the behaviour it has. Imagination play with Hobble as a playmate, Hobble assumes a role and becomes a 'living' playmate. Sensory play with Hobble, play focused on an individual sense. Specifically sound was interesting, the children were just

listening to the gait and rhythm of the wheels tapping on the ground and even tried to imitate the sounds they heard.

In general one of the most interesting insights of the play activities was the following.
Instead of the expected outcome of the children following Hobble around and actively helping it along, the opposite happened. Children passively observed Hobble from a distance or even moved away to create distance from Hobble. This got to the point where running away from Hobble was more common than walking behind Hobble. And if the children started following Hobble, the locomotion was mostly crawling and sliding on the knees or butt towards Hobble.

What did the wheels do?

Different ways of playing are invented and created by the children with their own interpretation of Hobble. Hobble is interpreted for example as a car, robot, animal or monster by only changing the wheels or sometimes even without and simply by changing the play. Because of how

Role	Characteristics	Wheels	Movements
Climber	Climbing (over obstacles) toy	Hooked wheels	Make obstacles, use environment, walk over other wheels, try different surfaces
Escaper	Walking/running away	Rounder wheels	Follow, observe, direct, help, steer and control.
Chaser	Running towards	Swimming wheels/big up and down motions	Walk/run away, observe
Monster/Destroyer	Aggressively run towards or around, falling motions	S-wheel, long arm wheels	Walk/run away, observe, get to higher ground to observe, run to parents, push away, grab and 'attack' other objects.
Crazy/Stuntman	Stunting and weird walks	Square and long wheels	Observe, walk around it, encourage it, imitate it, show to others, make fun of it
Fool/Klutz	Going in circles, bumping into things, getting stuck.	Potential in all wheels	Walk around it, observe, help, direct, encourage it, make fun of it
Helpless	Slow sad movement, struggling forward	Fin-like wheels	Observe, encourage, help, direct, push, make fun of it
Puppy	Happy, enthusiastic, jittery	S-wheel, +-wheel	Walk around it, push it, make it follow, direct it

Table 9: Overview of all the roles Hobble took based on interpretations of the children.

open-ended the play is, exploring the possibilities and testing the limits of Hobble become part of the play. There are no fixed associations to the parts, except for them being geometrical shapes and forms. This means that the interpretation is dependent on the toy's characteristics and behaviour, especially concerning the wheels as these can be changed. The wheels gave different behaviours to Hobble that made the kids interpret the toy as a different thing or being. Children usually start with observing until the characteristics and behaviour are familiar, then they start manipulating and playing with Hobble. In the beginning Hobble's role is mostly as an impaired motor, this quickly becomes an entertainer. Only after a certain amount of playing, Hobble starts to be something part of the children's imagination. This includes being seen as a robot, car, plane, train, but also as a living thing, like an animal, beast, monster and playmate.

The role and behaviour of Hobble changed and consequently the play changed when the wheels changed. Children use a lot of different descriptions for the roles, but the characteristics will usually fit one in Table 9.

For example the +-shaped wheels were interpreted mostly as 'enthusiastic walking' and in turn Hobble was treated like a living thing in the play. Children were saying things like: "He needs to sleep now." and trying to talk to Hobble: "No! You can not walk this way!" The variety was very valuable for the unexpectedness of Hobble. Hobble became a different character with each different set of wheels and this kept the children interested and the play free.

Focus point: Empowerment through a sense of control

As stated before, this focus point could not be As stated before, this focus point could not be tested, because the empowerment was specifically for children with ALL. However, what was apparent in the tests is that children play in their own way, unstructured and spontaneous. This tells us that they have control over how they play. They decide by themselves what to do and how to do it. This can be seen by the many different activities that arose during the tests with the all the different children.

Another indicator was that the play changed when the role of Hobble changed. Especially when Hobble was not functioning well, children became much more attentive and active in trying to control Hobble's movements and helping it along. So when Hobble was clumsy, weak and helpless, it stimulated more physical activity in the form of helping and supporting Hobble. While when Hobble was properly moving forward, the children usually were much more passive and stationary with their interaction during play.

Social play

Playing independently is important, but parents did like that Hobble gives the possibility to play together, The social play of Hobble between child and parent was observed with almost all families, while the social play between peers was observed with families 4 and 5. Mainly three types of play arose while playing with the parents. The most frequent and common activity was show and tell. The children wanted to share what they had done with or discovered about Hobble. The other two play activities were about trying to control Hobble together. This was tried in the form of passing Hobble to each other or trying to direct Hobble's movements together. These social play activities involved a lot of walking, carrying Hobble to the parents and a lot of bending down and getting up to control Hobble. The social play between peers of the child, like siblings and friends, was more chaotic and was more prone to fights and arguments. Because there was only one Hobble toy base, the children had to share and play one by one. The interpretation of Hobble and the wheels was very varied per child and that made picking and deciding on the 'most cool ones' difficult. However, this did make the wheels much more prominent in the play. Comparing and deciding on the next set of wheels became a main play activity for the children that were waiting for their turn to play with Hobble. This also led to playing separately with just the loose parts. All of this gave the consequence of much more physical activity as the children boosted each other's physical play by encouraging and stimulating each other to try more or play differently.

3. **Bodily play - What are the children's movements during their play, specifically concerning locomotion and using the torso?**

Focus point: Elicit play that fits the energy as soon as possible.

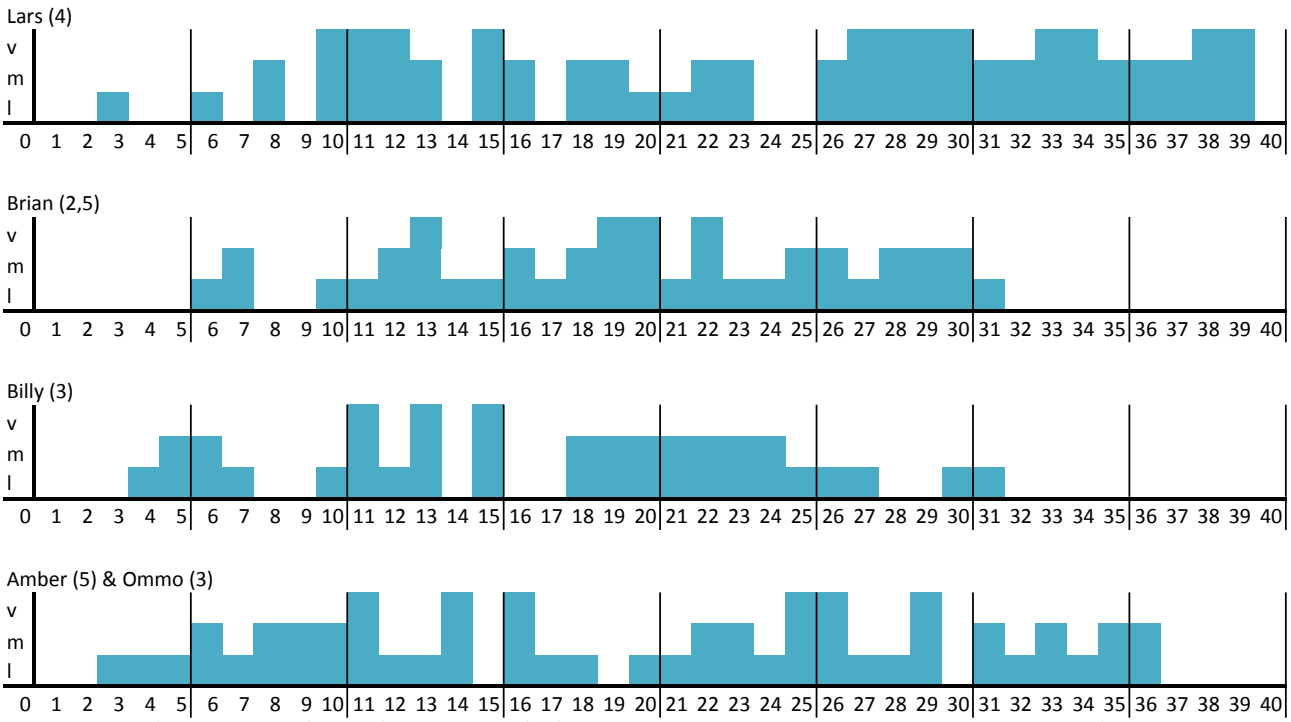


Figure 36: The average physical activity with fluctuations of intensity over time for four families.

Firstly this focus point will be addressed. The following movements are prevalent in the play with Hobble. They are ordered in a gradual range from vigorous descending to light activity. There was also a lot of sedentary play during the tests.

Physical activity play
- Standing up and moving away walking backwards
- Transporting/Carrying Hobble or parts
- Walking
- Moving forward by sliding on the ground on the knees
- Moving forward by sliding on the ground on the butt
- Crawling

Sedentary play
- Bending forward
- Squatting
- Standing
- Sitting on knees
- Lifting Hobble
- Sitting

These movements show that Hobble stimulates a variety of physical play that occurs at different intensities. Especially when compared to the physical ability scales of Figure 4 shown in section 2.2. Even when starting from the worst-case scenario where the child is only able to sit, the child can still play with Hobble if desired. While it is possible to play sedentary with Hobble, because Hobble tries to move forward, the child will be stimulated to move with the toy. In this way children will be elicited to be more physically active and to reach a higher physical activity level.

The fluctuation of physical activity over time, between vigorous (v) and moderate (m), to light (l) and even sedentary (0), is possible in the play with Hobble. This is in line with the general natural play of children in this age group. Hobble gives enough freedom for the fluctuating energy in play of children as the results in Figure 36 shows. The table shows the average physical activity changing frequently over time for all four tests. Even the consistent moderate intensity level of the last part of Billy's play consisted of multiple different activities that on average have a moderate intensity. These results should also be beneficial for children with ALL, where the energy fluctuation is much more relevant. This is especially true in the children themselves over their day and consequently in their way of and motivation for play. Hobble matches the intermittent play style of children.

In the graphs it can be seen that in the first 10 minutes there is a lot of sedentary play. This is mostly because the children needed to figure out how Hobble works. This meant a lot of sedentary exploration of the parts. After getting familiar with the toy, they slowly start to test the possibilities and limits of the toy. This gives

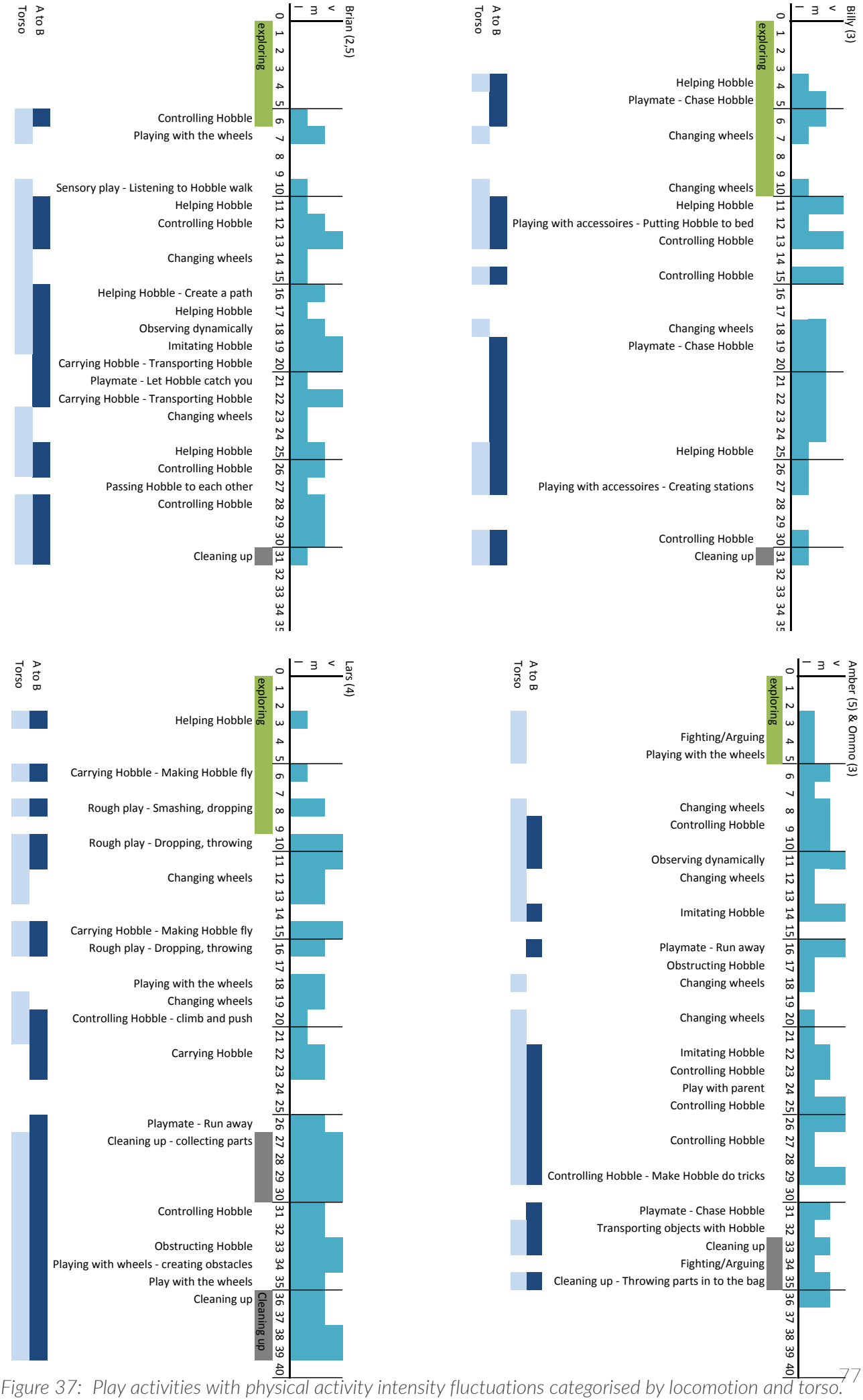


Figure 37: Play activities with physical activity intensity fluctuations categorised by locomotion and torso.

a gradual increase in intensity of play. The play slowly builds up to more vigorous play and that suits the target group. For example starting with sedentary play, like testing out the wheels and letting Hobble walk a few steps before retrieving it, to running away from Hobble. These play activities are categorized in the table of the next question. It is not mandatory for the children to play at a specific physical activity intensity to be able to play with Hobble. This makes it possible for children with ALL to find their own limits of physical play.

Focus points: Locomotion and torso in PA

The next focus points 'locomotion' and 'torso' are very relevant to the bodily play. The physical activity graphs and play activities were combined to create an overview with the play activities linked to their intensity levels. In these graphs the locomotion and torso use were highlighted to indicate which play activities contain these movements. This can be seen in the graphs on the next page. See Table 10 and Table 11..

Play activity	Description	Locomotion	Torso
Controlling Hobble	Following Hobble Trying to make Hobble walk straight or to a destination	Walking or sliding behind Hobble	Bending, squatting, sitting, getting up to adjust Hobble
Observing dynamically	Majority of the time the children stood up and stepped a few steps away to observe Hobble There was a tendency to keep distance from Hobble to be able to clearly observe what Hobble was doing	Walking, following Hobble, sliding on knees, sliding on butt, crawling	Sitting, getting up, squatting
Imitating Hobble	Copying the movements of Hobble	Walking, sliding on knees, rolling, hopping, jumping, stunting	Sitting, getting up, squatting, laying down, bending, falling
Cleaning up	Clean up all the loose parts Spreading all the loose parts helps the locomotion and bringing them all back to the bag as well	Walking, sliding on knees	Sitting, getting up, squatting, bending
Rough play	Testing the limits of Hobble	Walking, sliding on knees, hopping, jumping, running	Sitting, getting up, squatting, bending, throwing, kicking
Carrying Hobble	Bringing Hobble to different play areas Bringing Hobble back to the bag and the starting play area Bringing Hobble to others	Walking, running	Sitting, getting up, squatting, bending

Table 10: Overview of play activities that were prevalent in the user tests, part 1.

Play activity	Description	Locomotion	Torso
Helping Hobble	*Helping Hobble to walk straight after falling or getting stuck.* *Create a clear path for Hobble to walk on*	*Walking or sliding towards Hobble*	*Bending, squatting, sitting, getting up to help Hobble*
Playing with accessories	*Using other objects in the environment to enhance the play*	*Walking, sliding on knees, sliding on butt, crawling*	*Sitting, getting up, squatting, bending*
Obstructing Hobble	*Making it harder for Hobble to move forward* *Making Hobble climb and get over obstacles*	*Walking, sliding on knees, sliding on butt, crawling*	*Sitting, getting up, squatting, bending*
Playing with the wheels	*Using the loose parts on their own as individual toys.*	*Walking, sliding on knees, sliding on butt, crawling, jumping, hopping*	*Sitting, getting up, squatting, bending, throwing*
Transporting objects with Hobble	*Move objects with Hobble by placing them on top or by pushing them*	*Walking, sliding on knees, sliding on butt, crawling*	*Sitting, getting up, squatting, bending, placing objects on Hobble*

Table 11: Overview of play activities that were prevalent in the user tests, part 2.

The resulting graphs show that locomotion and using the torso are well represented in the play activities of Hobble. Most activities involve at least one of the focus movements, meaning that the intended bodily play is stimulated quite well through Hobble.

To see which play activities stimulated the most locomotion and use of torso the play activities were categorized. The play activities were ordered into an overview of the most vigorous and an overview of the lowest intensities of locomotion and torso use.

From the graphs of Figure 37 it can be seen that the play is intermittent, children switch activity after around 20 seconds to 2 minutes of play. The physical play frequently switches from higher intensity to lower intensity to even stationary or sedentary. Table 10 contains the play activities that stimulated the most vigorous physical activities during the play with Hobble. Most play activities stimulate both locomotion and using the torso. These are the play activities that the final design should be focused on, trying to get the children to reach this intensity level of physical play. The play activities in 'italics' of Table 11 had parts that did not work as well and will be discussed next.

Although mostly only the vigorous intensity results have been touched upon before, there were also play activities that emerged with lower intensities. These activities (almost) did not stimulate the intended movements. Some of these were part of the same activities that did stimulate vigorous intensity. The lower intensity results with a description of what happened and what the problem was are listed below per play activity.

- Observing stationary
  - This is something that happened quite naturally, as the children are first very passive. They observe what Hobble does and do not move much.
- Helping Hobble
  - This was expected to be a continuous stimulus for locomotion, because children were supposed to follow Hobble and help Hobble walk in a direction. In practice this did not happen much. Mostly children stayed stationary

and observed Hobble, until Hobble got stuck. This is when the child would go and help Hobble get unstuck. After doing so he would come back to the initial spot to observe again.

- Controlling Hobble – Making Hobble push & climb
  - Hobble is capable of climbing a little bit and he pushes objects forward. This did not work on carpet as well as it should have. This made the children less interested in Hobble and kept them stationary. While on flat surfaces children got excited and followed Hobble or celebrated the feat.
- Obstructing Hobble
  - Obstructing Hobble was supposed to be part of following Hobble and trying to make it harder for it to walk around and go far away. Making the child move around to build obstacles or place himself in the way of Hobble. However, because Hobble is quite slow, obstructing Hobble now is a simple task. The children just grab Hobble before it is out of reach and place it back near them.
- Transporting objects with Hobble
  - This was an extra idea in the concept, but during the play multiple children tried to make Hobble transport objects. Which in this case did not work, because Hobble was not designed nor shaped to be able to hold objects.
- Playing with the wheels – Ordering wheels in pairs
  - During the tests all the children only used matching wheel pairs, none were inclined to use two different wheels. In this case, most children started ordering the pairs of two wheels before playing with the wheels. This also gave the children the tendency to always put a matching pair of wheels on Hobble.
- Imagination play – Chase Hobble
  - As expected children liked to chase Hobble, but because Hobble was slow and did not really keep to the given direction, children did not chase for a very long time. They stayed close and observed what Hobble would do.
- Passing Hobble to each other
  - Making Hobble walk from parent to child and back is not a stimulating activity for locomotion. The parent and child both sit down and try to direct Hobble towards each other.

4. Dispersed play - Does Hobble stimulate dispersed play?

Children tend to stay within their play area with their current toy. Usually they only start to move away from this area when they move to a different toy. In general this results in quite a low intensity of movements. The play is mostly sedentary with the occasional switch to high intensities (Appendix C and K). In the case of Hobble, children tend to move Hobble to different areas to test it. In the tests it turned out to be mostly to elevated areas, like tables, counter tops, couches and other furniture. The tests showed that Hobble stimulates dispersion.

The figures on te next page are time-lapses of videos of play with a fixed interval overlaid into one photo. These time-lapses are a visualization of how dispersed the play was during the tests. The visualisations can be seen in Figure 38.

A moment of the child while moving around in the room is captured per minute. The more saturated (concentration of black) or unsaturated (concentration of white) the photos are, the more frequent physical activity was in that area. Meaning if the concentration is spread out a lot the dispersion is high, but if the concentration is centred the dispersion is low.

In general the dispersion of the child is quite high. All the participating children seem to be moving around the whole room. There were two clear insights found. Firstly, the bag is a clear central point to the play. Secondly, the wheels, the loose parts, were spread out through the room and made the children disperse more.

Central point

In many of the videos it can be clearly seen that the bag with wheels was used as a central point. The children would always return to the bag after their play, so their play was always concentrated in that area. Initially the bag seems to work against dispersed play, because it keeps the children in one spot. However, because Hobble walks away and the wheels are spread out slowly, the dispersion slowly starts to grow more. The play would spread out from the central point to the outside, making the children walk back and forth. This happened by allowing Hobble to walk away or by carrying Hobble. The children would then retrieve Hobble and remove the wheels. This was usually at the spot they retrieved Hobble from. This in return through makes children move back to the central point to get new wheels. At some point the wheels are spread out throughout the play area and all the wheels are out of the bag. The bag is not the central point anymore and the locations of the

Figure 38: Time-lapses of dispersion in play.

wheels by themselves took over as destination points. This makes the children walk from wheels to wheels a lot, so the locomotion is very high.

Children seem to start moving more because of the forward movement of Hobble. They tried to follow and frequently tried to control Hobble's locomotion. Following Hobble did not always happen; it was very dependent on the type of wheels. At the start of the tests following Hobble was not done, but the opposite was done. Children stayed stationary and just observed the movements and behaviour of Hobble or they stood up and moved away to get a better view of Hobble, but stayed stationary at a distance. After getting acquainted with Hobble, following Hobble was mainly done when the wheels made Hobble walk very poorly and clumsily. There was no need to follow Hobble if the movement was straight and predictable. But if Hobble got stuck, bumped into obstacles or stopped moving, it motivated the children to move towards Hobble and help it along.

As stated in the bodily play analysis, cleaning up was a good play activity as it encouraged the children to retrieve all the wheels and put them back in the bag. This stimulated a lot of back and forth movement to the bag. As well as a lot of using the torso to grab the wheels and placing them back.

Lastly next to the dispersion through the loose parts of Hobble by itself, obstacles in the play area were interesting. Trying to test the limits of Hobble by making it harder for it to move. Hobble was used in the home environment together with the already available toys, objects and furniture. The finding and using different objects in the room created more dispersion. In this way Hobble enriches the environment.

Extra general insights

- The axes were one of the most limiting factors of the user tests. The axes were a weak point of the prototype because they kept falling off. More importantly the connection with the wheels was an issue. All the children had the tendency to remove the wheels diagonally by pulling on the wheels on one side. This caused the wheel to get stuck on the axes or damaged the axes. Another insight was that the children did not turn Hobble off before changing the wheels. See Figure 39.

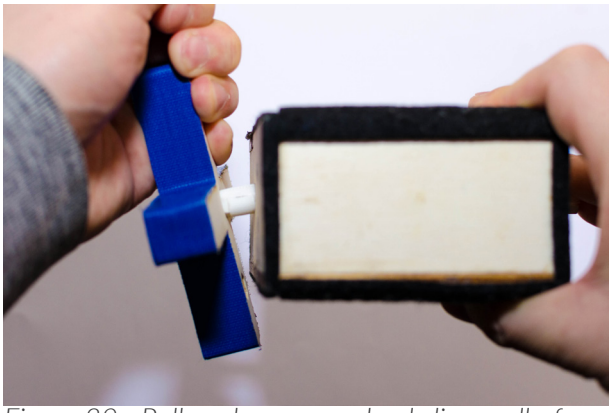


Figure 39: Pull and remove wheel diagonally from the axis

- The switch on and off button was clear to children. There were no problems during play, except occasionally the switch would accidentally turn off. Though some children were sometimes not sure whether Hobble was turned on and stuck, or off. See Figure 40.

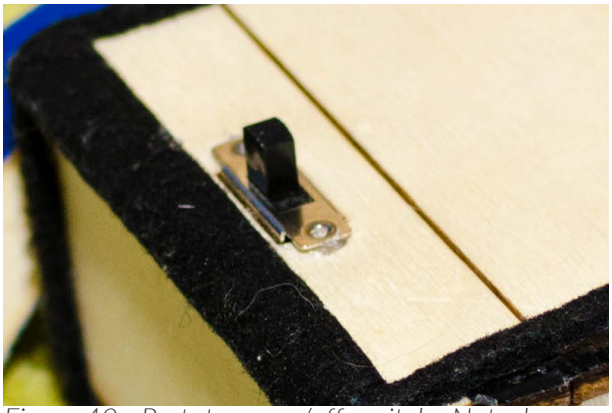


Figure 40: Prototype on/off switch. Not clear on what side is on or off.

- The small size of Hobble made it interesting for children to try and see if it fits under furniture. This became part of the play where they tried to find 'stations' or 'beds' for Hobble.

5.2 Conclusion & Discussion

Discussing the 4 research questions for the user tests and concluding what the strong and what the weak points were of Hobble. Then closing the chapter off with an evaluation of whether the test results with the prototype are valuable to children with cancer.

Strong points and weak points

1. **Does Hobble fit in the home context (family, environment, energy)?**

Hobble is considered as a good fit for the home context by the parents. Children are generally allowed to play everywhere in the house, but can usually be found in their bedrooms, in the living room and if applicable at their play corner. Although they usually like to be around other family members, so this tends to generally be the living room. Children should for this reason at least be able to play with Hobble in their most frequented play areas. A requirement to achieve this is that Hobble should work on almost all surfaces that can be found in a home. As tested, Hobble works fine on almost all surfaces, so the living room should be no problem either. The only exception is on carpets with long fibres (deep-pile carpets). See Figure 41. Hobble has problems dragging its base over the long fibres and does not go forward. This is a considerable issue, because a lot of play corners of children have their area defined by a carpet. Therefore, if this is the general starting point for play for children, Hobble should at minimum work enough to get children to start wanting to interact with Hobble. As mentioned before it is fine for Hobble to not work perfectly as this will give Hobble the role of helpless. Hobble is struggling and clumsy and that stimulates children to interact with Hobble more.

Therefore, the motor might need to be stronger to make Hobble be able to move and struggle on the carpet. Important here is to keep the rounds per minute (RPM) of the motor the same and heighten the torque power. A big consideration is the safety, as stronger motors might make the motors too dangerous for the children to use, while the current motors are weak and harmless.

When it comes to the family, parents seem

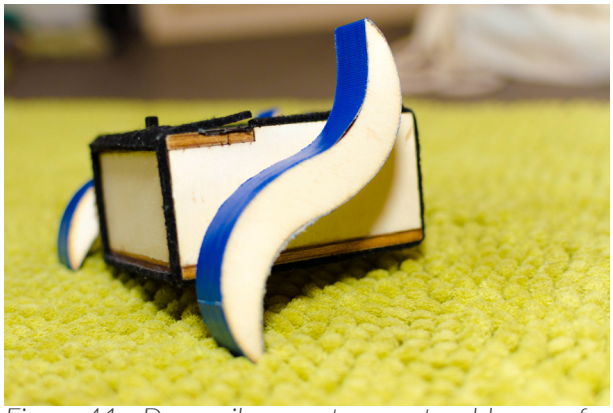


Figure 41: Deep-pile carpets were troublesome for Hobble, especially for the backside of the base.

to like the toy. Mainly because they like that children playing with Hobble keeps them away from 'screens'. Hobble also gives the possibility to play together, but allows children to play independently by themselves. Parents seem to like to have a slight sense of guiding control over what children play with to have influence over what they believe is healthy for their child. Hobble gives parents the knowledge that the movements the child will make are good for their development.

The hygienic and safety concerns that the parents have are not different from the general concerns for all toys. That is why this should not be a problem as long as the materials are well polished and the electronics are properly sealed away.

Some target group specific goals could not be tested or validated.
Part of creating a safe and 'normal' environment was to remove the doubt and overprotectiveness of the parents and dealing with the lack of guidance at home. However, neither could be tested because the tests were not done with families of children with ALL. Another important aspect was to see if Hobble would still fit the

home context over a longer time. These all are important to test and validate but were not part of these tests.

One of the solutions mentioned before to create confidence in the children with the safe and 'normal' environment focus point was to enhance the play environment. Hobble fits in the home context and becomes by itself an enhancement of the environment, this can be seen in the results because Hobble is used on various surfaces, furniture and with other toys during the play.

2. **Which kinds of play activities arise with Hobble? (Does Hobble provide free play?)**

Various play activities arise through the interaction with Hobble as can be seen in the Figure 35. A lot of the play activities are dependent on what the wheels do to the role and behaviour of Hobble. The play goes from exploring and trying the wheels, manipulating and controlling Hobble to children interpreting Hobble as different things. The play evolves through familiarity and changes through different roles brought by the changing of wheels. The children's interpretation of the character and role of Hobble changes their play and activities. In the beginning Hobble's role is mostly as an impaired motor, this quickly becomes an entertainer. Only after a certain amount of playing, Hobble starts to be something part of the children's imagination. This includes being seen as a robot, car, plane, train, but also as a living thing, like an animal, beast, monster and playmate. This unstructured, spontaneous, self-directed play shows that free play is stimulated.

Children are able to self-direct their play and this gives them a sense of control, especially a sense of control over Hobble. Having this control makes children more confident in their play and allows them to play more boldly. This is beneficial to the confidence of the child. The sense of control in children became more apparent when Hobble was clumsy or not functioning well. Children seem to tend to take care of Hobble and help Hobble, which stimulates more physical activity and makes children interact with Hobble more actively and frequently. Whether or not the sense of control is enough to empower children with ALL needs to still be validated.

Through social play different play activities are created. Children playing together with their parents produces: show and tell, controlling Hobble together and trying out new wheels together. While playing with their peers creates more chaotic play that is prone to fights and arguments because sharing the toy becomes a factor. Social play also stimulates playing with the loose parts more, separately from playing with the base. Overall, playing together stimulates and encourages the other to play more. However, because the play is more chaotic, it might not be ideal for children with ALL. On the other hand, this does not occur specifically because of Hobble, it is a regular occurrence in cases where children have to share toys.

3. **What are the children's movements during their play, specifically concerning locomotion and using the torso? (Does Hobble provide bodily play?)**

A clear result is that the play with Hobble is very intermittent and it fluctuates the play and energy of the children very often, allowing for a lot of sedentary play as well. Therefore, the question is whether the fluctuation of energy is inherently bad? The fluctuation is actually very natural, even more so for children with ALL. Their energy fluctuates even more because they are a lot weaker from the treatment. 'Eliciting play that fits the energy as soon as possible' focus point was not tested with children with ALL. Hence, specifically fitting the play with the energy level of the children with ALL at home during treatment was not done. However, Hobble matches the natural intermittent play of children. The play with Hobble shows fluctuations of physical activity intensities and that is similar to the fluctuations of energy in children with ALL. Play with Hobble is possible at various physical activity intensities, so Hobble can provide physical play at an intensity level that fits the energy of the child. The treatment makes dealing with the energy fluctuation much more relevant during everyday play.

The core functionality of Hobble is to walk away, which elicits locomotion from the children. They need to stay close to be able to keep interacting with Hobble. In the tests, when the children got more familiar with Hobble, they were stimulated to become more active to be able to play with Hobble more.

Purely testing whether Hobble could elicit the child to play has not done with this prototype. Hobble might need some action or indicator to

Vigorous physical activity	Light physical activity
Controlling Hobble	Observing stationary
Observing dynamically	Helping Hobble
Imitating Hobble	Controlling Hobble – Making Hobble push & climb
Cleaning up	Obstructing Hobble
Rough play	Transporting objects with Hobble
Carrying Hobble	Playing with the wheels – Ordering wheels in pairs
Helping Hobble	Imagination play – Chase Hobble
Playing with accessories	Passing Hobble to each other
Obstructing Hobble	
Playing with the wheels	
Transporting objects with Hobble	

Table 12: Overview of vigorous and light physical activity that stimulated locomotion and using the torso.

trigger the child to come play, eliciting children from sedentary to physically active. Though this trigger might not be needed once children get acquainted with Hobble. Hobble starts to be seen as a playmate that needs to be taken care of after a while.

Locomotion and torso are definitely represented in the physical play with Hobble, both in the vigorous and in the light physical activities. This means that locomotion and torso are both stimulated during the play with Hobble. Children with ALL should be stimulated to play in a higher physical activity level. The activities that arise in the bodily play do suggest that Hobble stimulates physical activity more than sedentary play.

The movements that are relevant can be found in the in Table 12. The play activities were a clearer way to categorize the movements seen during the play. The play activities that stimulated the most and the least locomotion and use of torso are shown in the overview above.

Several play activities did not function like expected or did not work well:

Obstructing Hobble

- The problem was that children were able to grab Hobble before it could walk out of reach. Adding more speed to the motor of Hobble could take care of this problem. This allows Hobble to walk away faster and makes it harder for the children to obstruct Hobble. However, sedentary play is not an inherently bad thing and that is why the speed should not be increased too much. Children should still be able to play sedentary.

Transporting objects with Hobble

- Multiple children tried to make Hobble transport objects. Redesigning Hobble's form to be able to carry some objects would increase the potential functionality of Hobble. However, a big limitation would be to keep the ambiguous and abstract form. It should not seem like carrying objects is Hobble's main functionality.

Playing with the wheels – Ordering wheels in pairs

- The children always tried matching the wheels and put matching wheels on the base. It would be valuable to check if this behaviour can be affected to make children also try not matching wheels. What roles, behaviours, and consequently play activities would this add to the play?

Imagination play – Chase Hobble

- The same problem here as with the obstructing Hobble play activity. Because Hobble was too slow with walking away, chasing Hobble did not occur very often. So if Hobble was able to walk slightly faster chasing Hobble could be more interesting for children.

Passing Hobble to each other

- This was a very sedentary play activity, although it did actively stimulate using the torso. The play activity does not stimulate locomotion, but as a play activity it is well liked by both parents and children.

4. **Does Hobble stimulate dispersed play? Does Hobble provide dispersed play?**

Hobble does stimulate dispersed play. It is stimulated mostly through the loose parts and the forward movement functionality of Hobble itself. It walks away and stimulates children to follow and retrieve it. The various wheels stimulate the dispersion because they are spread out through the play area during the play. Children tend to leave the wheels behind in the room when changing the wheels and this causes them to spread throughout the whole play area. Children need to retrieve these wheels if they want to play with them again. Having a bag filled with the wheels as a central point stimulates a lot of back and forth locomotion. The play can disperse to other areas, but the children are still elicited to come back to the first area where the bag is located. The bag also helps in the sense that it is the container of the toy. Therefore, at the end of the play, the children need to clean up. They have to recover all the spread out loose parts and put them back into the bag.

Technical results

- Diagonally removing wheels was a problem during the tests. Children had the tendency to pull on the edges of the wheels to remove them from axis. This looks to be the easiest and also most natural way to remove the wheels. All the children in the tests removed the wheels this way. As such the attaching system between the wheel and the axes should be improved to accommodate this diagonal removing of the wheels.

- The on/off switch was originally in the concept a LED push button. This would still be a better button for Hobble. The light would make it clearer for the children when Hobble is on, especially when Hobble gets stuck. A push button with a cover would also be more abstract, removing the mechanical look of a switch.

- The overall size of Hobble needs to stay relatively small. This is because the hands of young children are not very big and because carrying Hobble needs to be easy for the children.

How valuable is this simplified version of Hobble?

The goal is to make children with cancer feel as much as healthy normal children as possible. The prototype that was made and used in the tests was a simplified version of Hobble. In the tests a lot of valuable information and insight came from testing just this simplified version. A lot of the free, bodily and dispersed play was already achieved with just the simplified version. Hence, the question is if the complete and more complex version of Hobble is needed? In this case, because the intended outcome was reached with a singular Hobble base, it might not be needed. The biggest risk with multiple Hobble bases is that they would lead to more sedentary play. The results showed that physical play got more stimulated when the children got more familiar with Hobble. With more Hobbles walking around and to play with, the play could become more chaotic. The rhythmical sounds of the steps will also overlap and become noise. This might remove the sensory play with sound experience. All this sensory input from multiple sources will probably lead to more observation and stationary play from the children. Despite these speculations it would be valuable to test the complete version of Hobble's concept to compare it with the singular Hobble. This is to see if it helps strengthening the focus points' goals more, especially because it increases the capability to spread the loose parts for more dispersed play. Multiple Hobbles could be shared with others and would be more interesting for social play. Overall it might also change the play and interaction with Hobble completely.

How suitable are the results and conclusions to children with ALL?

The results of testing Hobble with healthy children were discussed to see how well they fit with the focus points of this project. Most of the results were in line with focus points, except for a few points that could not be tested without the actual target group. The user tests showed that Hobble does stimulate free, bodily and dispersed play. Therefore, evaluating the results with healthy children to the limitations and needs of children with ALL, they have proved Hobble to be suitable for children with ALL. The exceptions were the points of empowerment of children through sense of control and eliciting children to play. These two respectively could not be tested without the target group and was not tested in this user test. They should still be tested to validate the concept Hobble completely with all the other results matching the goals and focus points of the project; Hobble has proved to be suitable for children with ALL.

Conclusion

Overall the four strongest and weakest points found in the user tests are described below.

Strong points Hobble

- A helpless/sad/clumsy role and behaviour stimulates a lot of locomotion. Hobble stirs up empathy in the child, which is a very effective trigger for children to go towards Hobble. This makes this role and behaviour one of the most successful ones when it comes to the bodily play goals.
- Hobble fits in the home environment. Parents mention that they like the toy and the children seamlessly integrate other toys in to the play with Hobble.
- The down times (sedentary and light PA intensities) are necessary and fit well with the energy fluctuations of children with ALL. Hobble can accommodate physical play at an intensity level that fits the energy of the child. So even when children are very weak from the chemotherapy treatment, they can still play lightly or even completely sedentary with Hobble.
- The bag as a central point and the wheels as loose parts stimulate dispersed play and thus locomotion. The small size of the wheels and the having to grab wheels out of the bag stimulates bending forward, sitting down and getting up a lot.

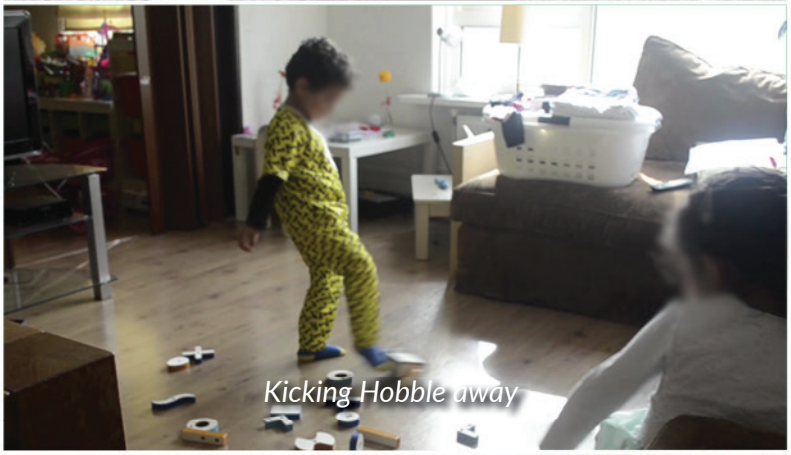
Weak points Hobble

- Hobble does not work on every surface. It especially has difficulties moving on carpets, which is problem because a lot of homes have a carpet in the child's play area.
- A lot of wheels mainly stimulate stationary observing. Wheels that mainly go forward and do not have a quality to make it stand out are usually just observed. This is not necessary a bad thing, as it does keep the interest of the child. However, these types of wheels should not be in the majority of the selection of wheels.
- Social play is very chaotic and prone to fights and arguments. The play is focused around where Hobble is and is kept. This makes both children play more sedentary, because they need to share Hobble. Whenever Hobble is released to walk away, the other child will immediately snatch Hobble away to start their turn of playing with Hobble, thus not allowing Hobble to move away.
- It was very easy for the children to obstruct Hobble and keep Hobble in their vicinity without having to get up. With a lot of the wheels Hobble does not move away very quickly. This gives the child the opportunity to block or redirect Hobble to stay within their reach while seated.

Encouraging and helping Hobble to come over

Hobble as an airplane

Trying to make Hobble transport a wheel



Kicking Hobble away

Hobble suddenly 'attacking' the mother

"The robot is tired, he needs to go sleep."

Imitating Hobble falling

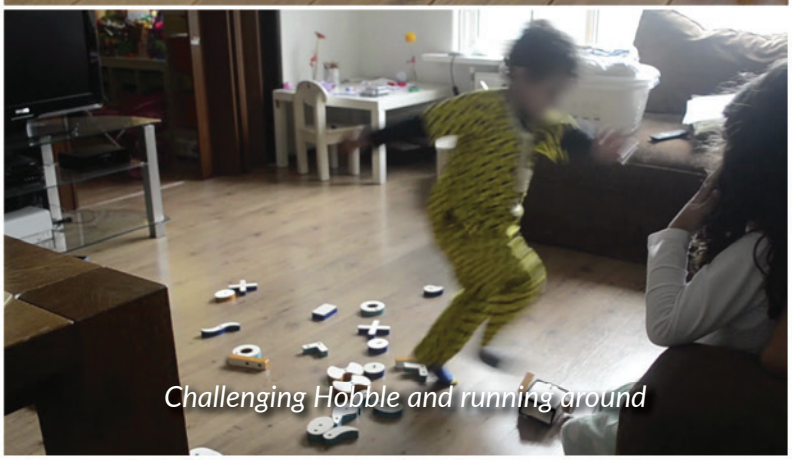
Emptying the bag with wheels

Ordering and pairing up all the wheels

Observing Hobble the entertainer

Hobble eagerly pushing for attention

Imitating Hobble

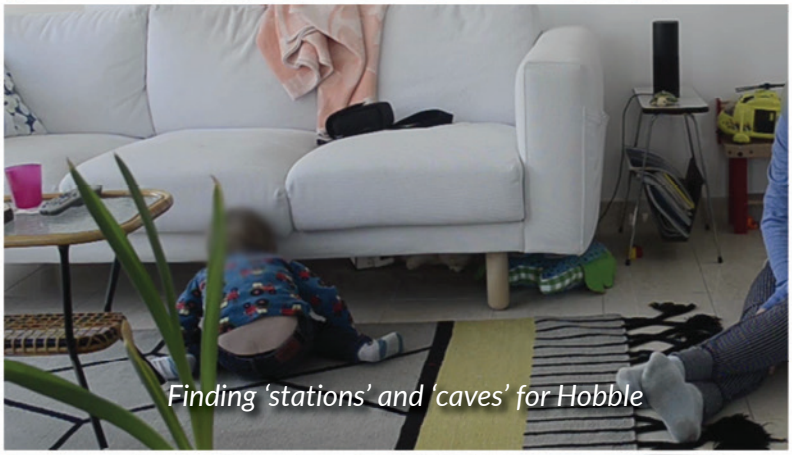


Challenging Hobble and running around

Guiding Hobble back and forth with the mother

Using the furniture and other objects in their play

Sensory play, listening to the rhythm and sounds of the wheels



Finding ‘stations’ and ‘caves’ for Hobble

“Where is it going?” and helping the stuck Hobble

Throwing and dropping Hobble

Chasing and challenging Hobble to climb

6

RECOMMEN-DATION

In this section recommendations are made for Hobble and the future of the project. First, an overarching concept will be explained that Hobble is supposed to be part of. Then a redesign proposition containing the recommended improvements that followed from the evaluation is presented. Lastly a short note on how this project should continue will be given.

Redesign proposition

With the results of the user tests, a redesign proposal for Hobble was made. Most of the suggestions are technical improvements to support the strong points and strengthen the weaknesses described in the discussion. A proposal for a redesign for Hobble version 4.0 was made and shown on the next two pages.

Initial (provisional) materialisation

The preferred main material for the production of Hobble is bamboo. This material was selected because of the superior hygienic properties compared to wood, the high durability and better sustainability. The covering of the wheels should be produced with of thin layer of rubber, which should give extra traction. This might already solve the difficulties of Hobble in traversing a deep-pile carpet, but will probably not solve the problem of Hobble being too slow when walking away. The axis should be made from a strong polymer that should be able to withstand the play forces and impacts of children's play. Especially the critical points like the split in the axis and the holes for the pins. The pins should be a smooth metal like stainless steel. They need to be durable, hygienic and strong. The electronics inside Hobble should not be reachable by the children. The push button should be sealed off completely from the outside with a translucent rubber. It needs to be flexible enough to press the switch under it and translucent enough to emit a soft LED light glow. The motion sensors can be protected by a strong polymer, which needs to be translucent or even transparent so the motion sensor can still detect movement. Lastly, a textile bag or a bamboo box to contain and store everything in is perfect. Both containers should be simple enough to still be ambiguous, so they can be used in the play as well.

Next steps

The next steps for this project are to continue the user testing and prototyping in iterations to further improve and research the potential of Hobble. The first step is to go through the procedures and get into contact with children with cancer and their families and to get permission to work with them. At the same time, the redesign of Hobble should be built into a new prototype version. Furthermore, a meeting with the physiotherapists should be planned to get their feedback on the results thus far. When all the tests and check-ups are done, the next steps should be towards implementation: materialisation, production, costs, and market analysis.

Overall, more research should be done before any concrete steps toward production are considered.

Overarching concept: Toy Library

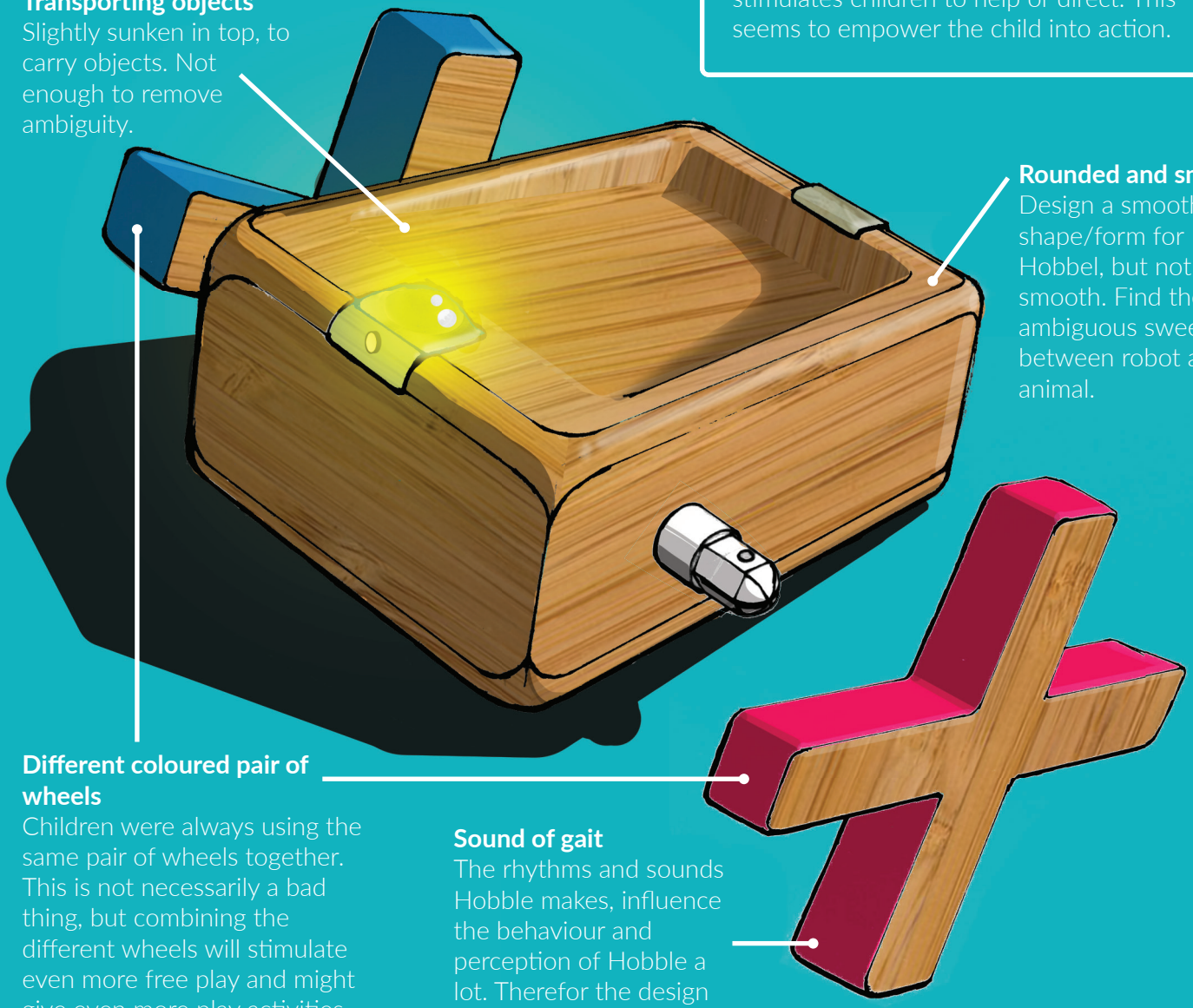
One of the biggest insights that came out of the research was that each cancer type could affect different parts of the body, but a certain type of cancer could also affect different parts of the body. This means that it is too vague and broad to design a toy that targets children with cancer, because the needs of these children vary greatly dependent on their type of cancer. Therefore, instead of focusing the design on a specific disease or cancer, the design should target specific movements or muscle groups. This resulted in an overarching design idea: a toy library or a product family. This library or family would consist of toys that all were designed to target and elicit different movements when played with. In this way, physiotherapists would be able to recommend and give a certain toy that elicits certain movements that they want the child to do frequently. This would solve the problem that physiotherapists cannot recommend exercises to children. This toy library could also be produced as a product family, or in this case a toy series. The toys could be bought with the parents knowing what physical play the toys would stimulate in their child.

HOBBLE V4.0

Clumsy/sad/helpless Hobble stimulates locomotion and using the torso
Intentionally make Hobble clumsy stimulates children to help or direct. This seems to empower the child into action.

Transporting objects
Slightly sunken in top, to carry objects. Not enough to remove ambiguity.

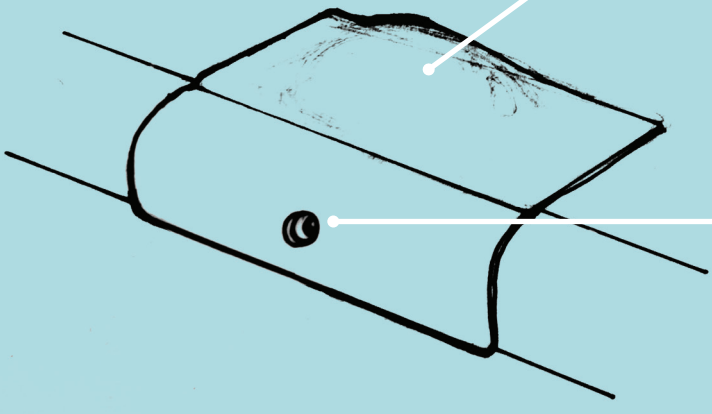
Rounded and smooth
Design a smoother shape/form for Hobbel, but not too smooth. Find the ambiguous sweet spot between robot and animal.



Different coloured pair of wheels
Children were always using the same pair of wheels together. This is not necessarily a bad thing, but combining the different wheels will stimulate even more free play and might give even more play activities, roles and behaviours for Hobble.

Sound of gait
The rhythms and sounds Hobble makes, influence the behaviour and perception of Hobble a lot. Therefor the design of the wheels should take this into account.

Button and motion sensor



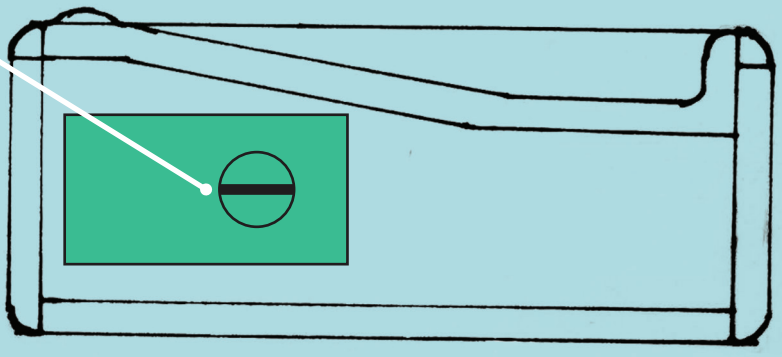
Push button with 'on' indicator
The left to right switch sometimes accidentially turned off. Instead a push button covered with a translucent rubber material that is flush with the top surface. In other words, a clear on and off button to let the children know when Hobble is 'on'/'alive'. There is a LED light indicator underneath the button for indicating when it is on. As little mechanical parts visible as possible to make Hobble more ambiguous.

Eliciting physical play with sensor
To keep the play interesting and to elicit play from the children, a motion sensor is added to the front and back of Hobble. Hobble can thus be programmed to respond to the child's movement or rather the lack of movement.

Stronger motor
More torque to make Hobble able to walk on all surfaces

Slightly faster (more RPM) to further stimulate following Hobble around the room and lessen the tendency to sedentary play.

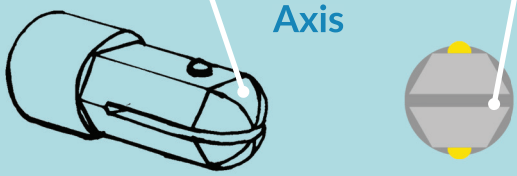
Base - cross section side view



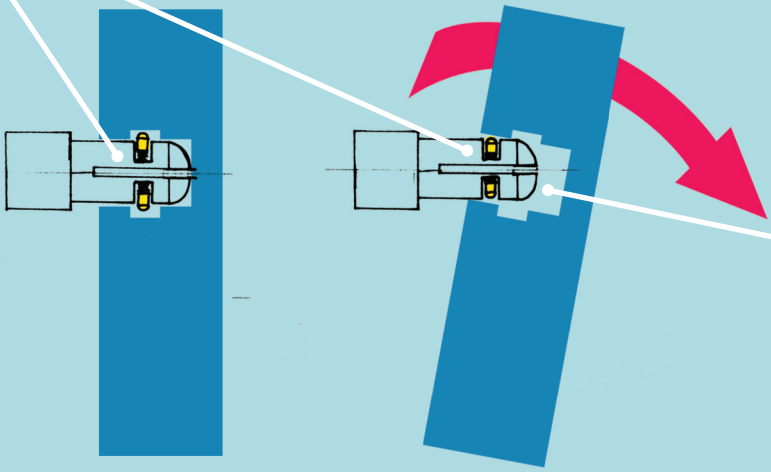
Attach and detach while turned on
Both the new clicking mechanism and rounded axis ends will allow the children to attach and detach wheels when Hobble is still on.

Axes are weak points
Weak points of the prototype, but also of the design. Needs to be reinforced using a stronger material and a stiffer clicking mechanism.

Axis



Axis - cross section side view



Clicking mechanism
Better connection with the wheels by adding smooth and retractable pins with springs that lock into the wheel. A groove may be incorporated along the axis if further flexibility is required in the removal of the wheels.

Diagonal removal of wheels
Rounded axis ends to allow diagonal removal of the wheels.

Size
A slightly larger size might enhance the ability to get over objects and walk through the carpet.

A bigger size means more weight and different dimensions. This possibly requires a stronger motor to maintain the same output.

Next tests and studies to be done:

- User tests with children with ALL
  - o Focus: Empowerment of children through sense of control
  - o Focus: Eliciting children to play

- Consequences of asymmetrical wheel combinations and different coloured wheel pairs.

- Extensive study on the effects of the wheel shapes individually on Hobble and children.

- Long term interactive play with Hobble.

Hobble

stimulating physical play in children with cancer

7

REFLECTION

This graduation project was a rollercoaster of ups, downs, twists and turns.
First of all, let me say that I loved and still love this project. For most of my studies I have felt that I wanted to do something that mattered. Something I believed in, adding something (as cliché as it might sound) positive to the world. This project was that. Working on something I believed in felt great and kept me going, although there were still a lot of times where I was struggling to keep on going. Part of it was wanting too much for the project, being a perfectionist and feeling it was never enough or good enough. This was a double-edged sword as it motivated me to do more, but also hindered me because it seemed like I had to move mountains. I have always had a problem with this and thus sadly also during this project. To counter this, I had to set hard deadlines. This helped by forcing and pushing me to focus on the work.

This project combined several interests I had during my studies at the TU Delft, like play, behaviour (change) and interaction design. However, I also challenged myself to get out of my comfort zone. This project focussed on prototyping, which I had not done much off, and less on an ideating with the focus on co-creation and creative facilitation like I was used to. This caused my ideation to be a very short and intense phase to get to prototyping as soon as possible. This was strange since it felt like I did not do my work properly. The prototyping and testing on the other hand were a lot of fun and I gained and learned a lot more than I thought

I would through building and eventually testing the prototypes. I learned how to laser cut and how to 3D-print. No matter how small the build, the insights gained helped tremendously and gave me a much more concrete understanding of my design.

There was a sore point for me in my project. I strongly believe my project would have been a lot better if I would have succeeded in getting in contact with children with cancer and their families. Just like how the interviews with the physiotherapists and Jannie were invaluable to my project. I learned that not being able to contact my intended target group really weighs down on me as it kept on bothering me during the project. But learning to find alternatives and doing as much as possible within the limitations that I was bound to at the time was a good experience.

The biggest obstacle in this project was writing the report. This caused a lot of demotivation. I realised that I almost always had a project group with people I could talk to and process information through. Doing this by myself most of the time was difficult. Apparently, I have become more of a team player than the individual worker I used to be, probably because of the many group projects during my studies. I felt the absence of having continuous direct communication and feedback with others and as a consequence I dived into the information and details too deep to compensate and had a hard time to keep seeing the whole picture. The times I processed information with the help of my supervisors or friends, the data became much clearer to me and I gained more focus. This told me that I could work hard and well individually as long as I have a clear focus and overview of the work. To get this overview I have a need for frequent feedback and direct communication moments with someone to discuss the project.
Part of my problem was that I wanted to create a solution to every issue I encountered, until I discovered the power of ambiguous and simple products. Designing with allowance of freedom of interpretation is limiting, but at the same time very broad. The power lies in very small things that have big effects. For example, the projection of human emotion of people on products is fascinating and happens instantaneously. This phenomenon could give rise to so many different reactions, responses and behaviour changes with just the tiniest movements in an object. This was a major switch in my project from the (in hindsight) complex toy design, to a simple core iteration of that concept. My project got much richer and interesting by working with a simpler solution. The 'unsolved issues', Hobble being clumsy and having difficulties to walk away, turned out to be valuable for the project. Hobble being clumsy stimulated children to start helping and moving. Issues are not always issues.

Overall, despite the many setbacks, I learned a lot about myself and I managed to stay true to wanting to do a lot of things in this project that I did not do much of during my studies. I really enjoyed creating and building a toy for children and seeing them play with it. Although I have to say it would have been even more meaningful if I could have tested with my target group. I have learned a lot about human-robot interactions, which was fascinating and not planned at all. I would not mind continuing learning and working in that field. Overall, continuing this project would be a joy, especially now that the research is moving more towards designing. Other than that I hope to continue to do projects that matter in the future; projects that connect, stimulate and engage people. Designing something positive to add to the world.

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