

Designing a stroller harness to improve infant motor development



Master Thesis
By Max Hessels

Integrated Product
Design



JOOLZ

Master Thesis
by Max Hessels
5275997

MSc Integrated Product Design

Delft University of Technology
Faculty of Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands

Supervisory Team

Chair - S.M. Persaud, MSc
Mentor - R. de Bruin, MSc
Company Mentor – S.J.J. Janssen, MSc

Client

Joolz / Milk Design BV.
Distelweg 89
1031 HD Amsterdam

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Abstract

This thesis investigates children's ergonomics within the stroller industry, a field in which brands are often influenced by each other, following recent trends and innovations. In collaboration with Joolz, this project aims to provide a new perspective through a user-centred approach.

To explore this field, insights were gathered through desk research, a literature review, observational studies and stakeholder interviews. The findings showed concerns regarding the overuse of infant sitting devices, leading to a lack of movement freedom and a decline in overall motor development. This, in turn, can negatively affect both their physical and mental well-being.

Following this exploratory phase was an iterative process of ideating, sketching and evaluating. As a result, a design goal was formed to improve the motor development of children between the ages of 9 to 18 months through a new harness design, which redefines the parent-child interaction and offers both mobility and safety for the child.

By separating the harness from the stroller, the resulting concept improves the usability for the caregiver and enhances the child's movement freedom, without sacrificing safety. The concept is demonstrated and evaluated through a prototype that includes a three-point harness, with two connections to the seat. By rethinking this everyday interaction, the project illustrates how conscious and informed design for strollers could better support children's development while improving caregiver experience.



Figure 0.1: Sketch study Joolz Day 5

Acknowledgements

The thing about graduation is that, although it is an individual project, it is impossible to complete it alone. This thesis marks both the end of my time as an IDE student and the beginning of something new. I am extremely grateful to everyone who believed in me and supported me throughout this journey.

First of all, I would like to express my appreciation to Stefan & Renate, my supervisors, for their guidance, feedback and encouragement throughout this project. Thank you Stefan for the extensive inspiring conversations, your creative ways of designing, helping me make decisions, and helping me trust the process. Thank you Renate for your relevant insights in ergonomics, helping me stay critical during the research, and regularly checking in on my progress. But I am even more grateful for helping me learn more about myself, my way of working, and my motivation.

Secondly, special thanks to Sem, of course for giving me the opportunity to undertake this journey, but even more for your involvement in my project. I really appreciate you taking the time to give feedback, or coming to Delft for meetings, even when you yourself were very busy. And thank you for pushing me to do better, to go out there, to go talk to people, and to come to Amsterdam. With that, I would like to extend this thanks to everyone at Joolz who made me feel welcome, was in for a coffee, or took the time to give feedback. It really is a kind of family, and I am glad to have been a small part of it.

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Finally, I would be remiss if I did not mention all the train conductors and bus drivers allowing me to travel hours and many kilometres from and to Amsterdam.

My sincerest appreciation to everyone for being part of my journey,

Max Hessels

Glossary

Buggy	A lighter type of foldable stroller, meant for easy transportation.
Comfort	For this thesis, comfort has been defined as the child's feeling of physical ease. Due to inability to test with children, assessment has been based on the parents' perceived comfort on behalf of their child. Emotional comfort has been left out of scope.
Cot	The bed-like component of a stroller, allowing newborns to lay flat until they are ready to sit independently.
Ergonomics	For this thesis, ergonomics has been defined as physical ergonomics for the child. This is defined as the practice of designing products that fit the child's measurements and natural posture. During the project, the term ergonomic will be specified as allowing a natural change in posture instead of a single posture. Cognitive and organisational ergonomics have been left out of scope.
Infant	A child between birth and 1 year old.
Parent	Throughout this thesis, the word parent is used to refer to the caregiver of the child and user of the stroller, this also includes grandparents and nannies.
Parent Facing	When a seat or cot is positioned on a stroller so that the child faces the person pushing the stroller.
Prone	A position where a person is laying flat on their stomach.
Seat	The chair-like component of a stroller, replaces the cot when the child can sit independently.
Supine	A position where a person is laying flat on their back.
Stroller	Any transport device on wheels in which a baby or small child can be pushed around in. Also includes terms pram, buggy, pushchair.
Toddler	A child between 1 and 4 years old.
World Facing	When a seat or cot is positioned on a stroller so that the child faces away from the person pushing the stroller.

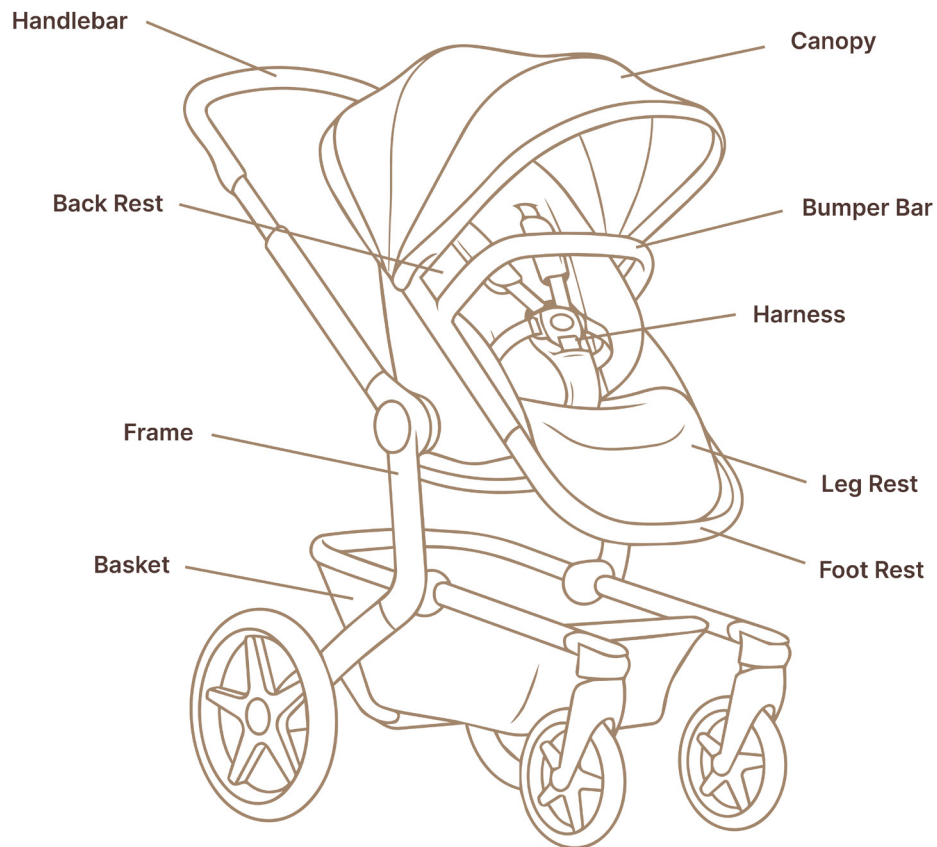


Figure 0.2: Stroller Terminology

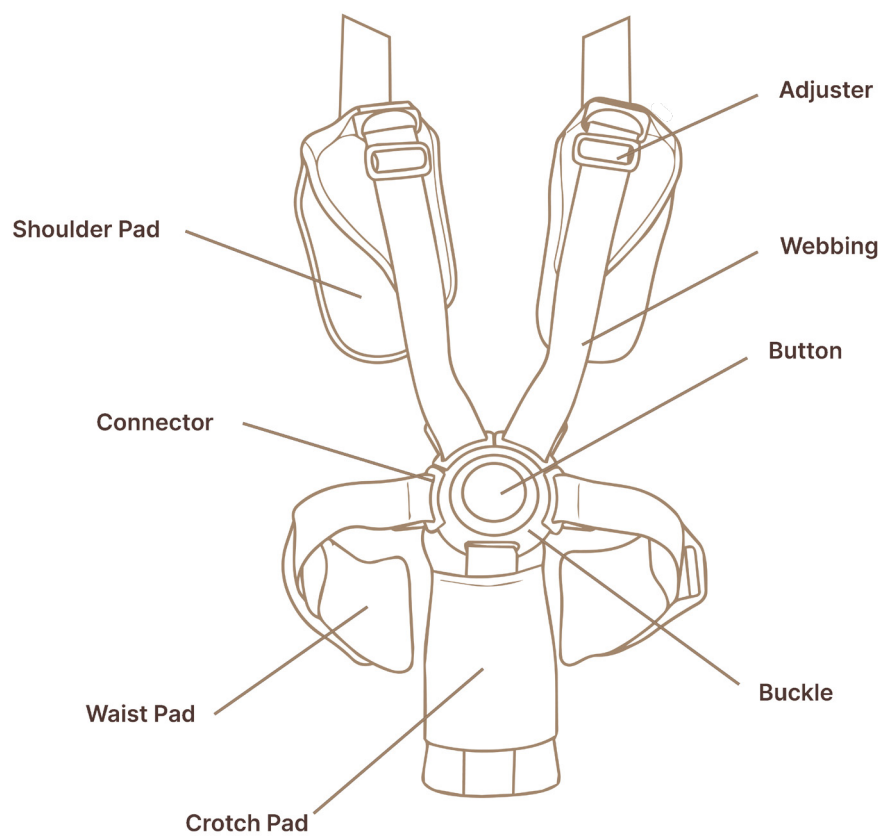


Figure 0.3: Harness Terminology

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1. Introduction

This introductory chapter explains the motivation and context of the project, and provides an overview of the approach.

1.1 Motivation

Assignment

This project is conducted in collaboration with Joolz, a premium Dutch stroller brand. Within the stroller industry, companies are often influenced by one another, following recent trends and innovations. Many of the resulting designs claim ergonomic benefits, but the actual evidence and long-term value for the child's development are not always clear.

Furthermore, parents are conventionally motivated to choose what they believe is best for their child, however the information they rely on is often influenced by marketing, perception or advice from others.

This presents two opportunities for Joolz and this project: first, to explore the scientific support behind ergonomics in strollers; and second, to relate these findings to the child's development as well as the parents' knowledge and decision-making. The research could then be used in developing a conceptual design, aiming to improve the physical ergonomics for the child.

As defined in the original project brief (Appendix A), the assignment stated:

"Investigate the gap between design vision and actual practice in the stroller industry and design a conceptual prototype to ergonomically improve Joolz' comfort strollers for both child and parent."

Stakeholders

Figure 1.1 shows the important stakeholders related to this project. The main stakeholders include, Joolz, TUDelft, the parent, and the child. The success of the project depends on managing their needs and expectations, which will be elaborated further in the analyses in Chapter 2.7.

Regarding me as a stakeholder, my motivation for this project originated from a business trip to Joolz organised by the faculty's study association, where we were asked to solve a case in a day. Through this visit, I became intrigued by their products, their vision and open atmosphere at the company. Their focus on physical products would allow me to make use of and develop my drawing and prototyping skills. As a result, sketches and prototypes have been used throughout this thesis to develop, deliver and evaluate. Furthermore, through my work as a sailing instructor & scouts leader, I have experience with working with older children, which also made me very excited to learn more about children's development at a much younger age. Finally, my love for design projects comes from being able to dive deep into new topics, trying to learn as much as I can from others in a very short time frame. Well, I can confidently say that at the start of this project, I had no prior experience nor knowledge of the world of babies and strollers, which made me even more eager to dive in.

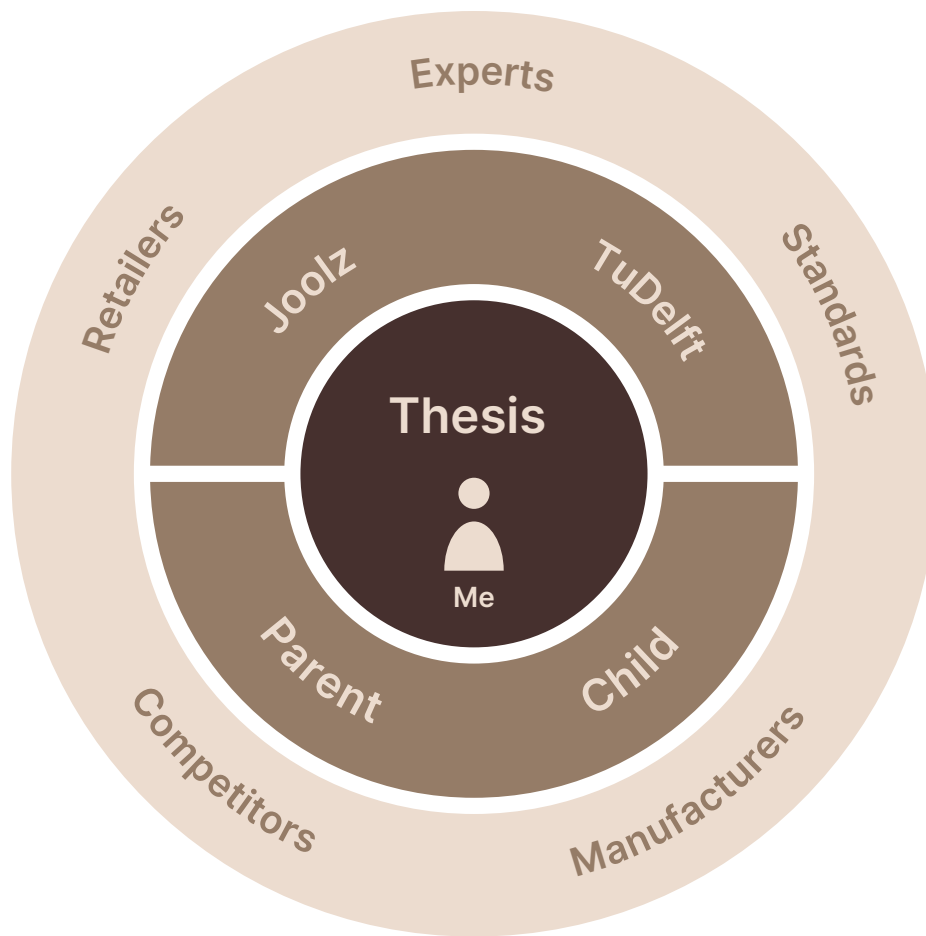


Figure 1.1: Stakeholder Map

1.2 Project Approach

This project generally follows the user-centred design approach as described by Van Boeijen et al. (2020), consisting of 5 steps: Research, Define, Create, Prototype and Evaluate. The approach focuses on the needs, desires and capabilities of the users of a product, and is most useful when there is a gap between designer and user. Figure 1.2 shows a more in depth overview of the steps taken and depicts the diverging and converging stages of the project.

As a result of the broad project brief, a lot of attention was given to research (Chapter 2) and defining the scope (Chapter 3). Ideation and design drawing were used as means of finding this scope and to communicate problem areas and solutions. After the specific scope and concept brief had been determined, an iterative design process of prototypes and testing was used to develop and evaluate the final concept (Chapter 4).

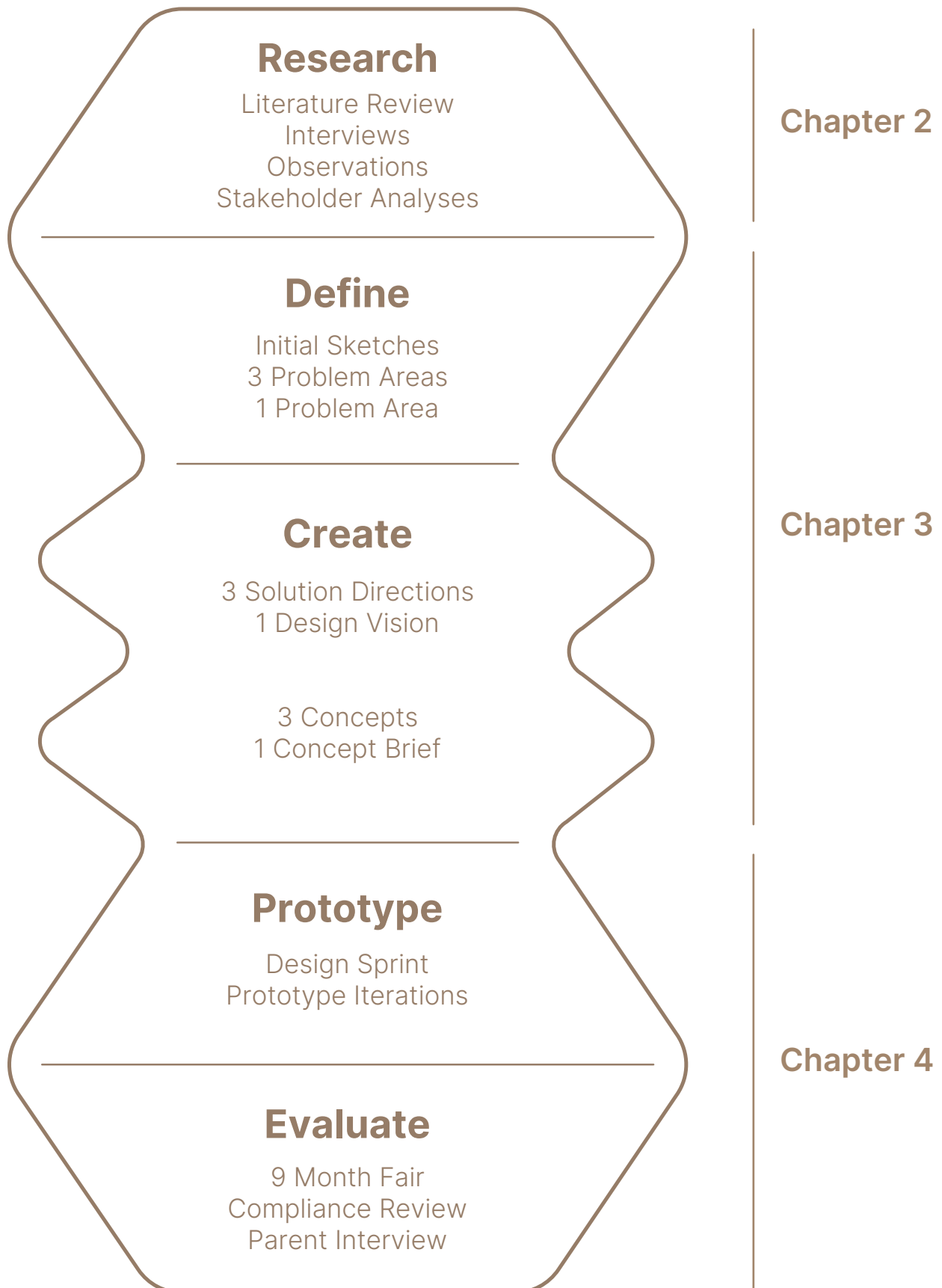


Figure 1.2: Project Approach



2. Research

This chapter discusses the front-end research conducted to explore the beliefs and behaviours of the stakeholders. This includes literature reviews, observations and interviews.

2.1 Approach

Objectives

User-Centred design is most valuable when there is a gap between designer and user (Van Boeijen et al., 2020). This front-end research phase was used to bridge this gap. Therefore, the aim of was to broadly explore ergonomics in the stroller industry. The acquired knowledge and insights would be used in defining design opportunities. To take into account ethics and privacy, a risk planning session (Appendix B) was held to be consulted throughout the project for interviews and consent forms. It provides an overview of risks, mitigations, informed consent and data management related to this project.

Although this was a highly exploratory phase, the following research objectives were defined to provide direction:

- 01.** What scientific and grey literature exists around the topic of ergonomics and comfort in strollers?
- 02.** How did strollers evolve over the years, and what are the current trends and innovations?
- 03.** What is the customer journey like for users? What influences their decision-making?
- 04.** What do users and retailers know about ergonomics in strollers? And where do they get this information?
- 05.** How, why and when are strollers being used, both by caregiver and child?
- 06.** How do medical experts look at ergonomics for children in strollers?

Research Methods

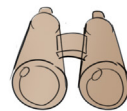
To explore the objectives, the research was structured into five different methods (Figure 2.1), which will be elaborated further in this chapter. The research results are discussed in Chapter 2.8.



2.2 Literature review (O1, O2, O6)



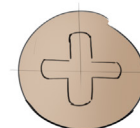
2.3 Retailer Visits (O2, O3, O4)



2.4 Observations (O5)



2.5 Parent Interviews (O2, O3, O5)



2.6 Expert Contact (O6)



2.7 Stakeholder Analyses (O5)

Figure 2.1: Research Methods

2.2 Literature Review

Goal

To provide a solid foundation of knowledge on the topic of ergonomics and comfort of strollers, current literature was reviewed. A holistic overview of the literature creates a context for this thesis and allows identifying knowledge gaps and design opportunities.

Method

Firstly, to find papers and other publications on ergonomics in strollers, Scopus was used as a database. Below are two iterations of the initial search strings:

TITLE-ABS-KEY(ergonomic* OR comfort* AND child* OR pediatric OR newborn OR infant OR baby AND stroller OR buggy OR cot)

TITLE-ABS-KEY(ergonomic* OR comfort* OR anthropometry AND child* OR pediatric OR newborn OR infant OR baby AND stroller OR buggy OR cot OR pushchair OR pram)

However, the search strings did not lead to enough or relevant results. Therefore, a less systematic method was used to find additional sources through the databases of Google and Google Scholar.

Of all the screened sources, 41 were selected and thoroughly read. This led to the selection of 35 references. These were included in an Excel file describing relevant information, insights and questions they raise, and can be found in the supplementary document *Literature_Review_Thesis_Max_Hessels.xlsx*

After gathering the insights from each source, they were clustered into eight different categories and a name was chosen to represent each category. Figure 2.2 depicts this particular process.

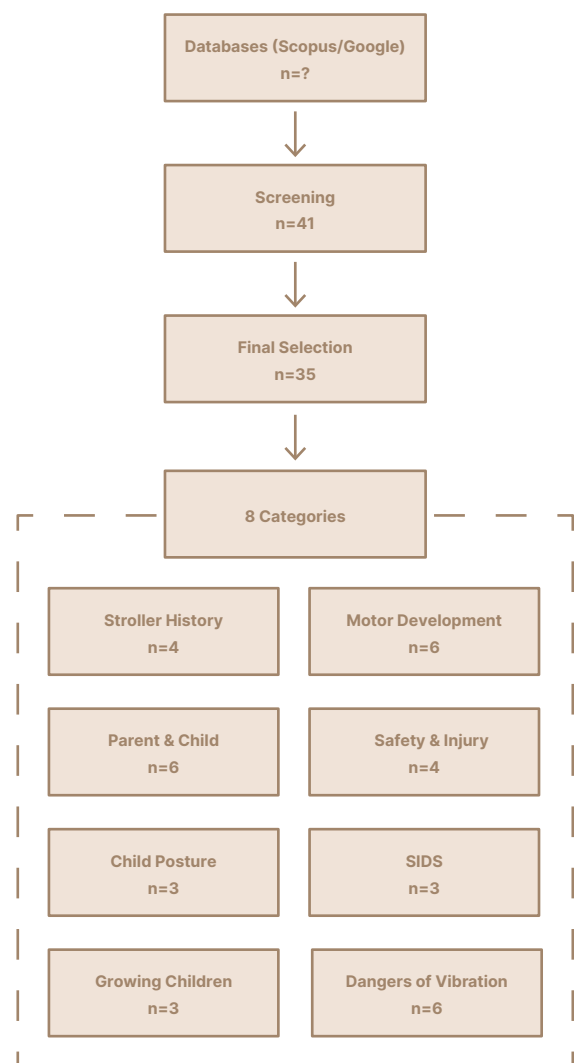


Figure 2.2: Overview of Literature Review

Results

In this section, the categories are explained, showing the current knowledge on the topic of ergonomics and comfort of strollers. Furthermore, these categories have also been included and described in the supplementary Excel sheet.

Stroller History

This first category describes how strollers have evolved over the years, and where it all started. In stroller history, one can see a development from a luxury item to a widely used mobility product (Figure 2.3). Earlier strollers seem to give the child much more space, whereas more recent stroller prioritise portability and usability for the parent. The first stroller appeared in 1733 (Nirmal et al., 2019) and was meant to be drawn by a small horse or dog. In the mid 1800s, parents replaced the animal, pulling the stroller behind them. Around 1848, the stroller became a product meant to be pushed, and in 1889, the first reversible carriage appeared (McClung Museum of Natural History & Culture, 2018; Nirmal et al., 2019). After WW1, safety features became much more prominent. Furthermore, due to the emergence of plastic parts after 1930, an inexpensive and accessible stroller market opened up. Later inventions included the lightweight and portable umbrella stroller in 1965, and the jogging stroller in the 1980s (Kin Kin, 2016; Nirmal et al., 2019). In more recent years strollers have innovated in extra seating, storage functions, foldability, seat recline, modularity, and electronics, among many others (Nirmal et al., 2019; Sehat & Nirmal, 2017). However, Sehat & Nirmal (2017) also argue innovation in strollers has plateaued. There seems to be no real fundamental functional change anymore with new designs focusing more on aesthetics and usability.



1733

First Carrier, a fashion piece for the wealthy. Designed to be pulled by animals



Mid 1800's

Easier use for parents or nannies. Stroller is pulled behind them. Child facing forward



1848

Pushing a stroller is easier than pulling. Patented in England as perambulator, now known as pram



1889

First reversible stroller. Also improved turning radius through individually turnable wheels.



Post WW1

Baby boom opened market. Much more safety focus: Bigger wheels, deeper cot, lower to the ground, sturdier frames, more spacious



1930's - 1950's

Mass produced. Rubber and plastic in manufacturing. Inexpensive chrome instead of brass. Not just fashion piece but budget friendly



1965

First umbrella stroller. Lightweight and collapsible. Aluminium frame. Made for travelling.



1980's

Strollers made for jogging, Three wheeled, bicycle tires sturdier frame. Running as hobby popular.

Figure 2.3: History of Strollers. Adapted from (McClung Museum of Natural History & Culture, 2018; Nirmal et al., 2019; Kin Kin, 2016).

Parent & Child

If recent developments in strollers focus more on usability, it is crucial to understand the needs and preferences for the user. For this category, various papers were reviewed which proposed stroller concepts by exploring parent preference and functional requirements. Soewardi & Nariswari (2021) and Wu et al. (2020) have found similar product attributes to be of importance (Figure 2.4).

Birken et al. (2015) did a qualitative study with parents on the reasons for stroller use and its perceived impact on their child’s physical activity. They identified 6 purposes for stroller use, seen in Figure 2.5. Additionally, they looked at what influences parents’ decision for using a stroller (also Figure 2.5). And they state no clear connection was found between stroller use and physical activity (Birken et al., 2015). On one hand overuse of the stroller is recognised as bad, on the other a stroller allows transportation to a place for activity.

Throughout the literature, it was found that children have preferences too, which influences the lifestyle and behaviour of the parents. Birken et al. (2015) mention it as an influencing factor (see Figure 2.5). Furthermore this is found in various forums about parents’ experiences. For example Suzannek86 states “Ideally [a stroller] that sits up really straight as wee man likes to see around” and later “Little man likes it although would prefer to walk at the moment!!” (2020). Some children seem to have a low tolerance for the stroller, or even hate it, [deleted] states in a different forum: “my 8 month old son usually prefers to just be carried and has a low tolerance for riding in the stroller for longer than a few minutes” (2018).

Stroller product attributes	
(Soewardi & Nariswari, 2021)	(Wu et al., 2020)
Simple	Portable
Comfortable	Storage
Safe	Reconfigurable
Multifunction	Replaceable
Durable	Foldable
Easy to use	Mobility
Serviceability	Stable
Aesthetic	Sit & Lie
Affordable	
Adjustable	

Figure 2.4: Stroller product attributes. Adapted from Soewardi & Nariswari, 2021; Wu et al., 2020).

Stroller Purposes	Influencing Factors
Transportation Getting from A to B	Caregiver Preference Convenience or impatience
Storage One of main conveniences, to carry stuff	Time Constraints Child walking takes longer
Leisure Spend time outside	Family Lifestyle Depends on working hours or use of daycare
Supervision Allows restraint and can ensure safety	Child’s walking ability Distance could be too big or risk of injury
Parent’s activity Walks and exercise	Child Preference Some like exploring, others like just looking
Sleep Allows sleep away from home	

Figure 2.5: Purposes and influencing factors for stroller use. Adapted from (Birken et al., 2015).

Child Posture

To research ergonomics in the stroller industry, special attention was given to proper posture of children. However, very limited literature was found. Most information originated from 'baby-ergonomist' Brecht Daams. She argues the strollers are not at fault, but the biggest problems lie in usage (Daams, 2024c) For sleeping, the best position is lying flat. When awake (and the child is able to sit unsupported) the best posture is upright, with lower legs vertical, as seen in Figure 2.6. She argues that horizontal legs while upright is very uncomfortable and could even lead to deformation of the spine. To prevent this posture, children would hang their legs over the sides of the leg rest, shown in Figure 2.8. According to Daams (2024c) an inclined position (Figure 2.7) is almost never an acceptable position as it causes uncomfortable friction and resists freedom of movement, which is necessary for healthy development.



Figure 2.6: Good posture in a stroller for children who are able to sit up straight by themselves (Daams, 2024c)

Figure 2.7: Inclined back support: not recommended when the child is awake or can not sit independently (Daams, 2024c)



Figure 2.8: In strollers with horizontally raised leg supports children still manage to find ways to sit with their feet down. (Daams, 2024c)

A German health certification Aktion Gesunder Rücken (AGR, 2025) similarly highlights the importance of a stroller seat being able to alternate between a lying and a sitting position. However, regardless of seating posture, AGR (2025) also states there should always be enough breaks for the child to play and move around.

Growing Children

An important part of ergonomics is anthropometry and making the product physically fit the user. Therefore a separate category was formed to address the changing needs of infants and young children. Pardue (2019) addresses this in designing a rocker. Pardue argues a desire for grow-with-me products, and creates a final concept using both adjustable angles and a foldable head- and footrest.

Furthermore, children grow not just physically, but also cognitively. Cao (2019) proposed a stroller design, taking into account the change in needs and short life span of the stroller. The result is a stroller concept that has several stages, with the final stage being used as a toy car (Figure 2.9)

Lastly, at one point, the children will outgrow their stroller. ABC News (2011) shows how some parents will still use the stroller while their child might be too big, likely due to convenience. However, this could cause long term problems for the child, as they need to develop their strength by walking themselves.

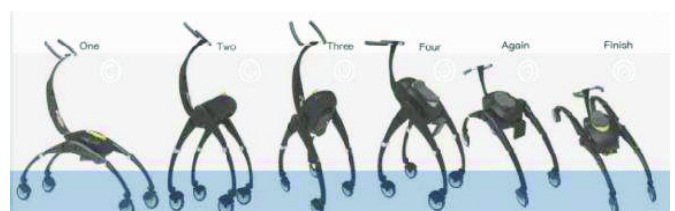


Figure 2.9: Use effects of different stages of growth baby stroller (Cao, 2019, p. 4).

Motor Development

During the literature research on infant seating ergonomics, a growing concern for delayed motor development was identified. Michalska et al. (2023) explain this through the term 'Container baby syndrome'. This refers to the overuse of sitting devices for infants, limiting motor activity. This claim is supported in the study by Siddicky et al. (2020), who measured EMG signals from infants in various positions (Figure 2.10). They recorded the lowest muscle activity in a car seat, and warn for the overuse of strollers. Highest muscle activity was recorded in the prone position, emphasizing the need for sufficient daily prone time.

Recent grey literature also mentions this slowdown in motor development. An example is the blog post by a child safety expert, who draws attention to research showing that children learn to walk later, are slower, and are less agile (Cotterink, 2022). She also warns for children falling more often, or developing insecurities or aversion for physical activity. Furthermore, in their newsletter article, Van der Velpen & Van Loon (2024) even argue an increase in obesity, injuries, and neck & back pain in young children, due to lack of movement.

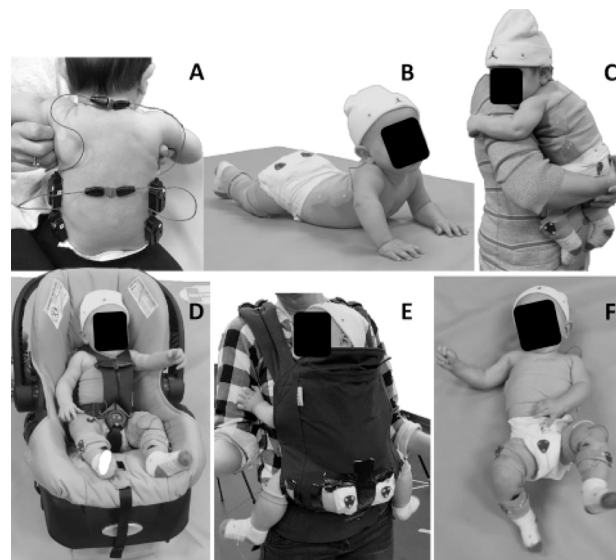


Figure 2.10: (A) Infant fitted with bilateral electromyography (EMG) electrodes in (B) Prone position, (C) Caregiver's arms, (D) Car seat, (E) Inward facing soft-structured baby carrier, and (F) Supine position (Siddicky et al., 2020, p. 3).

Finally, recommendations by the Health Council of the Netherlands (2022a, 2022b) advice on daily physical activity for children aged 0-4. However, it is important to note that even in their extensive literature review, not enough research was found to provide strong evidence that physical activity promotes motor development.

Safety & Injury

A substantial portion of the reviewed literature focuses on child safety in strollers. Injuries, safety practices and standards receive constant attention. According to Fowler et al. (2016), the most common causes of injury in strollers were falling or the strolling tipping over. Batra et al. (2015), analysed deaths associated with sitting and carrying devices. Their study showed almost all deaths were a result of asphyxiation.

Fortunately, this attention has also sparked many recommendations to prevent injuries. This includes not leaving the child unattended and using the restraint system, not using a sitting device as a place for sleep, but also not to hang bags from the handlebar (Zunjic, 2017). Furthermore, in the Netherlands, organisations such as Kinderveiligheid show tips and advice in concise and clear graphics (Figure 2.11). They highlight the importance of proper ventilation, and to never fully close off the stroller with a screen or blanket (Kinderveiligheid, n.d.).



Figure 2.11: De 4 van Veilig wandelen (Kinderveiligheid, n.d.). Retrieved from <https://www.kinderveiligheid.nl/adviezen/tips-en-advies/de-4-van-veilig-wandelen>

SIDS

An important part of infant safety, requiring a separate category, is the Sudden Infant Death Syndrome (SIDS). It refers to unexplainable deaths of children below the age of 1 year. Today we know multiple risk factors and ways to reduce the risk of SIDS..

SIDS became an official term in 1969, but in the study by Abramson (1944), attention was already called to the excessive number of infants dying from mechanical suffocation. Most deaths occurred in prone position, which at that time was thought to be most comfortable, and often due to loose items in the sleeping environment. Studies like this one have raised awareness and have led to various campaigns and guidelines. This includes safe practices such as sleeping on a flat surface in supine position, and to not have any objects in the baby's sleeping space (Daams, 2024b; Michalska et al., 2025).

However as shown by Michalska et al. (2025), even though parents are aware of the safe practices, they are not always adhered to. Furthermore, Daams (2024b) argues negative effects of the recommendations for supine positions, namely deformation of the head, and lower motor development. This, in turn, led to newer recommendations promoting tummy time during awake hours.

Dangers of Vibration

An final very recently emerging topic in stroller literature related to safety is the concern for the vibration experienced by the child and the possible negative effects it could have. This is seen in the studies by Dell'Orto et al. (2025), Trivillin et al. (2025), Sierzputowski et al. (2021) and Sun et al. (2022). Other papers in this category focus on dampening the force on the caregiver's arm (Kamio et al., 2021) or are related to motion experienced by infants in car seats. Arya et al., 2017).

Firstly, the studies show the biggest influence for vibration is the stroller body, dampening structures can delay impact, but do not absorb the energy. Furthermore, older heavier prams seem to show lower accelerations than the modern light ones, which can be seen in Figures 2.12 and 2.13 by Dell'Orto et al. (2025).

Secondly, this category highlights the need for proper standards and guidelines for vibrations on infants, as they currently only exist for adults. Based on the adult standards, the papers show the experienced vibrations would reach uncomfortable to extremely uncomfortable values, and could pose a health risk (Dell'Orto et al., 2025; Sierzputowski et al., 2021; Trivillin et al., 2025). However, the lack of standards seems to be an important limitation in supporting the claims.

Finally, what is specifically interesting in the papers by Trivillin et al. (2025) and Arya et al. (2017) is the testing of the physiological effects of real infants, rather than only measuring acceleration (see Figure 2.14).



Figure 2.12: [Strollers used in the study]. Adapted from (Dell'Orto et al., 2025, p. 4)

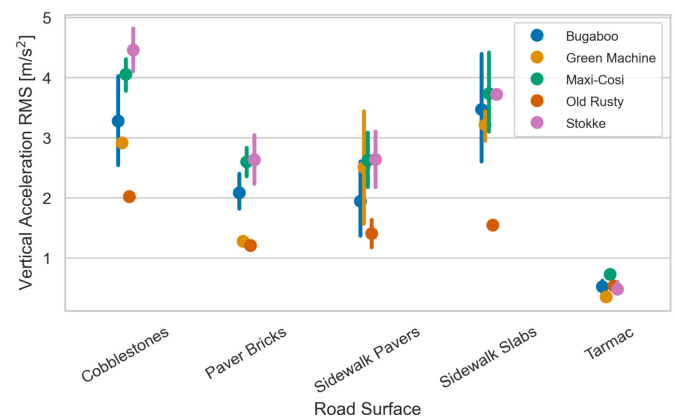


Figure 2.13: Plot of stroller accelerations for each road surface. (Dell'Orto et al., 2025, p. 12)

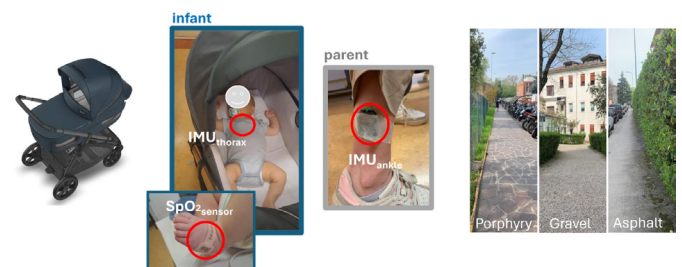


Figure 2.14: [Research setup] (Trivillin et al., 2025, p. 3)

Takeaways 2.2

- » Strollers have become smaller over the years, putting portability and convenience first. Furthermore, stroller innovations seems to have plateaued.
- » Limited literature was found on proper posture in strollers. But regardless of posture, time spent in a stroller should always be limited.
- » A growing concern for delayed motor development was identified, due to an overuse of sitting devices. This delay can lead to walking later, falling more, being slower, being less agile, obesity, neck and back pain, and development of insecurities for physical activity.
- » However, the Dutch Health Council did not find sufficient evidence for physical activity promoting motor development in 0-4 year olds. Furthermore, parents see no clear connection between physical activity for their child and stroller use.
- » Children grow rapidly and have preferences too. However, the child is not involved in the purchase of the stroller.
- » Most injuries and deaths in strollers are caused by falling or asphyxiation.
- » SIDS has led to various practices promoting sleeping in supine position. However, this also led to campaigns promoting prone time when awake. Furthermore, parents do not always adhere to safe practices, even when aware of them.
- » More recent literature shows concerns for vibration in strollers. However, no real conclusions can be drawn due to a lack of standards for children.

2.3 Retailer Visits

Goal

Three different baby stores were visited to explore how different brands were presented and advertised, and what distinguishes Joolz from its competitors. Furthermore, I wished to learn more about current trends and what influences the customer journey, and to find out retailers' knowledge on ergonomics in strollers. The latter would help to understand stores as a source of information for users.

Method

3 Stores were visited: Babypark Barendrecht, Babydump Leiden & Prénatal Leiderdorp. Besides walking around taking pictures, semi-structured interviews were held with a total of 5 employees (E1 - E5), of which 3 were working at Babypark. Questions were prepared (see Appendix C) and written down in a notebook, which was also used to take notes during the conversations.



Figure 2.15: Joolz Babypark Display



Figure 2.16: Joolz Babypark Accessories

Results

Observations

Babypark:

Compared to other brands Joolz' presentation was simple, easy on the eyes & didn't use hard lights or a big screen. Moreover, Joolz has a unique style-it-yourself stand and seems to be the only one addressing sustainability through reusable packaging (Figures 2.15 and 2.16).

Ergonomics is not actively advertised by any brand, only on a small scale by Maxi-Cosi and Cybex (seen in Figures 2.17 and 2.18).

Unique selling points of other brands included a 6in1 stroller by Jiffle and Cybex having a specific stand to show luggage compatibility of their buggy (Figures 2.19 and 2.20).



Figure 2.17: Maxi-Cosi ergonomics

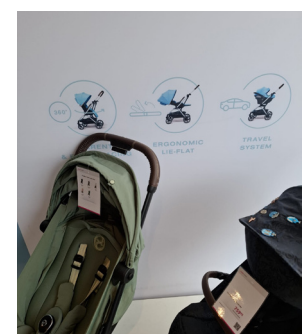


Figure 2.18: Cybex ergonomics



Figure 2.19: Jiffle 6 in 1



Figure 2.20: Cybex Buggy

Babydump:

Compared to Babypark, the brands have less room for a custom display. However, Joolz (Figure 2.22) and Dubatti still have a separate space, instead of the rows of strollers for other brands. Again, the Joolz display really eases the mind, compared to the crowded feeling of the other displays.

Joolz seems to be the only brand confidently displaying their accessories in the middle of their display. For other brands, one would have to go to another floor where shelves are shared with other brands. However, for some reason the Joolz Aer+ and Aer2 have been displayed without a bumper bar (Figure 2.21).

Prénatal:

All company displays were very similar in setup & looks (Figure 2.23). Again Joolz does display their accessories next to the strollers (Figure 2.24) and the Aer2 is shown without the bumper bar.

Only Maxi-Cosi mentioned ergonomics in their product description on a tag for their Oxford+. Another interesting observation was that this was the first store where I noticed a specific stand for baby carriers (Figure 2.25).



Figure 2.21: Joolz Babydump Aer 2



Figure 2.22: Joolz Babydump Display



Figure 2.23: Prenatal Display



Figure 2.24: Joolz Prénatal



Figure 2.25: Prénatal Carriers

Interviews

The results of the interviews are depicted in Figure 2.26. They have been separated into two categories. The first shows the current trends in the stroller industry and what parents are often looking for in a stroller. An interesting and potentially dangerous trend for children's development is the 3 in 1 stroller, as it prolongs the time the child spends in a car seat. The second shows some of the answers given by employees in conversation about their knowledge of ergonomics. However, Babypark and Babydump employees seemed to have a very different opinion on seat ergonomics compared to the Prénatal employee.

	Trends / Demands	Ergonomics
Babypark	E2. Accessories (lights & E-strollers) E2. Big Basket E2. Lightweight E2. All-Terrain E3. Foldability E3. 3 in 1 stroller E3. Smooth driving E3. Sales of accessories depends on the sales pitch (accessory / necessity)	E1. Round and deep Dubatti seat better than flat Cybex seat E3. Also showed Dubatti E3. Not sure if Day 5 flat recline is better than the Dubatti recline E3. Cot to seat after 6 months E3. Ergonomics isn't advertised or searched for but is mentioned in pitch E3. Dubatti/Joolz/Uppababy would be more ergonomic than Cybex
Babydump	E4. Colour trend (natural colours) E4. All-Terrain Strollers E4. Accessories (phone chargers & holders)	E4. First mentioned Dubatti & handlebar height & child position E4. Dubatti/Joolz/Maxi-Cosi would be ergonomic brands, but they wouldn't say any other is not ergonomic E4. Ergonomics is vague term, no customer has ever asked for it E4. Mostly about thigh support, depth of seat, high backrest, angle of seat
Prénatal	E5. Trends in colours (taupe/green) E5. Companies follow each other E5. Sets, like 3 in 1 strollers E5. Size of the stroller, fit in car E5. Every customer unique and has different requirements E5. Customers come for Bugaboo or Joolz, they come for brand they know	E5. It's all the same, all seats are good, they would not say any brand is better than the other E5. Mentioned moving from cot to seat after 6 months

Figure 2.26: Interview results from Retailer Visits

Takeaways 2.3

- » Joolz displays are often more calm and ease the mind, compared to other brands with bright lights or big screens. Joolz also proudly shows accessories, and highlights their sustainable packaging.
- » Main trends in the stroller market include colour, 3in1 sets, all terrain strollers, and all kinds of accessories. This popularity in 3in1 strollers leads to more time spent in a car seat.
- » Ergonomics is not avidly advertised in stores, but is mentioned in conversation with the customers. For example in advice for moving from a cot to a seat at 6 months of age or when promoting a high backrest or a specific seat recline.
- » Differences occurred in opinions of what is ergonomic for the child. Employees at Babypark and Babydump mentioned a deeper, bowl-like seat as more ergonomic, whereas a Prénatal employee states it does not really make a difference.

2.4 Observations

Goal

To gain better insights into the usage of strollers, observations were done. Special attention was paid to the behaviour of the caregiver, the position of the child and the use of any additional storage.

Method

2 types of observation studies were performed. First, through taking notes of strollers encountered naturally during the duration of the project. Second, through user observations at Blijdorp Rotterdam Zoo. Due to privacy and ethical concerns, especially regarding underage users, no recordings were taken and child positions have been visualised based on memory. The visuals were made using Gravity Sketch.

Results

On the go

During the project I have extensively made use of public transport, or walk or cycle from place to place, encountering quite some strollers along the way. Paying attention to user behaviour, both by child and caregiver, I took notes of anything that stood out. The results can be seen in Figures 2.27 and 2.28.

Description	Location	Stroller	Visual
Child was hanging to the side in the buggy	Babypark Barendrecht	Easywalker (buggy, but could not recognise model)	
Child had a slumped posture with one leg over the edge of the footrest	Metrostation Noorderpark	Stokke Yoyo	
Seat was in reclined position, but thighs of the child too short for deep seat	Leiden Centraal	Uppababy Vista	
Child was not strapped in, sitting almost perpendicular to seat	A'dam Noord Roundabout	N.A. (buggy)	

Figure 2.27: On the go Observations 1/2

Child was sitting with both legs over the side of the leg/footrest	A'dam Noord Roundabout	N.A. (buggy)	
Child was sitting upright at edge of seat, whilst backrest was reclined	Amsterdam Centraal	Seemed like Cybex model	
Child was sitting, while holding and watching a tablet	Schiedam Centrum	N.A. (buggy)	
Woman walking with stroller, while man was carrying the child	Delft Abtwoudse-brug	Nuna trvl	N.A.
Woman was using the side basket of the Donkey whilst having her child in the seat	Metrostation Noorderpark	Bugaboo Donkey	

Figure 2.28: On the go Observations 2/2

Blijdorp

A day was spent in Blijdorp/Rotterdam Zoo, taking notes of stroller use. Special attention was given to the use of storage bags, use of the bumper bar, and child positions (Figures 2.29 and 2.30).

Other interesting observations at Blijdorp included:

- The amount of empty strollers, as the child was being carried, or standing by themselves to be able to look at the animals
- Usually the empty strollers had a bumper bar that was attached on only one side, to allow the child to easily get in and out
- Twice a buggy seemed to be used solely for carrying bags and other stuff
- Presumably an older sibling pushing the stroller for the younger sibling.

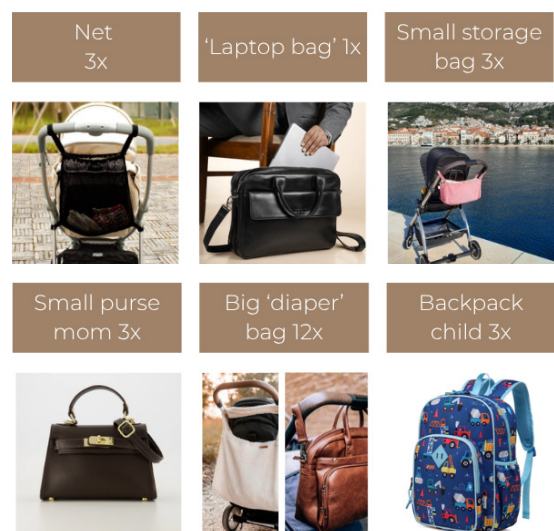


Figure 2.29: Blijdorp Bag Observations

Description	Visual	Description	Visual
Seemed too tall for the backrest 3x		Child in upright position with legs horizontal 1x	
Slouching very low in the stroller, (one easywalker model) 2x		Legs extended far past legrest (cybex eezy s twist) 1x	
In reclined position with legs vertical 1x		Child leaning forward against bumper bar 5x	
Father was using baby carrier, while cot was empty 1x		Legs too long for the footrest 1x	

Figure 2.30: Blijdorp Observations

Takeaways 2.4

- » Numerous different child positions were observed, from sitting on the edge of the seat to sitting sideways with legs hanging off the sides to slouching all the way down.
- » Children did not always properly fit the stroller, cases were seen where the backrest was too short, or the legs extended far past the legrest. Additionally, both the results of having too short and too long thighs in a reclined position have been noted.
- » Two situations were observed where the child was being carried in arms or in a carrier, and the stroller was empty.
- » Specifically in the use case of Blijdorp, children were often observed out of the stroller (often a buggy) to look at the animals, highlighting the importance of being able to quickly exit and enter the stroller.

2.5 Parent Interviews

Goal

The goal of the interviews was to gain more insights into the customer journey and use of strollers. Furthermore, an additional goal was to assess their knowledge of ergonomics and to find the source of this information.

Method

Two separate semi-structured interviews were taken. One interview was taken with an experienced mother (P1) and one interview with soon to be parents (P2-P3). Beforehand, an ethical checklist was used in creating a consent form (Appendix D). Moreover, questions were prepared (Appendix C), as well as a few interactive elements to facilitate discussion.

The latter consisted of a list of product requirements to be ranked on importance (Figure 2.31) and monochrome images of strollers/buggies to be ranked on their perceived ergonomics (Figure 2.32). Audio recordings and a few notes of the interviews were taken, allowing the researcher to focus on the questions, and analyse the results subsequently.

- All-Terrain
- 3 in 1
- Opvouwbaarheid
- Zitting/positie voor kind
- Prijs
- Uiterlijk
- Soepel rijden
- Gewicht
- Boodschappenruimte
- Accessoires

Figure 2.31: Parent interview ranking list



Figure 2.32: Parent interview stroller images

Results

Questions

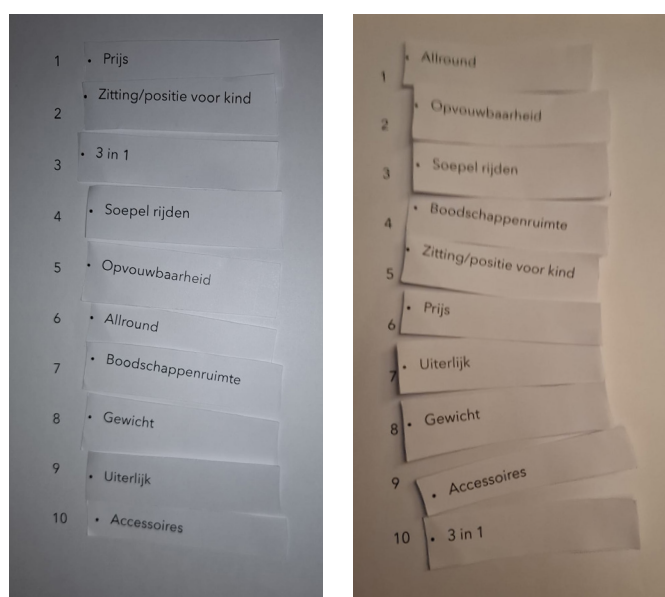
Based on the answers given during the interviews two user profiles were created (Figure 2.33). The profiles show information about their stroller purchase, use, preferences and struggles, knowledge of ergonomics and the source for their information, and other comments made during the interviews.



Figure 2.33: Parent interview User Profiles

Interactive Elements

The interactive elements were used to spark discussion and in providing direction for the questions. Due to the low number of participants, no quantitative conclusions were drawn. The value of the results lies in the qualitative reasoning and thoughts behind the answers. The answers for the interactive elements can be seen in Figures 2.34 and 2.35. The discussions with the participants during and after the ranking provided insights into what parents find important in a stroller, and what parts they take into account when assessing stroller ergonomics.



P1 found price most important, since they also opted for a second hand stroller. The second requirement for them was the child's seat and position. However, they did miss the handlebar height as a requirement, showing how important this is to them.

P2 & P3 looked more at the usability of the stroller, in having an all-round versatile stroller. They also stated the stroller should be portable, as they have a smaller car. Lastly, in choosing a stroller they really considered the driving experience and possible basket space.

Figure 2.34: Parent interview Requirement Ranking
(Left are answers from P1, Right are answers from P2&P3)



Figure 2.35: Parent interview Ergonomics Ranking (answers P1 on top, P2 & P3 on the bottom)

When asked to rank different strollers from least to most ergonomic (Figure 2.35), the participants took into account a variety of aspects.

P1's decisions were based on:

- Size and presence of canopy
- 5-point harness was chosen over a 3 point harness, in their experience it is better to secure the child
- Deeper seat looks more cosy
- More pillows and cushioning also makes it seem more comfortable
- Preference for parent facing
- Looked at backrest and footrest, and if it would be long enough for taller children
- Size of the wheels
- Based on past experience with e.g. buggies, they prefer a stroller where the entire seat reclines, not just the backrest, otherwise the child would slide down and sit slumped.

P2&P3's decisions were based on:

- Presence of a footrest and its adjustability
- Size of the wheels, with larger wheels often meaning a more robust stroller
- Cushioning for the head
- The participants did not agree on whether the canopy would be part of ergonomics.

Even though the participants were made aware of the specific focus on children's seating ergonomics, they looked at much more than just the seat. Combined with the insights into their requirements and preferences, it shows how important it is to consider the entire stroller and caregiver experience. When designing for stroller ergonomics, the entire interaction with the product should be considered.

Takeaways 2.5

- » Parents take a lot of aspects into account when buying a stroller, every user is different and has different needs.
- » Use context is often for walks or some shopping, sometimes walks are in the forest, which creates a preference for all-terrain and robust strollers.
- » All participants mentioned 6 months as a transition point from the cot to seat, and mentioned the maximum time for a car seat, due to restriction of the child. However, they did recognize them as a guideline. P1 highlights the importance of the child's opinion when showing signs of discomfort.
- » Parents gather information from various sources, ranging from Google to forums to ChatGPT to experiences from other users. P2&P3 gained a lot of information from in store conversations with employees.
- » In evaluating perceived ergonomics of the strollers, parents take a lot of elements of the stroller into account. Aspects influencing their decision included: size of the wheels, depth of the seat (deeper = more cosy and comfortable), use of foot- or headrest, size of the canopy, 5-point harness instead of 3, and perceived comfort through cushioning and pillows.

2.6 Expert Contact

Goal

To substantiate the literature and gather different perspectives on the topic, certain experts were contacted. One person contacted was Brecht Daams, due to her presence in the literature. As she makes quite some interesting claims, the aim was to get more background information.

The second goal was to understand strollers better from an unbiased medical perspective. Multiple types of experts were contacted, eventually, contact was reached with a paediatric occupational therapist, working for a rehabilitation centre.

Results

Daams

In the literature review (in Chapter 2.2), Daams was found making some big claims on child posture, motor development and vibrations experienced in strollers. Through e-mail a conference poster was shared, which essentially states that there are only two acceptable postures in strollers, either upright or completely flat. According to Daams, wrong posture affects motor development and could cause deformation of the spine. In her book *Geef je baby de ruimte!* (Daams, 2024a) she elaborates on this further and mentions the importance of movement freedom, and how a reclined seated position limits the child's ability to look and move around, resulting

Method

Preferably, information would have been gathered through semi-structured interviews. However, due to various reasons (e.g. time constraints and availability), this could not be achieved. Therefore, contact with Daams was reached via email, which led to buying her book *Geef je baby de ruimte!*, which provided more information. The book was read, highlighting and annotating important parts. Contact with the paediatric occupational therapist was reached via a phone call, during which notes were taken.

in weakening of the muscles. She also argues babies have a natural urge to move, which has advantages for the bones, muscles, coordination and brain development (Daams, 2024a). Finally, all movement counts. Moving arms and legs or lifting and turning the head are already helpful. The variation in position is what is important. You can't make up for a total day spent in a stroller with just some scheduled tummy time (2024a).

In her e-mail, she discusses the following reasons for why we still observe these unhealthy postures in strollers, and why no-one is doing anything (Figure 2.36).

Reasons for wrong posture

- Parents do not even think about it, and think it is probably fine or comfortable for the child
- Parents copy the behaviour they see
- Current seats are too deep for smaller children.
- With some strollers, the footrest is automatically horizontal, requiring an extra step to put it down.

Why no-one does anything

- Doctors and nurses are not aware, so neither are manufacturers of strollers.
- People do not realise how much time is spent in a stroller.
- People are not aware of the consequences of fixating children.
- Knowledge on raising children has been lost over the years, which used to be common 100 years ago.

Figure 2.36: Expert Arguments Brecht Daams

Paediatric occupational therapist

To analyse what was discussed in the phone call, a schematic overview was made of statements and arguments, based on the notes made during the call. Below, the discussed topics have been summarised into categories (Figure 2.37).

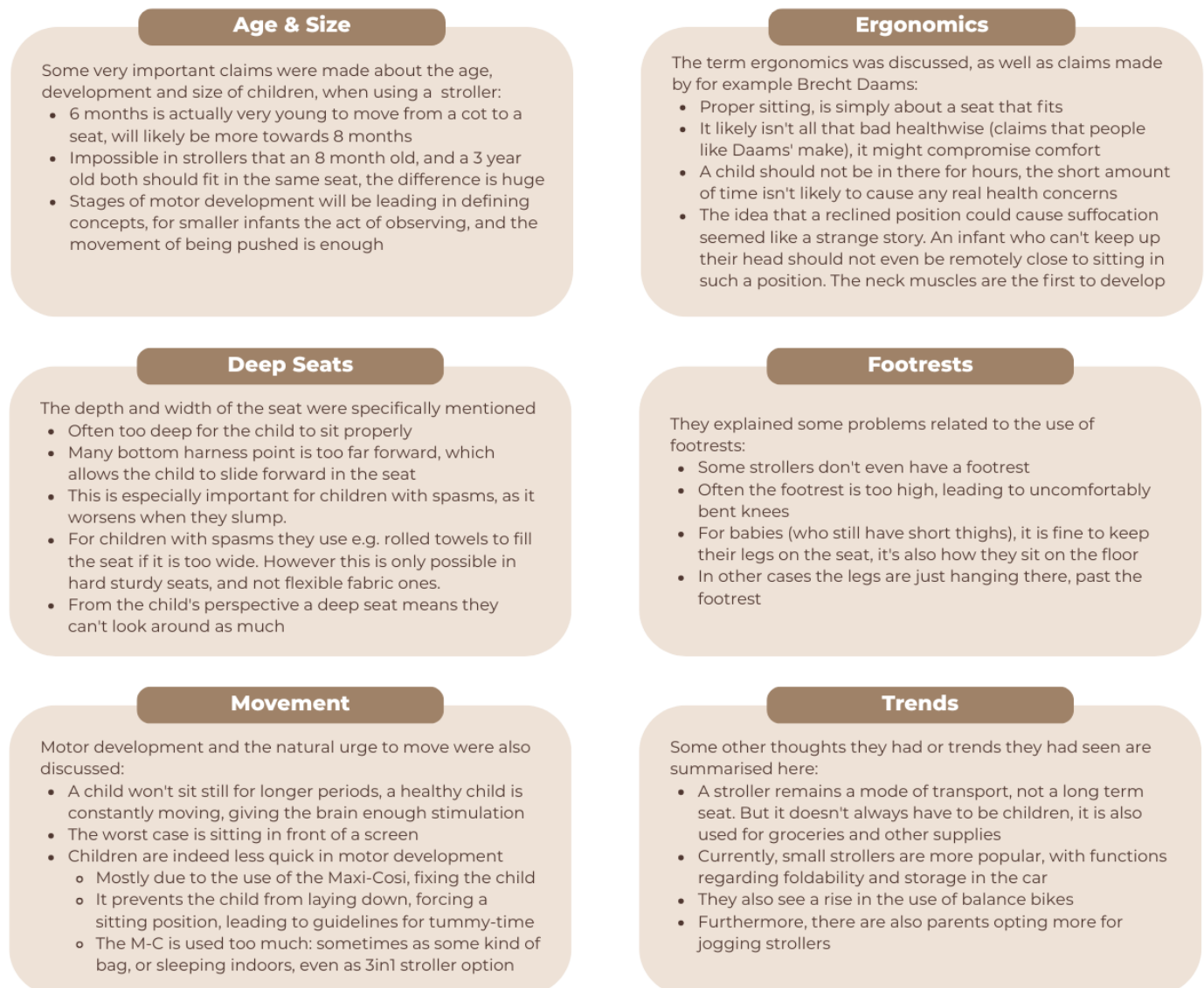


Figure 2.37: Expert Arguments Paediatric Occupational Therapist

Takeaways 2.6

- » The occupational therapist argues that 6 months is early for a child to move from a cot to a seat.
- » Current strollers do not properly fit all target ages, the size difference between an 8 month old and a 3 to 4 year old is too large, especially in the thigh length.
- » A child is constantly moving and should not sit still for longer periods, to stimulate the muscles and the brain.
- » Children are slower in motor development than in the past, mainly due to the overuse of car seats, as seen in 3in1 strollers.
- » The pediatric occupational therapist states that some claims made by Daams might not be that bad healthwise, due to the limited amount of time the child spends in the stroller.
- » Both Daams and the occupational therapist agreed that children should move to stimulate the brain, and that motor development has declined over the years. This seems to be a cause for concern.

2.7 Understanding the Stakeholders

Goal

For a user-centred design approach, it is crucial to have a solid understanding of the needs and expectations of the main stakeholders. Therefore, throughout the project, various moments of desk research were done to analyse these different needs.

Results

Joolz Brand Analysis

Joolz has the ambition to “support parents with smart designs and sustainable products” (Joolz, n.d.). This highlights two of the main pillars Joolz stands for, sustainability and being there for parents. Sustainability is integrated throughout the whole brand, in a sustainable office, use of recycled fabrics, reusable packaging, and initiatives like a 10 year transferable warranty or planting trees for every stroller sold. Supporting parents is not just done via their products, but also through their parent hideout and hosting community events. Through these goals, they aim to create a better world for both parent and child.

As observed during the retailer visits, Joolz display areas provide a sense of calmness and ease the mind, and highlight their sustainable focus. To further analyse their way of advertising, Figure 2.38 was created. In their communication Joolz does not just convey their products and quality, but also the playful and real-life aspect of parenthood and their brand. By using real parents instead of models, the communication is seen as honest and understanding of the reality of parenting.

Method

Three types of desk research were performed. Firstly, Joolz was analysed as a stakeholder, by defining the brand, values, and design style. Secondly, user journey mapping was used to get insights into the parent’s daily routine. Finally, for the child, an overview was created of the main milestones in children’s motor development, and anthropometric data was gathered for the specific target group defined in Chapter 3.4.



Figure 2.38: Joolz advertising

Appendix E shows a complete overview of Joolz' products and accessories, and the portfolios of their main competitors. This overview, together with the insights from the retailer visits, assisted in creating a perceptual map of the more premium brands in the stroller market (Figure 2.39). The vertical axis plots simplicity in the user experience of the design and portfolio against more complex use of technology, such as electronics. The horizontal axis plots a practical and rational appearance against a more emotional lifestyle product. The map shows how Joolz differentiates itself by leveraging clean appearance and designed product development.

To get a better feeling of their portfolio and design language, sketches were made of their current models (see Figure 2.40). From smallest buggy to largest comfort stroller, this includes the Aer 2, Hub 2, Day 5 and Geo 3. Furthermore, Joolz' designs were compared against the models of the three competitors closest in the perceptual map, and shown in Figure 2.41.

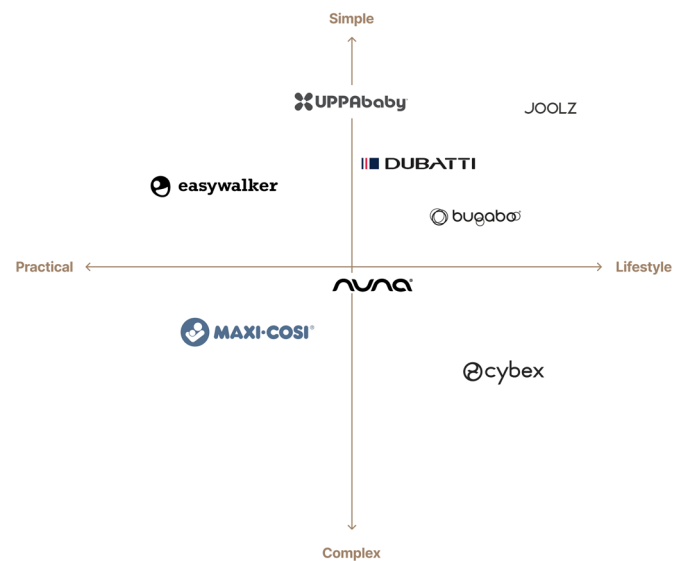


Figure 2.39: Perceptual Map



Figure 2.40: Sketch Study Joolz Portfolio

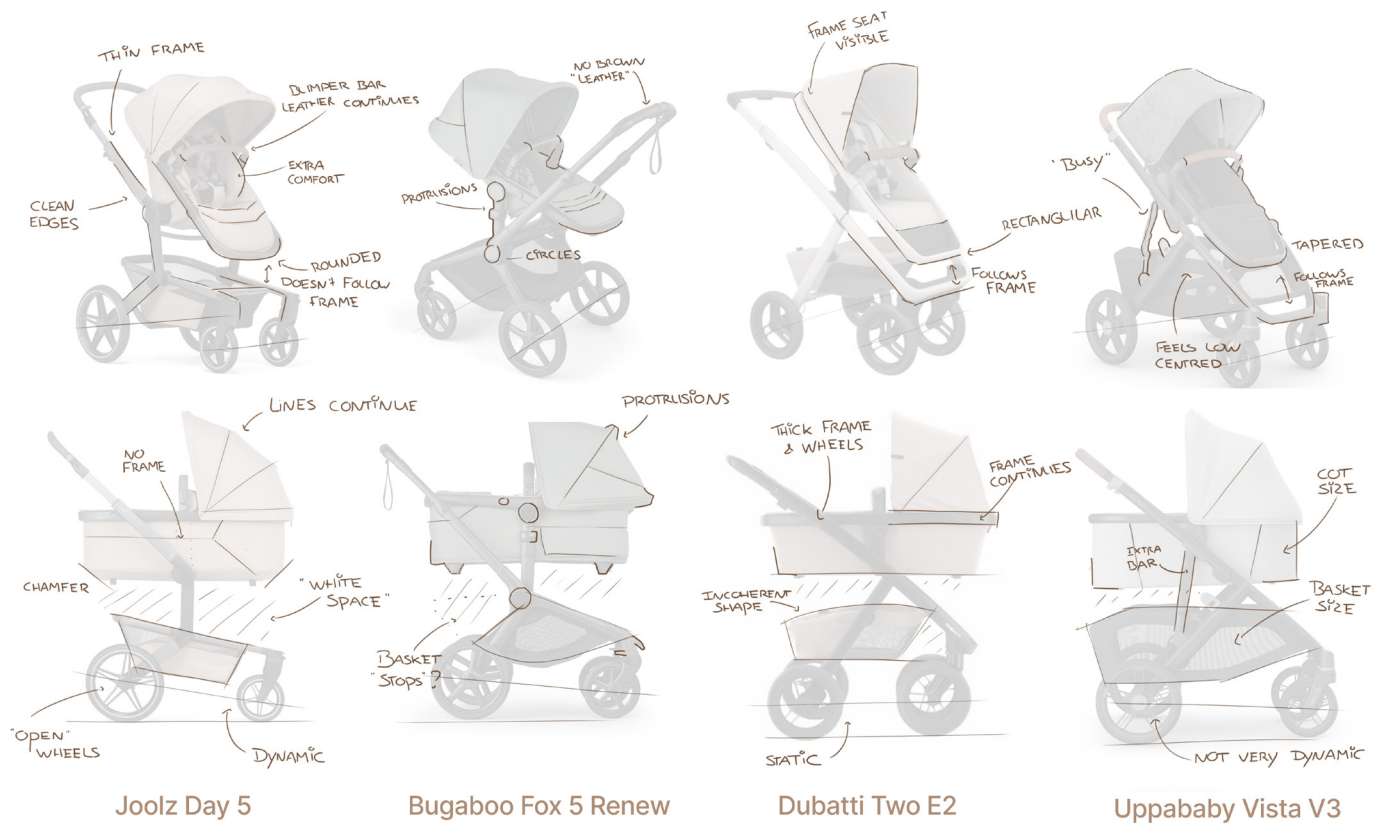


Figure 2.41: Competitor Design Comparison

When comparing the designs of the competitors, there are a few things that make the brand stand out. Bugaboo’s frame has a lot of protrusions, which could help portray their focus on innovation, but creates a less clean design language. Dubatti seems to have a very thick frame and wheels. This thickness combined with the wheels of the same size creates a very static and robust feel compared to the more dynamic stance of the Joolz stroller. The Uppababy model looks very low-centred and sluggish, especially due to the big basket and the straight cot.

When looking at the Joolz model, it immediately gives a certain feel of elegance and luxury. Its stance is more dynamic than the others, with thin and minimal use of a frame, creating a coherent balance between soft goods and technology. Lines are continuous and do not stop abruptly, edges are clean without protrusions, and a small chamfer at the bottom of the cot creates a much lighter appearance. Lastly, the stroller also has a certain calmness through the use of white space, by having an empty area between the cot and the basket, and making use of open rims.

Parent Routine

As mentioned in the study by Arimura (2008), parents have very busy lives, and they rely on routines to survive. This usually means a daily pattern of sleeping, feeding and playing. However, the life of a new parent is rarely very structured, newborns are unpredictable and every parent’s lifestyle is different. Two examples were found as shown in Figures 2.42 and 2.43 for a relatively realistic daily schedule. The schedules show the importance in balancing sleep, food, and play. Strollers play a role in this day to day life to transport the child from home to daycare or other places, going on walks, or doing groceries.

Schedule for Babies (9 Months)

7:00 a.m. Wake up and nurse
7:30 a.m. Get dressed, playtime in bedroom
8:00 a.m. Breakfast (“The more finger foods the better he loves it and as an extra bonus, it takes him longer to eat so I can tidy up the kitchen.”)
9:00 am Morning nap
11:00 am Wake up and nurse
11:30 am Go for walk or play outside
12:30 p.m. Lunch (Usually leftovers)
1:00 p.m. More playtime, reading or FaceTiming with family
2:00 p.m. Afternoon nap
3:00 p.m. Wake up and nurse
3:30 p.m. Playtime and cleaning/organizing. (“I’ll tidy or do laundry with the baby strapped to my chest or crawling around on the floor-it’s not easy but I can at least get some household chores done.”)
5:30 p.m. Dinner
6:00 p.m. Bath time
6:30 p.m. Bedtime routine
7:00 p.m. Bedtime

Figure 2.42: Baby Schedule (Brightwheel, 2025).

Infant Daycare Schedule

8:00am-9:00am Drop-off + bottles/ breakfast
9:00am-9:30am Diapers
9:30am-10:00am Circle time (books + songs + puppets/finger plays)
10:00am-10:15am Bottles/morning snack
10:15am-10:30am Diapers/clean up
10:30am-11:30am Nap time
11:30am-12:00pm Bottles/lunch
12:00pm-12:30pm Story time (books + songs)
12:30pm-1:30pm Outside play/gross motor time
1:30pm-2:30pm Nap time
2:30pm-3:00pm Bottles/snack
3:00pm-4:00pm Sensory or art activity
4:00pm-5:00pm Individual play time

Figure 2.43: Infant Daycare Schedule (Singer, 2024).

Child Development

Even though every child is different and develops at a different rate, there are guidelines used by paediatricians and occupational therapists to track children's motor development (Cava et al., 2022). Usually, motor development is divided into fine and gross motor development. Fine motor development refers to the use of the hands and fingers and hand-eye coordination. Gross motor development refers to the larger muscles, leading to milestones in rolling, crawling and walking. Figure 2.44 shows an overview of the major milestones in gross and fine motor development, together with the physical activity recommendations from the Dutch health council as mentioned in Chapter 2.2.

Age	Gross Motor Skills	Fine Motor Skill	Dutch health council recommendation
0-2 Months	Starts lifting head	Closes fingers Hands to mouth	Tummy time several times a day for total of 30min, playing on the floor, and no screen time.
3-5 Months	Lifts head Start rolling	Grasps and pulls Hands to midline	
6-8 Months	Rolls Both Ways Crawling Independent Sitting	Moves rattle Raking motion to grasp	
12-14 Months	Standing Start Walking	Pincer grasp Holds marker in fist	180min of daily activity, more is preferred. Should not be restrained in a seat for more than 60min. 2-3 years, max 1 hour of screen time.
15-18 Months	Creeps in stairs Walks backwards	Stack cubes (2 to 3) Digital pronate grasp	
19-24 Months	Immature Running	Stack cubes (4 to 6) Draws vertical line	
2-3 Years	Balancing Ascend stairs alternating	Draws a circle Unbuttons large buttons	
3-4 Years	Kicks Jumps Runs	Use tripod pen grasp Draws a cross Uses scissors straight	At least 180min of activity Including 60min of vigorous activity. Avoid sitting still for longer periods. Max 1 hours of screen time

Figure 2.44: Child Motor Milestones overview. Adapted from (Cava et al., 2022; Health Council of the Netherlands, 2022a).

To ensure an ergonomic fit, anthropometric data was researched for children between the ages of 9 to 18 months (the target group defined in Chapter 3.4) Due to lack of availability of critical measurements for this project, some assumptions and estimates were made, which will be elaborated in Appendix P. The main dimensions used originated from Annex A of the standard NVN-CEN/TS 13387-1 (CEN, 2025) and can be seen in Figures 2.45 and 2.46. Furthermore, throughout this project a Solidworks model by SLIMDESIGN was used of a child, aged 9 to 12 months, based on the anthropometric data of a KIMA survey by Steenbekkers in 1993 (3D Human Model, 2017). This model was used to substantiate estimations and create visualisations. Lastly, a weighted doll at Joolz, representing a 1 year old, was used for evaluating and testing physical prototypes.

Number	Dimension	9 months (p5)	9-12 months (mean)	12-18 months (mean)	18 months (p95)
1	Weight (kg)	7,5	9,2	10,9	12,7
2	Body Length (mm)	687	744	796	862
3	Chest breadth (mm)	132	151	158	175
4	Chest circumference (mm)	441	471	491	524
5	Hip depth (mm)	78	96	98	116
6	Sitting height (mm)	433	476	494	527
7	Thigh clearance (mm)	47	69	70	85
8	Popliteal height (mm)	128	145	184	200

Figure 2.45: Table of Child Critical Dimensions. Adapted from (CEN, 2025)

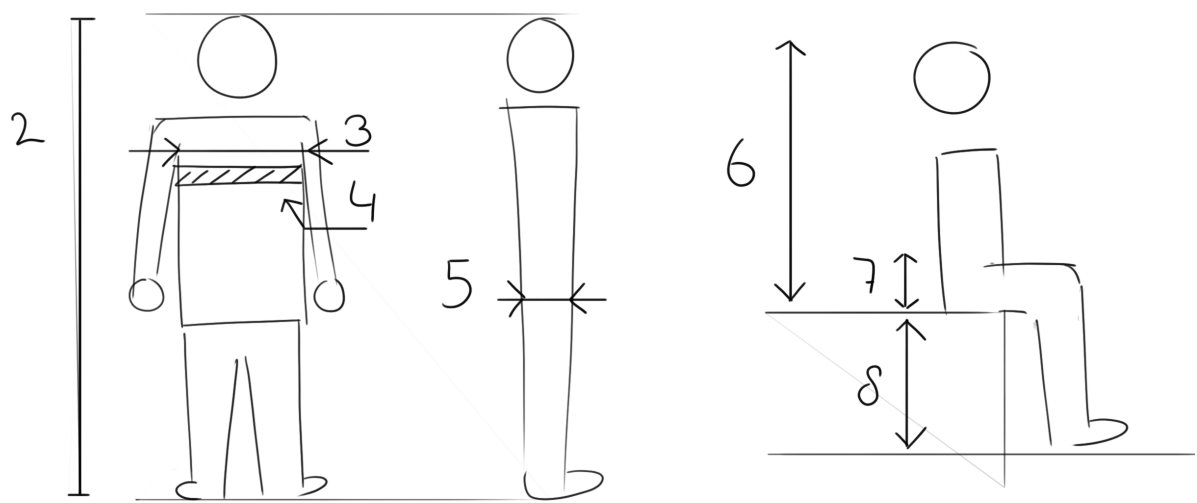


Figure 2.46: Schematic Overview of Critical Dimensions

2.8 Research Discussion

This section discusses the key insights from the research phase which were used in identifying design opportunities and supporting conceptualisation.

Varying children

The literature and observations showed how each child is different. Birken et al. (2015) argued how the child's preference plays a role in the behaviour and lifestyle of the parent. Some children like sitting and watching in the stroller, others hate it and would rather explore and walk around. This can also be seen in parent experiences mentioned in forums ([deleted], 2018; Suzannek86, 2020). Furthermore, in the interviews, parents stated how they would listen to their child's discomfort to take breaks during car rides, or postpone moving from a cot to a seat. This highlights the importance of the child as a stakeholder. Not only does the child have a personal preference, it also influences the behaviour of the parent.

Children are not just different in their preferences and behaviour, but also in their size and motor development. They grow and develop rapidly. Even in the small target group from 9-18 months old, children grow about 20cm in length and

go from barely being able to sit to crawling and walking around. Even though every child develops at their own pace, there are guidelines for when a child should develop a certain motor skill. The most important for stroller use is when the child is able to sit unassisted. At this point, the stroller should be transitioned from cot to seat. However, there seems to be some discussion on the child's age for this transition. Retailers advise parents to change at about 6 months, whereas the paediatric occupational therapist states this is too early and should be in the range of 7-9 months. Moreover, the therapist argued current stroller seats are not ergonomic in the sense that they fit the child. The size difference between a 8 month old and a 3 year old is so large that the seat would not fit both ages, especially in the seat depth and footrest length. This presents a possible design opportunity to make the seats better fit children of different ages.

Understanding parents

Just like their children, every parent is different. A lot of aspects are taken into account when buying a stroller. A stroller is also seen as a way of leisure and physical activity for the parent, to be outside and go for a walk. Therefore, there is an increase in demand for all-terrain and robust strollers. On the other hand, they are becoming more compact and portable. Parents are particularly concerned whether the stroller fits in their car.

When parents were asked to evaluate the ergonomics of various strollers, a lot of elements played a role. Besides seat dimensions, such as the depth of the seat and the length of the backrest, parents also paid attention to the size of the wheels and canopy. A deeper seat, bigger cushioning and larger canopy was perceived as more cosy and comfortable, and larger wheels would mean a more robust stroller. These would therefore also be considered more ergonomic for the child. For concept development, it is important to consider how these different elements, which might not directly be related to the child's physical ergonomics, still influence the parent's perception. Perceived comfort plays a role in how parents evaluate ergonomics.

Parents' current knowledge of ergonomics in strollers include the 6 month transition point from cot to seat, and the maximum advised time in a car seat. They also recognise these as guidelines, giving priority to the child's preference and signs of discomfort. The source for their knowledge varied, ranging from Google, to ChatGPT, to other users' experiences and forums. Furthermore, a lot of information is gained in retailer stores. Even though stroller brands rarely advertise ergonomics in stores, it is mentioned to parents in conversation with the employees (e.g. when discussing a seat recline). However, it is important to note the differences between retailer stores on their opinion on what is ergonomic. Babypark and Babydump employees argued for a deeper bowl-like seat, whereas a Prénatal employee argued no significant difference in seat ergonomics. For the final concept to be perceived as ergonomic, it is crucial to know parents' current knowledge, and to learn where they get this information from. This research highlights the importance of retailers as a source for information, and the need to make sure parents receive the correct and consistent advice.

Stroller safety

The literature review showed most injuries and deaths in strollers are a result of falling or asphyxiation (Batra et al., 2015; Fowler et al., 2016). Furthermore, Sudden Infant Death Syndrome (SIDS) emerged as a very important topic regarding safety. Over the years, various guidelines and campaigns have been created to prevent these deaths and injuries. However, these are not always successful. As argued by Michalska et al. (2025), even though parents are aware of safe practices, they are not always adhered to. Also in the observational research, children were often seen without the harness on. Moreover, these campaigns to prevent SIDS and asphyxiation promote sleeping in supine position. This in turn led to fear for a prone position, resulting in needing newer guidelines promoting prone position when awake (Daams, 2024b). For the concept development, extra attention should be given to preventing falling and asphyxiation. The research shows guidelines and campaigns might not always be helpful in achieving this, making it more interesting to reach behaviour change through the design of the product and interaction.

A relevant recent topic in stroller safety is the concern for the vibration experienced by the child and the possible negative effects it could have (Dell'Orto et al., 2025; Trivillin et al., 2025; Sierzputowski et al., 2021; Sun et al., 2022). These studies showed according to adult standards, the child in the stroller could experience extreme discomfort, and even be exposed to a health risk. However, they also highlight the lack of standards for children, which is currently a large limitation in supporting their claims. Although this could be a very important issue in stroller use, the lack of standards make it extremely difficult to evaluate concepts and design decisions. Therefore, this topic has been left out of scope for the project.

Posture in strollers

Limited literature was found on the best posture for a child in a stroller. For sleeping, the best position would be completely flat. When awake, and the child is able to sit unassisted, the best position would be upright with the legs vertical. Daams (2024c) argues against other positions, stating they limit movement freedom or could even lead to spinal deformation. Nevertheless, regardless of posture, the time spent in the stroller should always be limited. As argued by the WHO, restrained time should be no longer than 60min at a time (Health Council of the Netherlands, 2022a). Daams (2024a) states that for motor development variation in posture is key. Similarly, designer of the well-known Tripp Trapp chair, Peter Opsvik, states: "The best sitting posture is always the next." (Peter Opsvik AS et al., n.d.). In the observational studies, children were often observed in all kinds of positions, from sitting on the edge of the seat to sitting sideways, or

slouching with their legs hanging off the sides. This research shows how even though there might be a singular best position for the child to be in, a child should not be restrained in one for long periods. Varying in posture is more important for development of both their mind and muscle. As observed, this behaviour is already performed automatically by children.

Situations were observed where the child was being carried in the arms of a parent or in a baby carrier, while the stroller was empty. Furthermore, in the use case at Rotterdam Zoo, children were often seen out of the stroller. To be able to look at the animals, they were either walking around themselves, or being carried by the parent. To facilitate this, the bumper bar is able to be detached on only one side. Particularly for these use cases, this highlights the importance of being able to quickly transition in and out of the stroller.

Delay in motor development

The research showed a growing concern for a delay in children's motor development. The term container baby syndrome is used to refer to the overuse of infant sitting devices (Michalska et al., 2023). The research by Siddicky et al. (2020) showed how these devices limit the child's motor activity by measuring EMG signals. As a result, they state the overuse of strollers could be a cause for concern. Additionally, the retailer visits showed there is an increasing demand for 3in1 strollers, making it possible to use the car seat on the stroller frame. This even prolongs the amount of time spent in the car seat, which offers even less movement freedom than the stroller seat.

In grey literature, the negative effects of this lack of movement freedom include children learning to walk later, being slower and less agile, falling more often, or developing insecurities or aversion for physical activity (Cotterink, 2022). Others even argue an increase in obesity, injuries, and neck & back pain in young children, due to this lack of movement (Van der Velpen & Van Loon (2024). The experts interviewed similarly stated how motor development has declined, especially due to the overuse of car seats. Children have a natural urge to move, and this movement is needed to develop motor skills and stimulate the brain.

However, it is important to note the Health Council of the Netherlands (2022a, 2022b) did not find enough evidence that physical activity for children ages 0-4 promotes motor development. Yet, based on recommendations of the WHO and an expert panel, they still advise daily physical activity. Currently parents do not always see a stroller as limiting their child's physical activity (Birken et al., 2015). They do recognise the overuse of the stroller as bad, but it also offers transportation to another place for activity.

Even though there seems to be a lack of evidence on the effect of physical activity on motor development, the amount of sources and experts arguing a delay in motor development is a cause for concern. This creates a design opportunity to investigate how sitting devices could offer movement freedom to facilitate the child's motor development.



3. Design Opportunities

This chapter presents how the research findings were translated into a design vision and concept brief, through iterations of sketches and evaluations.

3.1 Approach

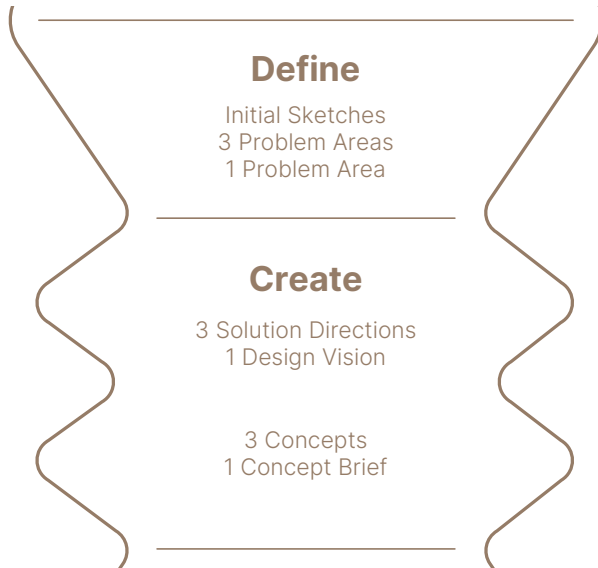


Figure 3.1: Chapter 3 Approach

To refer back to the project approach shown in Chapter 1.2, Figure 3.1 specifically shows the steps for this section. It depicts quite a flexible process with multiple diverging and converging steps.

First of all, during the research phase, multiple brainstorms were held to document thoughts and possible idea directions inspired by the research (seen in Appendix F). These ideas were examined through the PMI method (plus, minus, interesting), to note both advantages and disadvantages, and see their potential.

The insights from the research and the inspiration gained from the brainstorms were then combined and translated into 3 distinct problem areas, of which the one concerning a delay in children's motor development was determined to be most promising.



To explore this problem area, a diverging step was taken by dividing it into three different stages of the child's life. This was based on the development of two important motor skills: independent sitting and walking.



Solutions were proposed on how to possibly improve motor development for each specific stage. The overall solution directions were evaluated, and the most promising was chosen.



As a converging step, a design vision was formed, stating the main goal and underlying design conflict.



This design vision sparked a new series of ideation sessions, which were represented in a c-box.



Based on the c-box evaluation, three ideas were chosen to develop further in conceptualisation.



Evaluating the three concepts led to new insights and a more specific approach, resulting in a concept brief describing the design of a stroller harness.

3.2 Problem Areas

The research insights and brainstorm outcomes were combined and translated into three different problem areas, which are presented and elaborated through posters (*growing children* and *futures* are shown in Appendix G).

- *Growing Children*, concerning the rapid growth in children and mentioning how currently young infants and old toddlers should both fit in the same stroller seat, even though there are massive differences between these groups.
- *Moving Children*, stating a growing concern for a decline in children’s motor development, due to lack of movement and the overuse of sitting devices.
- *Futures*, building on past and current trends to present possible future visions for the stroller industry.

To determine the most promising direction, the areas were evaluated based on research relevance, value to Joolz, potential user impact, and feasibility for the project. A score of 1-5 was given for each criterion, shown in Figure 3.2. Appendix H shows a more in depth overview of the reasoning behind the scores.

	Growing Children	Moving Children	Futures
Research Alignment	3	4	2
Value to Joolz	2	4	3
Potential User Impact	4	4	2
Project Feasibility	4	3	3

Figure 3.2: Evaluation Matrix Problem Areas

Based on this evaluation, Moving Children (Figure 3.3) was chosen to be the most promising problem area to focus on in this project. This area has the best alignment with the research, could have a large potential impact on the child's development, and can provide a unique perspective for Joolz.

In presenting this area at Joolz, it was found to be the most interesting option. It's a more creative problem, and could therefore lead to more unique results or innovative designs. Nevertheless, the other identified areas are still relevant and provide design opportunities for further exploration beyond the scope of this project.

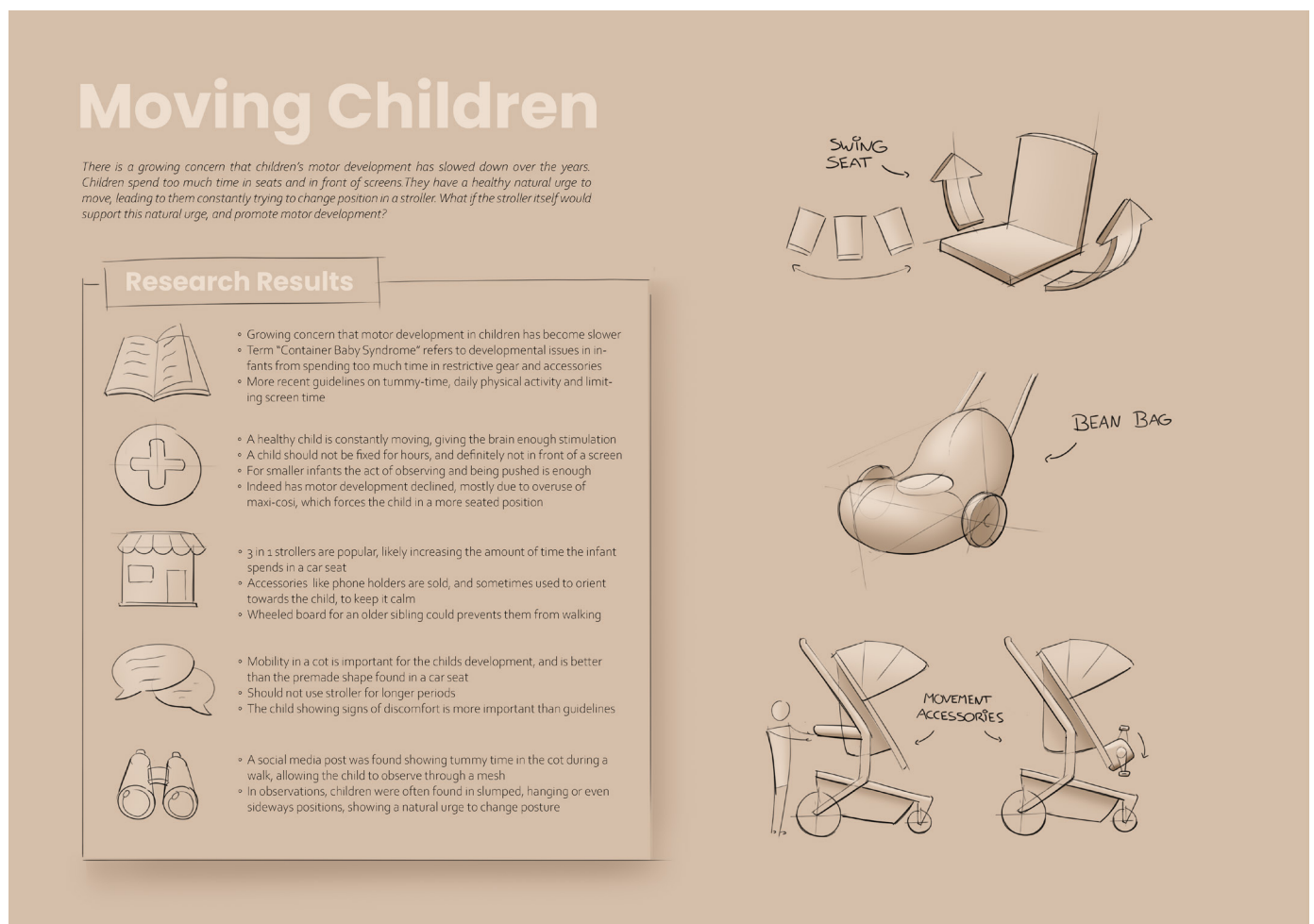


Figure 3.3: Chosen problem area: Moving Children

3.3 Solution Directions

Three Stages

To help develop solutions for the chosen problem area, three stages in the child’s life were defined in the context of strollers (Figure 3.4). Stage 1 and Stage 2 were based on the transition from a cot to a seat. As explained in Chapter 2.6, at around 9 months a child would be fully developed to be able to sit independently, and ready to sit upright in a stroller seat. The transition from the second to the third stage was based on the child starting to walk, usually at around 18 months. At this age, walking would be the best way to develop the muscles, but the stroller is still needed for rest, safety or convenience.

	Stroller Context	Age
Stage 1	In Cot 	0-9 months
	In Seat 	9-18 months
Stage 3	In and out of stroller 	18-48 months

Figure 3.4: Three Stages

Exploring Solutions

Stage 1 - Carry Over

This ideation addresses the problem of container baby syndrome (Figure 3.5). By making it easier for the parent to take their child out, they might be more inclined to move their child from the container to a flat surface, even when the child is asleep. This would prevent the child from staying too long in a fixed position in the car seat or in the limited space of a cot, and have more movement freedom.

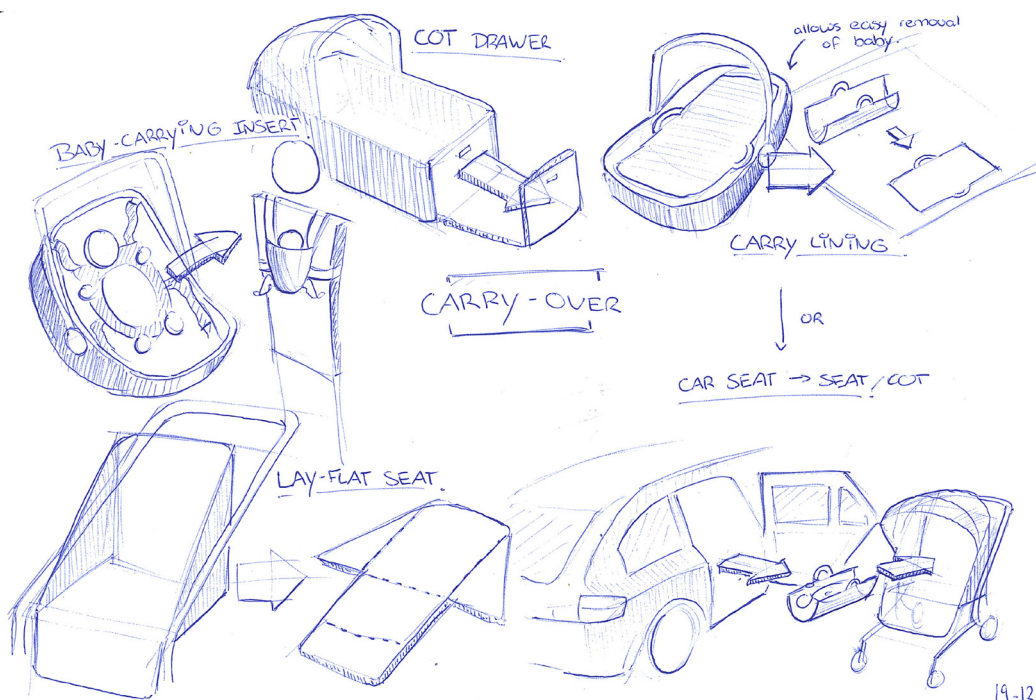


Figure 3.5: Solution direction: Carry-over

Stage 2 - Giving Space

Compared to the cot in stage 1, a stroller seat in stage 2 is more restricting for the child. Figure 3.6 shows an exploration of solutions to give more movement freedom in this stage. Due to the very limited lifetime of the cot before transitioning to a seat, it also explores possibilities of extending this lifetime.

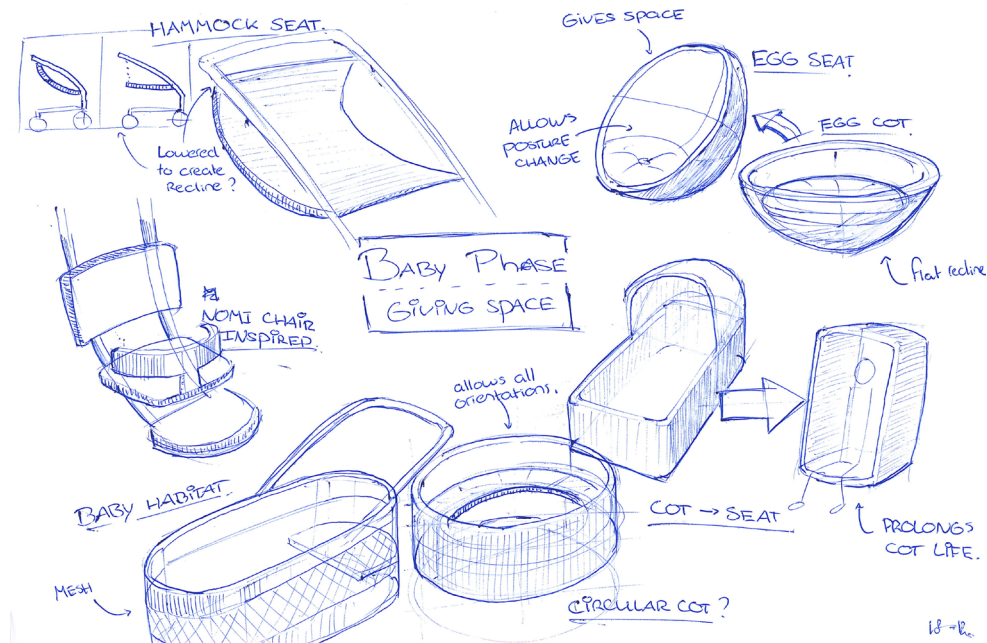


Figure 3.6: Solution direction: Giving Space

Stage 3 - Active vs. Rest

In the final stage, the best way to motor development is to walk. However, the stroller is still needed to provide moments of rest. This ideation explores how a stroller could facilitate and encourage this transition between an active and rest state (Figure 3.7).

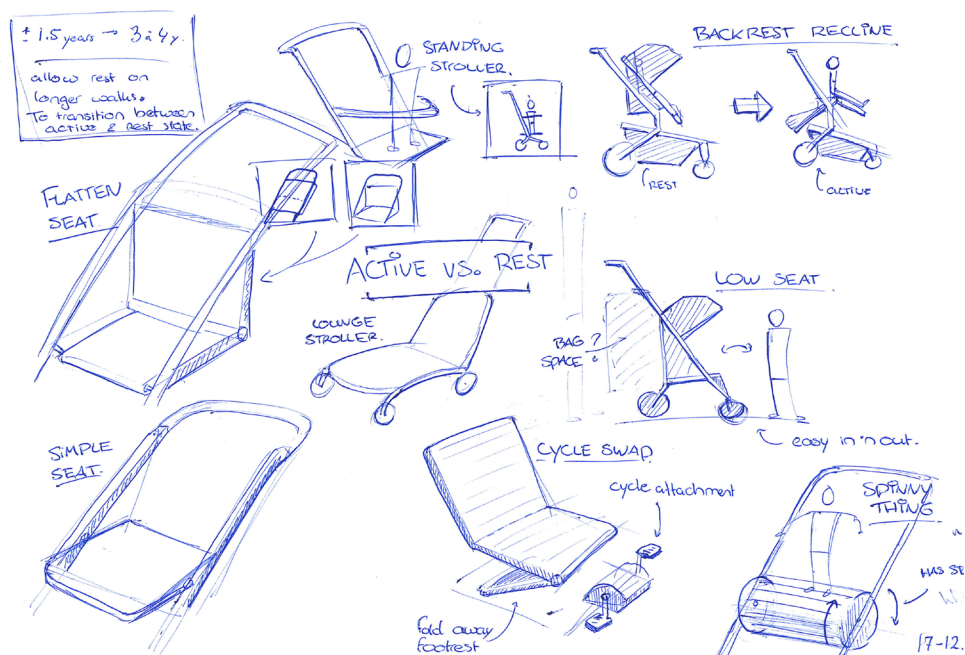


Figure 3.7: Solution direction: Active vs. Rest

Evaluation

Giving Space emerged as the most promising direction, due to the strong connection with the research insights and interesting trade-off between safety and movement freedom. The biggest disadvantage for Carry Over was the realisation that a very similar product already exists. For Active vs. Rest, the main weakness was the lack of fit with the research, which focuses more on infants. The PMI method was chosen to qualitatively evaluate the different solution directions (shown in Figure 3.8). Instead of evaluating every individual idea, the directions were analysed as a whole.

	Plus	Minus	Interesting
Carry Over	• Addresses a clear problem and situation • Provides a more ergonomic experience for parent • Indirectly could enhance motor development of child, by easy transfer to flat surfaces for play	• Already exists • Could make it even easier to move child from seating device to seating device, further creating container baby syndrome	• Explores more of behaviour change in the parent
Giving Space	• Improves motor development by giving space for the younger child to move • Extending cot life could prove to be more sustainable.	• Likely will be a big device, taking up a lot of space, and could be heavier and less portable • Impact of these small movements unclear compared to flat on the floor	• Interesting is the trade-off between giving space and still providing enough safety and restrictions • Could Replace the Cot entirely, prolonging the life of it until e.g. 1.5 years instead of 6-9 months • It could have a bit more of a societal impact, changing the way we currently see strollers
Active vs. Rest	• Allows and promotes best form of movement → walking, whilst still providing a place for rest. • Promotes independence of child, allows them to decide	• Less grounded in literature • Would be difficult to compete with the already simplicity of a buggy • Stroller itself is not 'bad' as it allows transport to a place of activity. The bad comes from sitting too long • 'Easy in' could also cause the child to actually sit more often, as it is easier to do so.	• Could also be in the form of smaller or more flexible stroller designs, just made as a portable place for short rest.

Figure 3.8: Solution directions Evaluation

3.4 Design Vision

Goal

The research showed how children's motor development has slowed over the years. As a result, children learn to walk later, are slower and less agile, and fall more often. Others argued an increase in obesity and neck and back pain. This is likely related to the overuse of sitting devices, as Carson et al., (2022) stated, higher restrained time for developing infants was associated with less advanced gross motor development.

Children have a natural urge to move and need it to both stimulate their muscles and brain, and can be observed taking all sorts of postures in a stroller. However, the current strollers do not facilitate this, and restrict their movement freedom. Based on the stages defined in Chapter 3.3 and their stroller context, stage 2 would be the most promising target group for enhanced movement freedom.

Therefore the design goal is to:

Improve the motor development of children between the ages of 9 to 18 months by giving space for posture change in a stroller system.

Design Tension

The underlying design conflict for this goal is a trade-off between safety, comfort, and mobility (Figure 3.9). How could a stroller allow children between 9 and 18 months to move, without compromising safety or comfort?

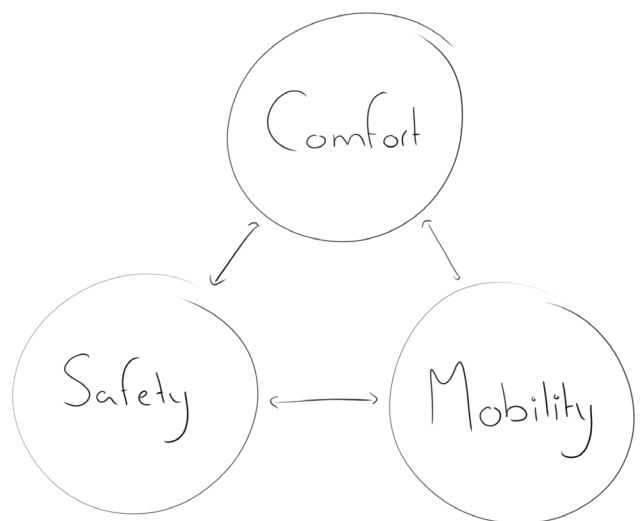


Figure 3.9: Design Tension

3.5 Developing Concepts

Ideation

To inspire the ideation, two mindmaps were made (see Appendix I). The maps revolved around the interpretations of comfort and safety. For each the question was asked: What if it was interpreted as...? This led to a few interesting insights:

- Safety can be categorised into physical, emotional, social and digital safety.
- In the context of strollers, physical safety would be most important in keeping the child away from harm.
- However, perceived danger (emotional) and trust (social) are also crucial, as the parent would base their stroller decision on the perceived safety of their child, and would have to trust the company or standards that it is safe.
- Comfort can be categorised in physical and emotional comfort.
- Comfort is highly related to the human senses
- A feeling of safety could also be a form of comfort, they can not be seen separately.
- Both being enclosed (like a blanket) as well as being free (unbuckling a seatbelt) can provide a feeling of comfort.

Currently, stroller seats make use of a harness to guarantee safety, most common being a 5-point harness. To facilitate more interesting ideas, a thought experiment was done to image a stroller without a harness, providing safety in a different way (see Figure 3.10). To introduce behaviour and movement, a chart was made (also seen in Appendix I) plotting these harnesses against observed postures.

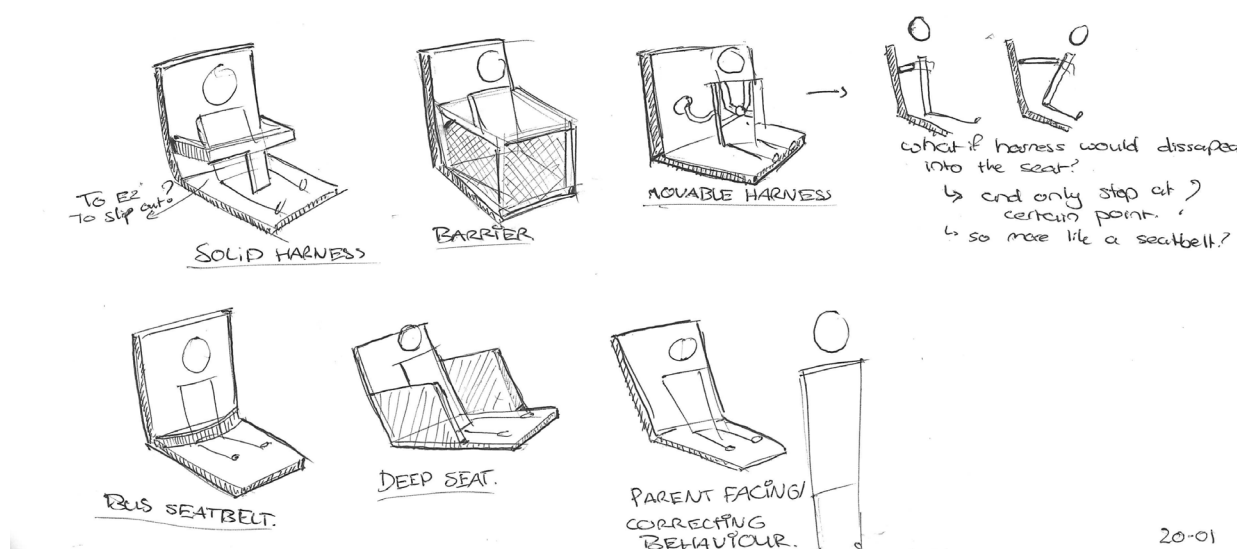


Figure 3.10: Harness Thought Experiment

Using the mindmaps and chart as a source of inspiration, ideas were generated and put in a c-box (Figure 3.11). The ideas include designs of various types of seats, meant to give more movement freedom. Furthermore, some designs include a variation of a movable harness, to facilitate this movement, whilst still providing safety. In the c-box, mobility is plotted against safety. The ideas in the upper right quadrant would be most promising, as they offer benefits in both areas.

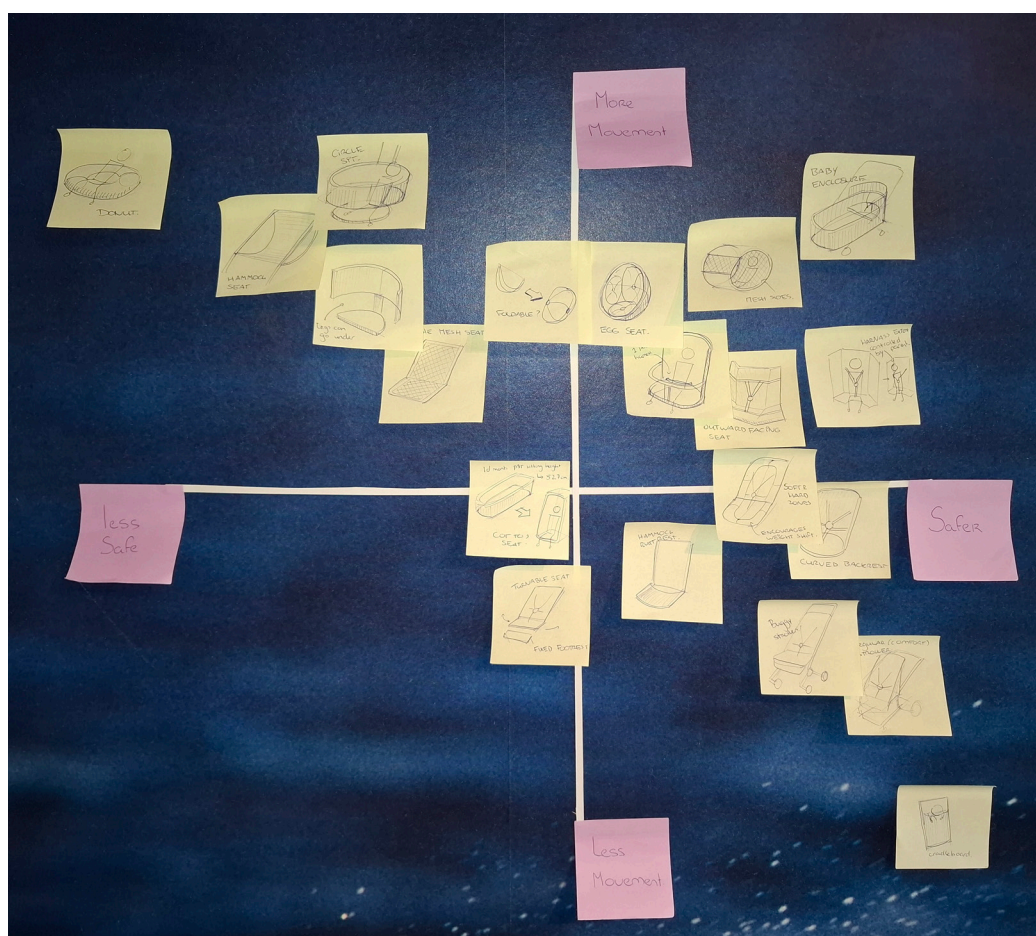


Figure 3.11: Idea C-box

Conceptualisation

Following the ideation phase, three distinct concepts were developed through sprints of evaluations and prototypes. All three concept make use of a clever combination of offering both mobility and safety. By taking inspiration from existing products, and applying them to the context of strollers, the resulting designs are novel, yet still feel familiar. The prototyping sprints can be seen in Appendix J.

Concept 1: Cargo? Go where?

The first concept presented in Figure 3.12 draws inspiration from cargo bikes and animal transportation. The idea is similar to a cargo bike, but meant for walking. Parents partly see their stroller as a way for engaging in some physical activity, to go on walks and be outside with their child. But why should the child not be able to move and explore? This concept allows the child to sit, lie, and explore, within a safely enclosed environment.

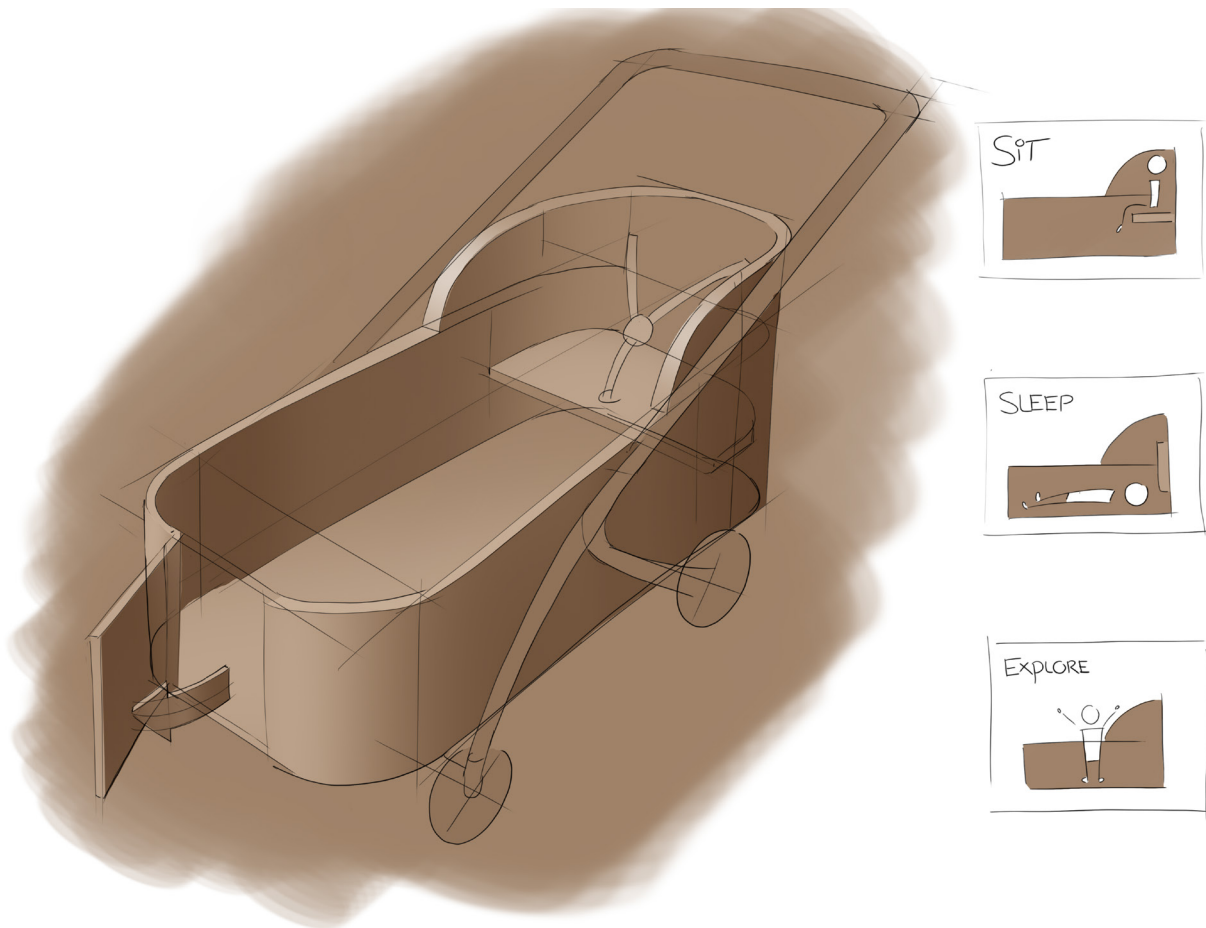


Figure 3.12: Concept 1

- Space for movement and exploration in a safe environment.
- P**
- Combination of existing products, cargo bike & carry cot, creating something familiar.
 - Both parent and child get to explore at the same time.
- M**
- Substantial size, going against current trend of compact strollers.
 - Due to size, moveability, foldability and storage of the stroller will be negatively affected.
 - Enclosure is close to the ground, possibly making interaction with their child more difficult.
- I**
- Due to size, it could allow seating for a second or even third child.
 - Compliance wise, the low centre of gravity would make the stroller less likely to tip over, which could make a harness redundant. However, a harness would likely still be necessary for rougher terrain.

Concept 2: Unleash the Beast

The second concept (Figure 3.13) works similarly to a car seatbelt. The child is given freedom to move, until a moment of impact. At this moment, instead of just a brake, the seatbelt will automatically retract, pulling the child back into the seat. First a mechanism similar to a dog leash was considered. However, this would place too much responsibility and pressure on the parent, and allow more room for user error.

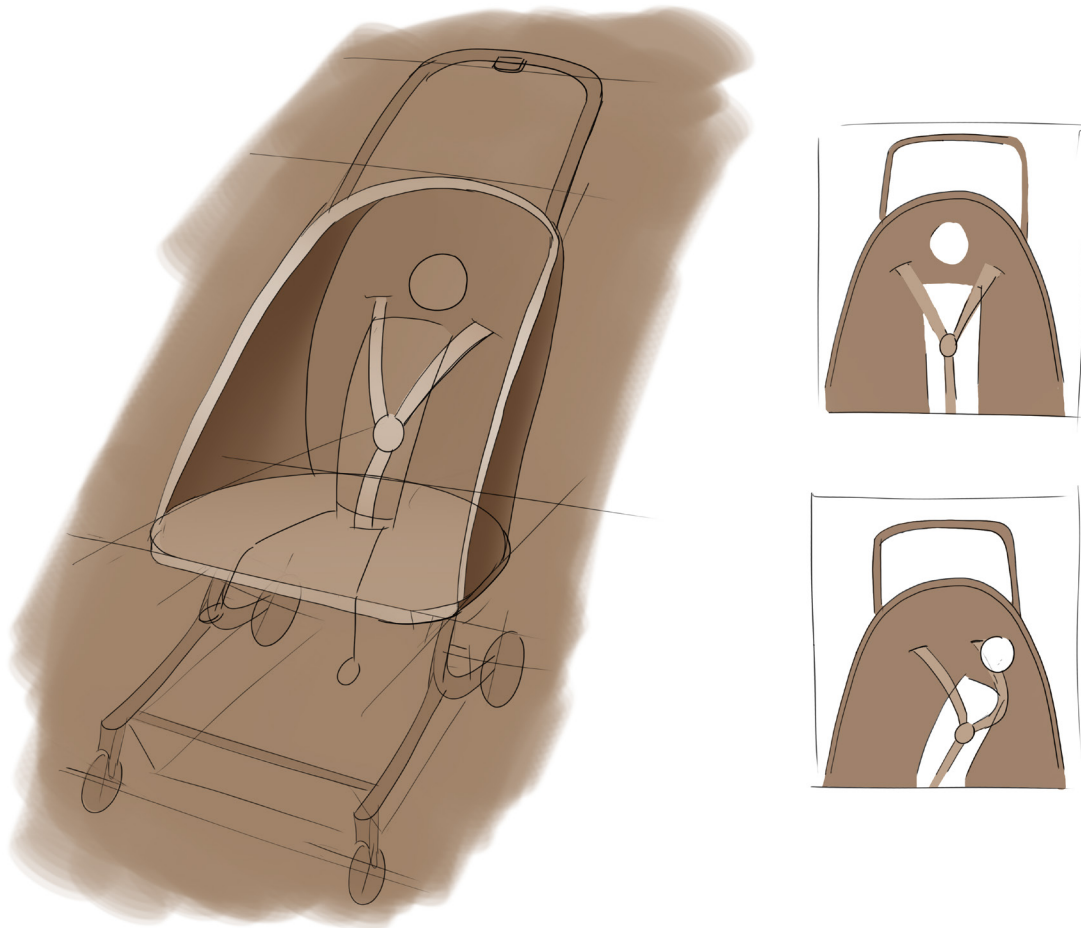


Figure 3.13: Concept 2

- P** • Allows movement freedom, but ensures safety only when needed.
- Making use of a wider seat will allow more movement freedom than current seats.
- A product similar to a seatbelt could more quickly be perceived as safe.
- M** • A loose harness might create risks for strangulation.
- When leaning sideways, the harness might be uncomfortable in the neck, similar to current experiences with seatbelts.
- A wider seat might encourage them more to start hanging in their seat.
- I** • Would take inspiration from existing seatbelt mechanisms, but would require an additional retracting function, in reaction to an impact or large incline.

Concept 3: Hang in There

The final concept (Figure 3.14) draws inspiration from a swing chair and a climbing or safety harness. Just like a hanging chair, it allows the user to take different kinds of positions, naturally supporting the body. The harness is movable to account for this change in posture, whilst still providing safety. Another advantage of this shape is that it could potentially replace the cot in the early infant stages.

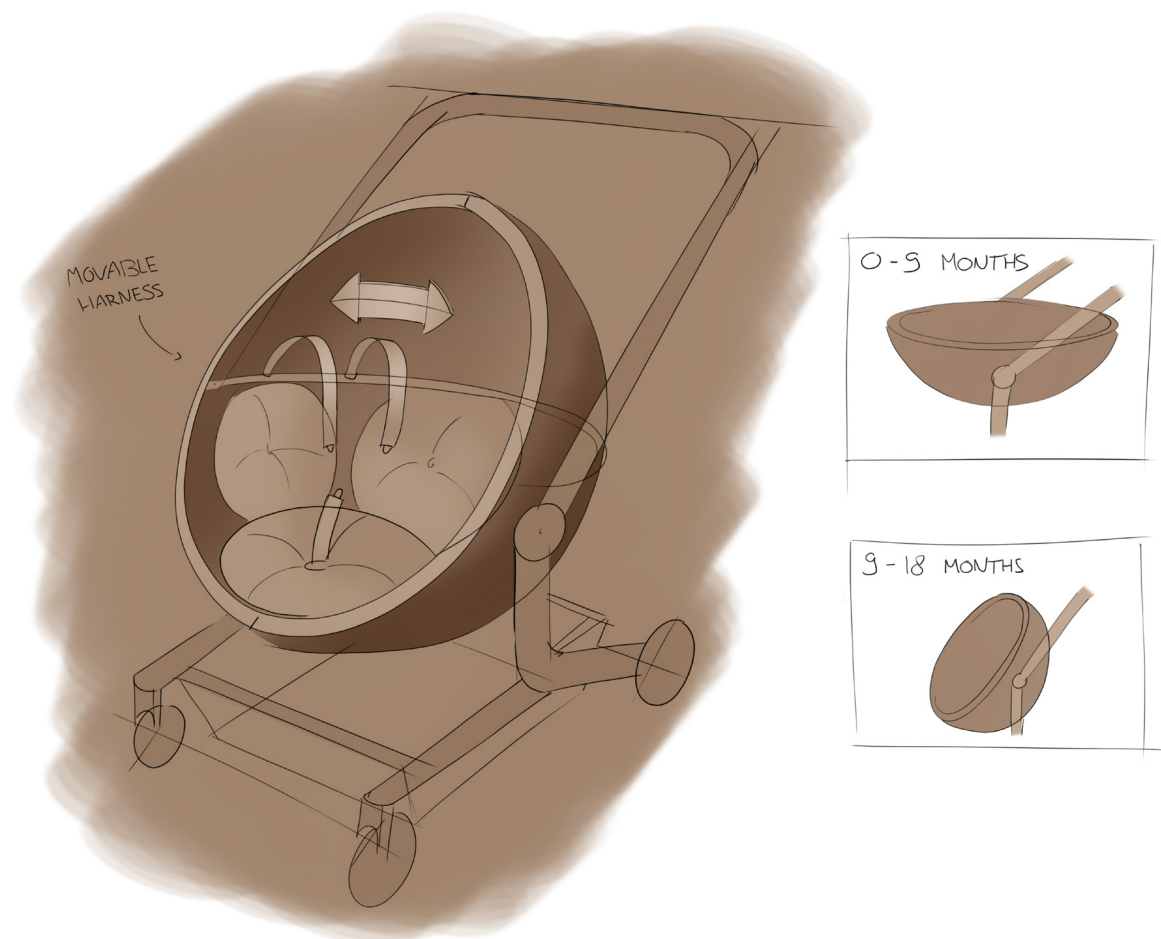


Figure 3.14: Concept 3

- P**
 - Design will allow various different postures, such as sideways sitting.
 - The sliding mechanism will allow the child to move, whilst ensuring the back is still kept against the backrest and the child can't move out of the seat.
- M**
 - Sliding mechanism might pose compliance issues, increasing the chances for fingers getting trapped or stuck.
 - A movable harness would be less reliable for safety, and more prone to wear.
 - Enclosure is close to the ground, possibly making interaction with their child more difficult.
- I**
 - The enclosed shape might be perceived as comfortable, cosy or safe.
 - The seat could be used as a cot, if there was a flat surface for the baby to lay on. This would extend the lifespan compared to the current cot.

Evaluation

All three concepts make use of a clever combination of offering both mobility as well as safety. As seen in Appendix J, for each design, a low fidelity prototype was made to help answer the main uncertainties. However, given the time frame of the project, the concepts could not be developed further in parallel, and a decision had to be made.

Evaluating the concepts turned out to be quite complicated, as their main elements could easily be interchanged. For example, the seatbelt from concept 2 could also be used in concept 3, or a movable harness as in concept 3 could be used in the large space of concept 1. They are all composed of two main elements, a stroller body which gives more movement space, and a harness providing safety within this movement space. This harness is what makes the concept interesting and unique.

Imagining a bigger type of stroller is simple, yet designing one is not. It takes years and multiple teams to design and develop a new type of stroller platform. Due to the nature of this project, and the added value a unique harness brings to the concepts, this thesis focuses on the design of a universal harness that can be applied to various seats or stroller bodies.

However, as seen in concept 2 and 3, merely introducing mobility into current harnesses through a sliding or seatbelt mechanism would also give more space for the child to slide out, or even become entangled in the straps. Therefore, the entire interaction of using a harness, for both parent and child, should be reconsidered.

3.6 Concept Brief

The concept brief shows the specific focus on the harness to conclude Chapter 3, and define the scope for Chapter 4. It consists of three parts, describing the current state, the product intervention, and the desired outcome and impact on the stakeholders.

Present State

As defined in the design vision in Chapter 3.4, the research findings showed concerns for slower motor development in children, negatively affecting both their physical and mental health. To provide safety, current harnesses restrict them in sitting devices and inhibit their natural urge to move. However, safety can also be guaranteed in different ways, without movement restriction.

An overview was made of current products, including harnesses, connections, child safety products and various child sitting devices (Figure 3.15). This is used as both an overview of the current context designed for and as a source of inspiration.



Figure 3.15: Existing products

Intervention

Introducing movement freedom into current harnesses leads to safety concerns regarding falling and entanglement, as seen in concept 2 and 3. Therefore, the entire interaction of using a harness, for both parent and child, is reconsidered. Instead of placing the child in the stroller, and then having to connect all straps, the interaction is moved to outside the stroller (Figure 3.16).

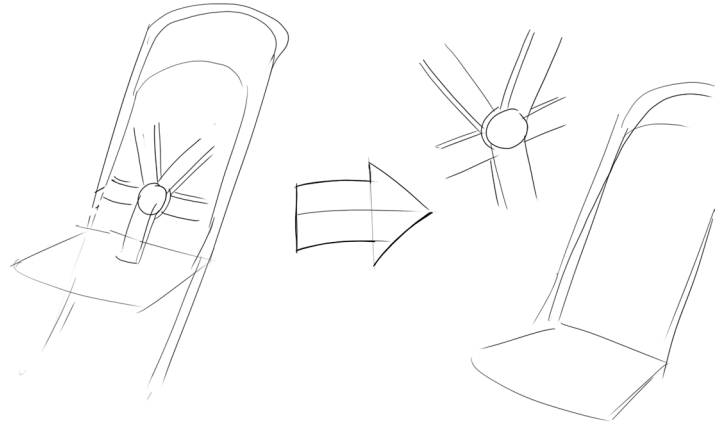


Figure 3.16: Separating the harness

Through this fundamental change, the harness allows movement freedom, without the child being able to slip out or get entangled. Furthermore, it makes strapping in the child easier, possibly making the parent more inclined to use the harness. And it allows an easy in and out of the stroller, especially useful when at the park or the zoo.

The moodboard shown in Figure 3.17 was created to depict the feeling of comfort and safety the intervention should convey. To fit Joolz' current portfolio, attention was given to their current design language and colour use (see also Chapter 2.7).



Figure 3.17: Moodboard and Joolz colours

Desired State

The harness should offer movement freedom, without compromising safety or comfort. Such a harness would encourage greater child-initiated movement compared to a conventional one, supporting their natural urge to move. This movement freedom will facilitate muscle activation and benefit their overall motor development.

Figure 3.18 depicts the potential impact the intervention could have on the stakeholders. To maximise this impact, seating devices beyond strollers should be considered, extending the use to e.g. cargo bikes, highchairs or car seats. However, for the scope of this project, the context of strollers is used.

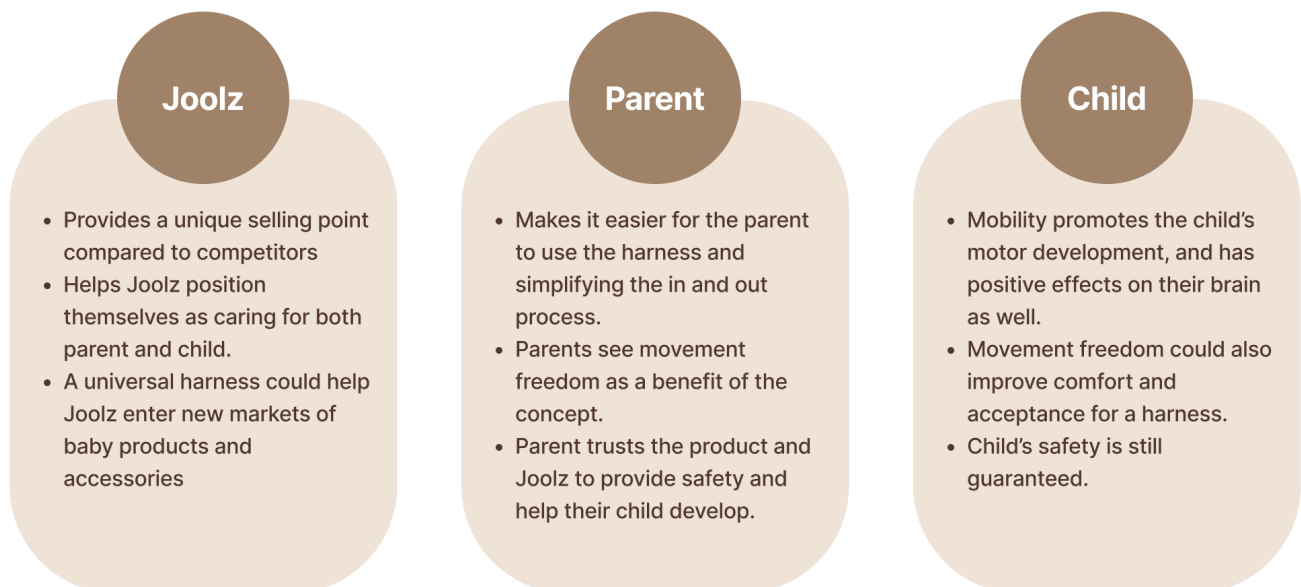


Figure 3.18: Potential impact on stakeholders



4. Development

This chapter shows the development process for the final concept. This includes an iterative process of prototyping and evaluating.

4.1 Requirements

Design Challenges

Based on the research and the concept brief, five main design challenges were defined (see Figure 4.1). These state what the product needs to do, and their importance to the design problem. Moreover, for each challenge, the main question to be answered was noted.

Job to be done	Reason	Puzzle
1. Give space for movement...	to increase muscle activity while seated and improve overall motor development.	How much space is necessary for actual development, or for the feeling of freedom for the child?
2. Fits snugly around the body...	to prevent the child from being able to slide out, even without crotch restraint.	How tight is enough, yet still comfortable? How to make adjustable for ages and sizes?
3. Prevents child from falling out...	to conform to existing norms for stroller safety and to be perceived as safe by the parent.	How to give enough space, yet still ensure the child stays in the seat in case of an accident.
4. Makes strapping in child easy...	to appeal to the busy parent, making their life easier.	How would parents perceive a harness, which can be put on while not in the stroller? How to make interaction as easy or preferably easier than current situation? How difficult is the current situation?
5. Looks child-like and fits the stroller...	to appeal to the parent buying it, without associating the product to animals or robustness (seen in military or climbing gear)	How to give the product a child-like appearance? What would appeal to the parent, and fit their existing image of baby products?

Figure 4.1: Design Challenges

Design Factors

To show how the jobs to be done relate to the design, Figure 4.2 shows an overview of all the relevant design factors influencing the jobs to be done. These should be considered throughout the development phase.

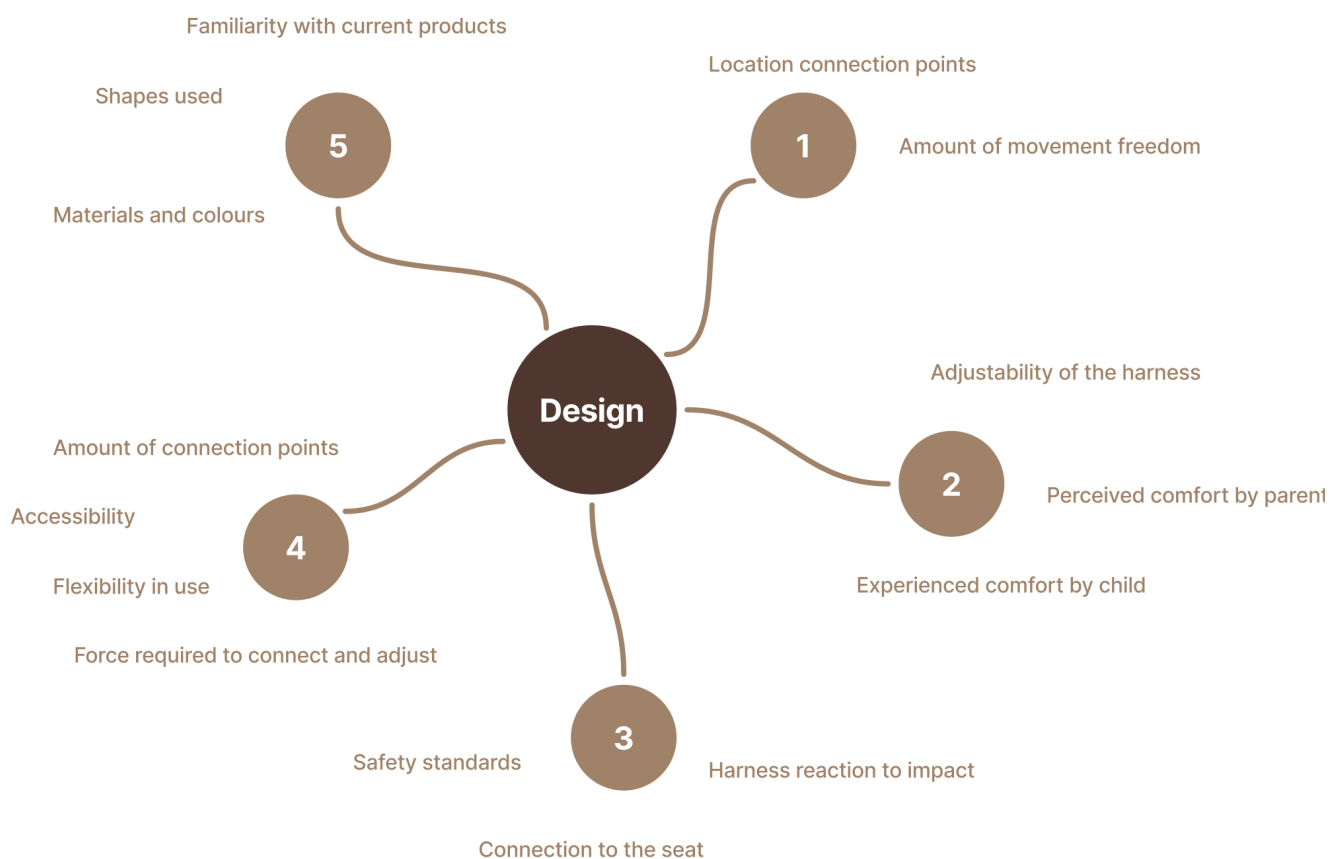


Figure 4.2: Design Factors

4.2 Design Sprint

A design sprint was done to gain a better understanding development process and difficulties and challenges I might encounter. It very quickly gives a complete understanding of the context and gives momentum to the project. This meant going through all the steps from research to evaluation in a single day (the complete overview can be found in Appendix K).

Ideation

After a quick field research, consisting of taking pictures of bike and cargo-bike harnesses, and online research, I moved on to ideation. The design problem revolves around two main topics: the connection of the harness to the seat, and the design of the harness. Both topics were explored in depth to determine valuable directions, techniques, and develop an better understanding of the design challenges. Figure 4.4 shows the an ideation session on the connections, and Figure 4.3 shows a brainstorm on the harness design.

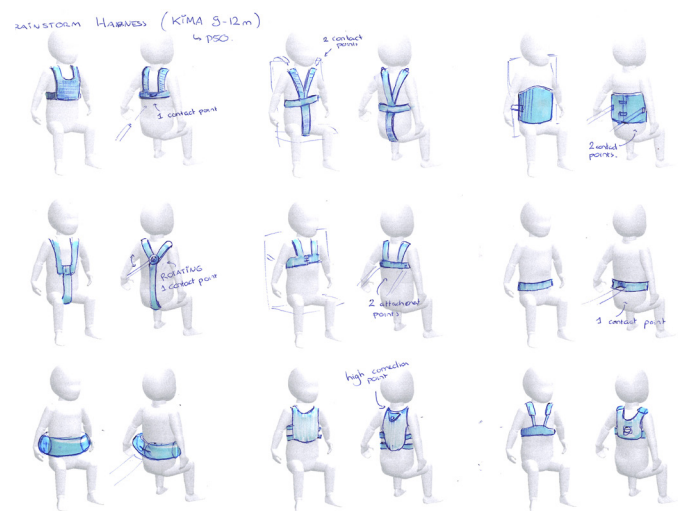


Figure 4.3: Harness Design Ideation

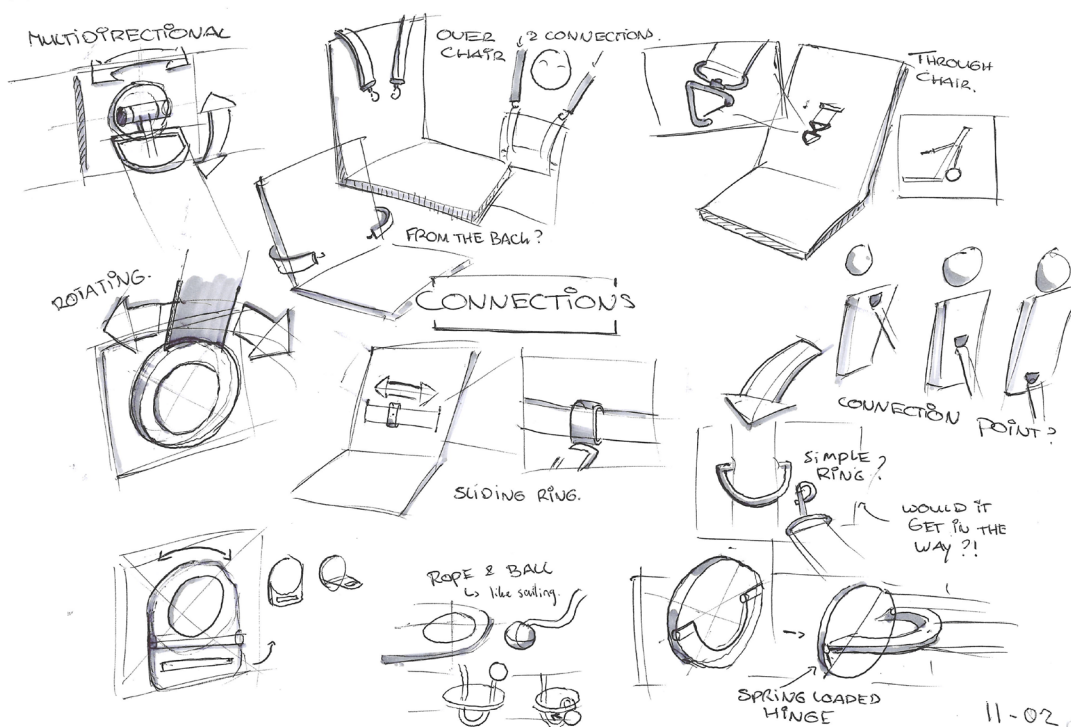


Figure 4.4: Harness Connections Ideation

Prototyping

A prototype was made to facilitate discussion and the evaluation process (Figure 4.5). For this prototype, the weighted doll was used, and by using materials available in the Joolz workshop.



Figure 4.5: Prototyping results from design sprint

Evaluation

- P**
 - Small, lightweight and portable
 - Tight fit around the body
 - Rotating clip allows movement in various directions
 - Only 1 buckle and 1 connection point makes use easy
- M**
 - Straps and buckles relatively big compared to the child
 - Connection in the back is likely uncomfortable for child
 - Currently not adjustable
 - Perceived as cheap and associated with dogs or military
- I**
 - Currently not adjustable, would different sizes be an option?
 - Are the associations with military or animals caused by shape, colour, or perhaps location on the body?

4.3 Nine Months Fair

The Nine Months Fair is a tradeshow organised in the RAI Amsterdam (see Figures 4.6 and 4.7). With tens of thousands visitors, it is a significant event for baby and maternity products. Therefore, it is an amazing opportunity to see new innovations and reach (expecting) parents to ask questions and gather valuable concept feedback. Fortunately, through Joolz, I was able to attend the fair for a day.



Figure 4.6: Nine Months Fair Entrance



Figure 4.7: Nine Months Fair Booth

Preparation

The goal of my visit to the 9 month fair was to gain feedback on my harness design proposal from parents. Therefore an interview setup was prepared (Appendix C), with calculated flexibility in the questions to zoom in on potentially valuable comments. For effective communication, a new visual and complementary prototype were also prepared.

Concept Visual

The visual shown in Figure 4.8 was printed and brought to the fair, to help parents get a better picture of the new interaction. It could help clarify what I meant by having the harness be separate from the stroller. Due to competitive advantage, the visual would not be shown to other companies.

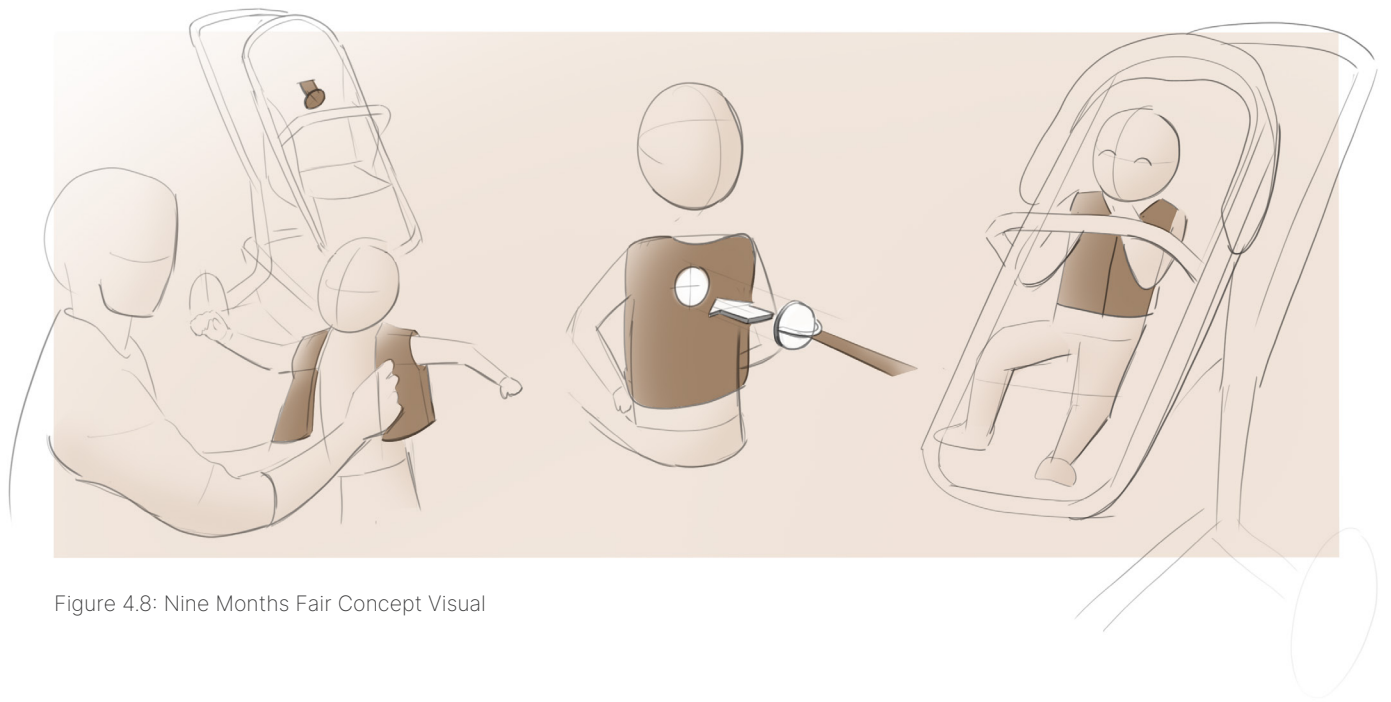


Figure 4.8: Nine Months Fair Concept Visual

Prototype

To actually have something tangible to show the parents, a new prototype was made (Figure 4.9). This was meant to be shown to parents in interviews. To prevent association with Joolz for bias or influencing brand image, the interviews were performed all over the fair, walking around in regular clothes. To improve compared to the last

prototype, more attention was given to size and appearance. A larger more refined connection could make it seem more luxurious than the commonly found hooks or buckles. Furthermore, by making use of a vest (a common infant garment) it would be less likely to be perceived as an animal accessory.



Figure 4.9: Prototyping results for 9 months fair, front and back

The prototype consists of a vest (originally a tote bag) and a 3D-printed connection, attached through handsewing. The vest was made using the sleeveless vest tutorial by Romy Stan Zak (2024). Based on her pattern for 3 to 10 year olds, and measurements taken in Solidworks from the KIMA model, a rough estimate was made for a vest pattern for a 9-18 month old (See Figure 4.10). The parts were then machine sewn together.



Figure 4.10: Nine Months Fair Prototype, pattern and cutouts

The 3D printed connection (Figure 4.11) was inspired by the circular joint made by 3DBlacksmith (2026). It consists of four parts, and allows multidirectional rotation. This allows the child to move comfortably in different directions. The hinge will allow the part to be pressed flat instead of sticking out when the child is leaning against the backrest, improving the comfort.

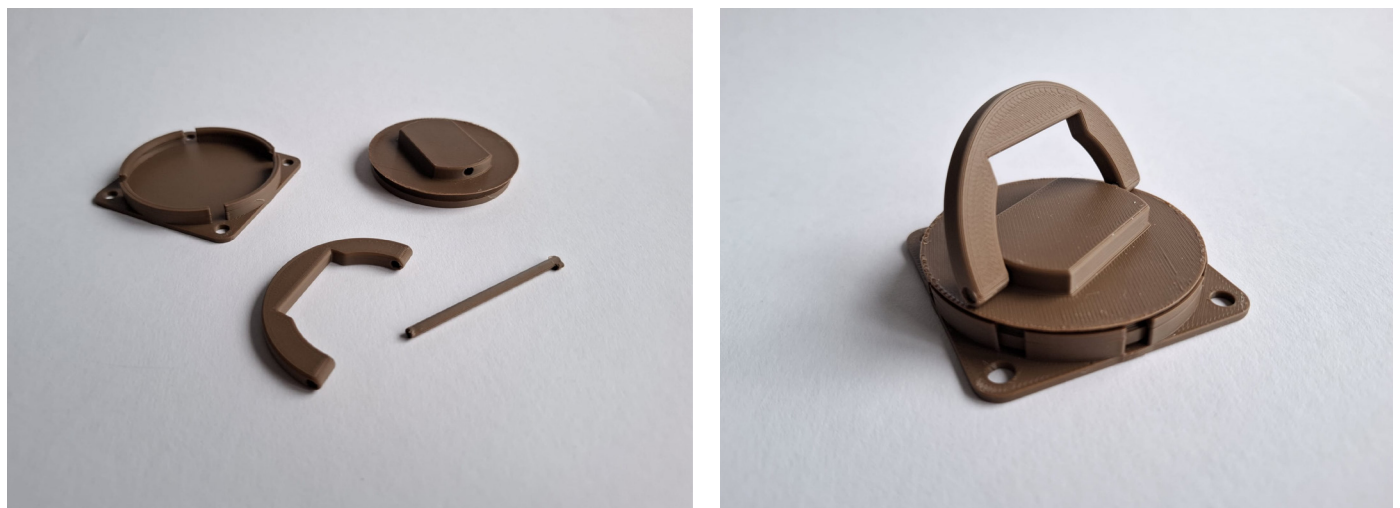


Figure 4.11: Nine Months Fair Prototype 3D print, components and assembled

Results

Interviews were conducted with six duos with at least one stroller with a seat, the complete overview of the results can be seen in Appendix L. Every duo included at least one parent, accompanied by their partner, mother or friend. As a secondary research opportunity, the fair was explored for harness products, paying special attention to novel solutions in other product categories, like bouncers. The results for these observations are shown in Appendix M. The answers given by the parents have been analysed, summarised and categorised into three topics, relating to the current use, the concept, and other comments.

Current Use

In the current use, the parents often find adjusting the straps to be difficult or tedious, especially when a winter jacket is taken off or put on. Some found 5 separate points convenient in allowing their own configuration, others found it annoying to have 5 different points. Parents with older children (2 < years) found it annoying that the child would not cooperate, or would unbuckle themselves, leading them to not using the harness. This brings me to the variety of ways

the 5 point harness was used. Some used all 5, stating the safety it provided. Others used 3 of the 5, either without the shoulder, or without the side restraints, and the two with older children did not use it at all (Figure 4.12). The reason for this behaviour was either related to the child's unbuckling themselves, or the parent wanting to give some movement freedom. These parents also did not mind their child hanging in the seat instead of sitting 'properly'.

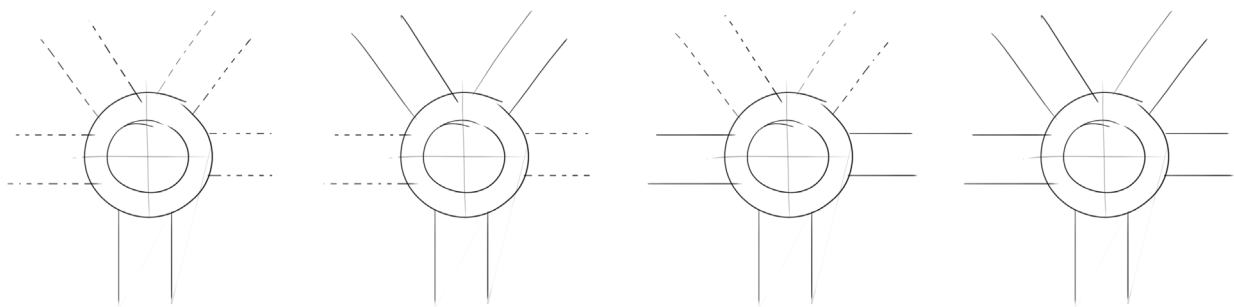


Figure 4.12: Observed use of 5 point harness (dashed = disconnected)

Concept

By multiple parents, movement freedom was seen as an advantage of the concept. Furthermore, no participant would perceive it as unsafe, partially because of their trust in safety standards. One concern raised was the lack of neck and head support. The vest was for some too much, being concerned the child would feel trapped or they argued a lack of breathability in warmer environments. They also raised questions

for the adjustability regarding size or clothing underneath. The connection on the back was perceived as uncomfortable, especially after observing the prototype, due to its size and sharp edges. Finally, some argued the connection on the back would be difficult for the parent to reach, and were afraid of not being able to check the connection due to the obstructed vision.

Other

When asked why some parents did not use the full harness or found movement freedom to be an advantage of the concept, they answered that a child should be able to move to play, eat and interact. Furthermore, one parent stated how pitiful she found the children sitting in a car seat

(on a stroller) all day at the fair. The final topic discussed was the possibility to have the harness universal for different brands. One parent argued you are usually loyal/stuck to one brand, so they would imagine it would be nice to use the harness, even if it is by a different brand.

Takeaways 4.3

- » Currently, 5-point stroller harnesses are used in a variety of ways, often to give the child some movement freedom.
- » Parents find movement freedom important for the child to play, eat and interact.
- » Movement freedom was seen as an advantage of the concept.
- » Concerns were raised for the adjustability and breathability of the prototype.
- » A connection on the back was both perceived as uncomfortable for the child and inconvenient for the parent.

4.4 Final Concept

The Interaction

In the final concept, the entire interaction of using the harness for both parent and child is rewritten. Figure 4.13 depicts the story, from putting on the harness, to connecting it to the stroller, to the movement freedom the child experiences. When an obstacle is hit, the harness acts as a seatbelt.

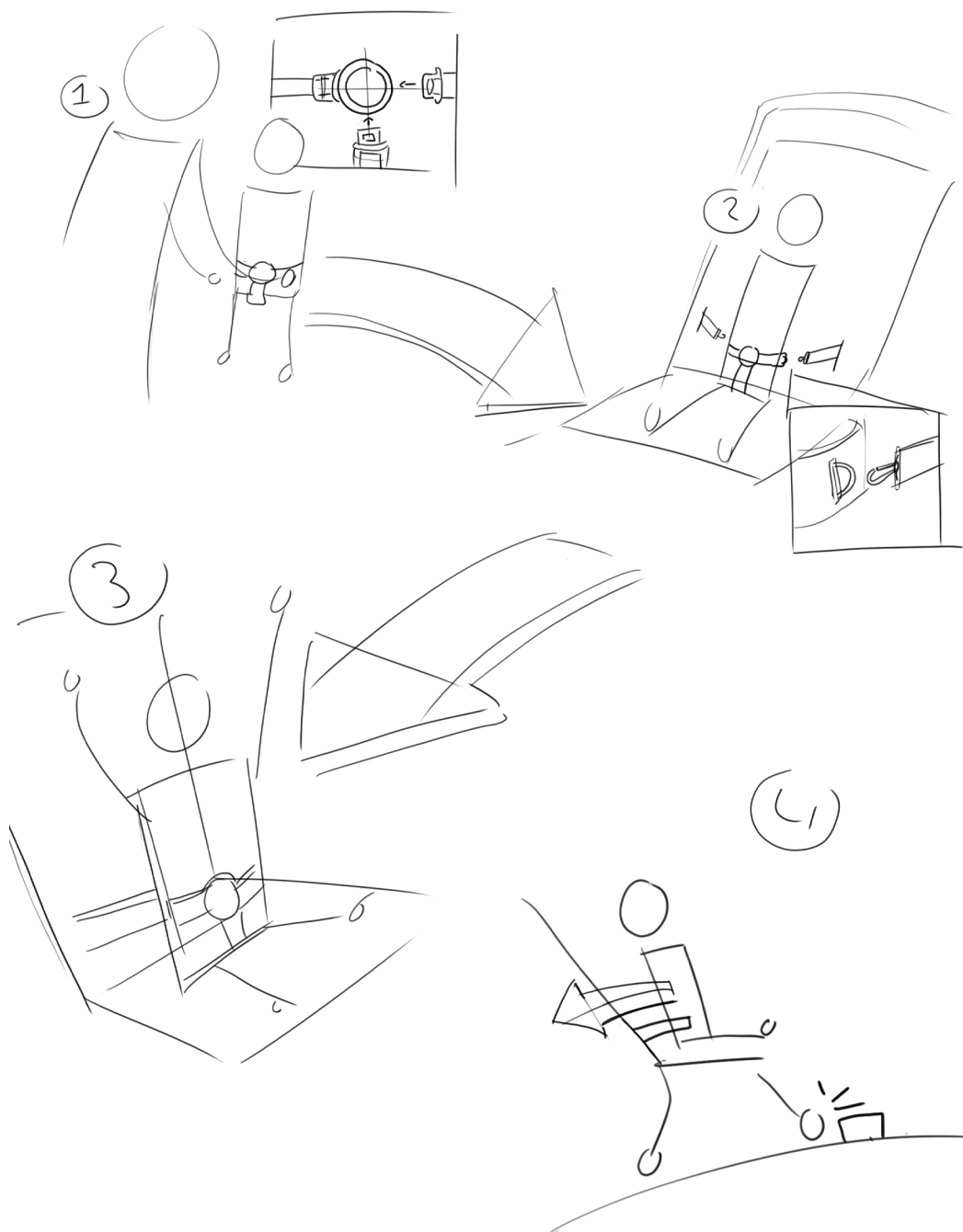


Figure 4.13: Final Interaction Visual

Design Iterations

To support the design process, Gravity Sketch was used. This is an immersive 3D design platform, allowing the user to sketch in virtual reality. The KIMA models were imported into this space, to be able to design around them, while having the right proportions (Figure 4.14).

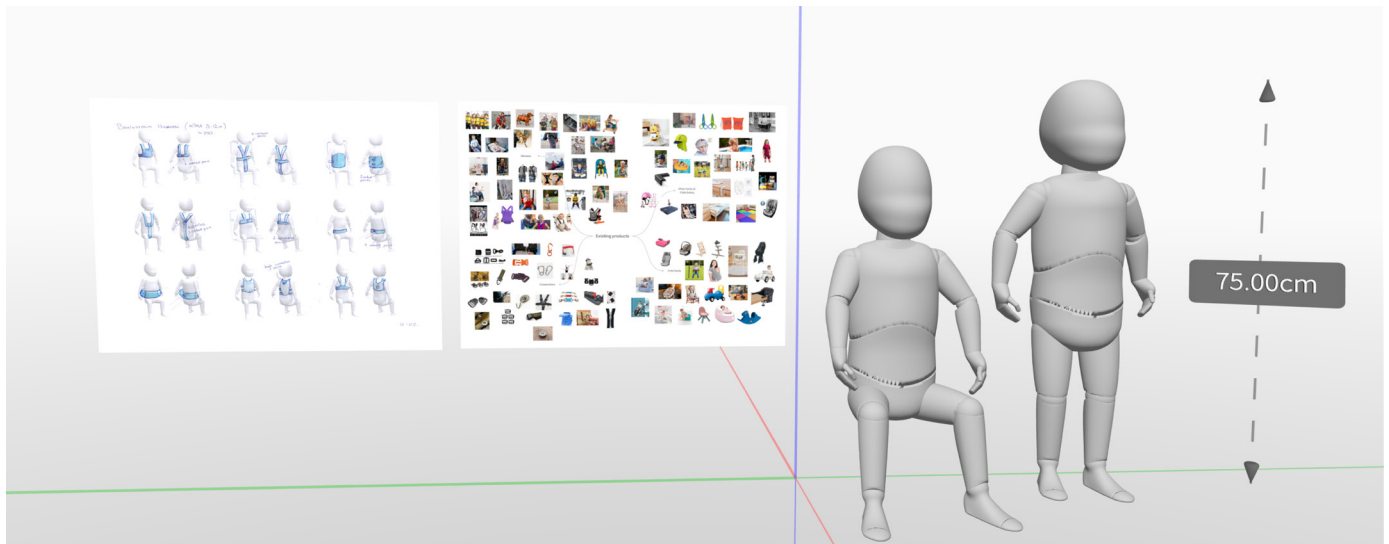


Figure 4.14: Gravity Sketch Environment

Figure 4.15 shows the design iterations done in Gravity Sketch, while consciously thinking about the adjustability, safety, comfort, and possible associations to animal or military items. For each iteration, a more detailed view can be found in Appendix N. However, before being able to choose a design or develop one further, the connection points on the harness should be defined. This process is shown in the next section.

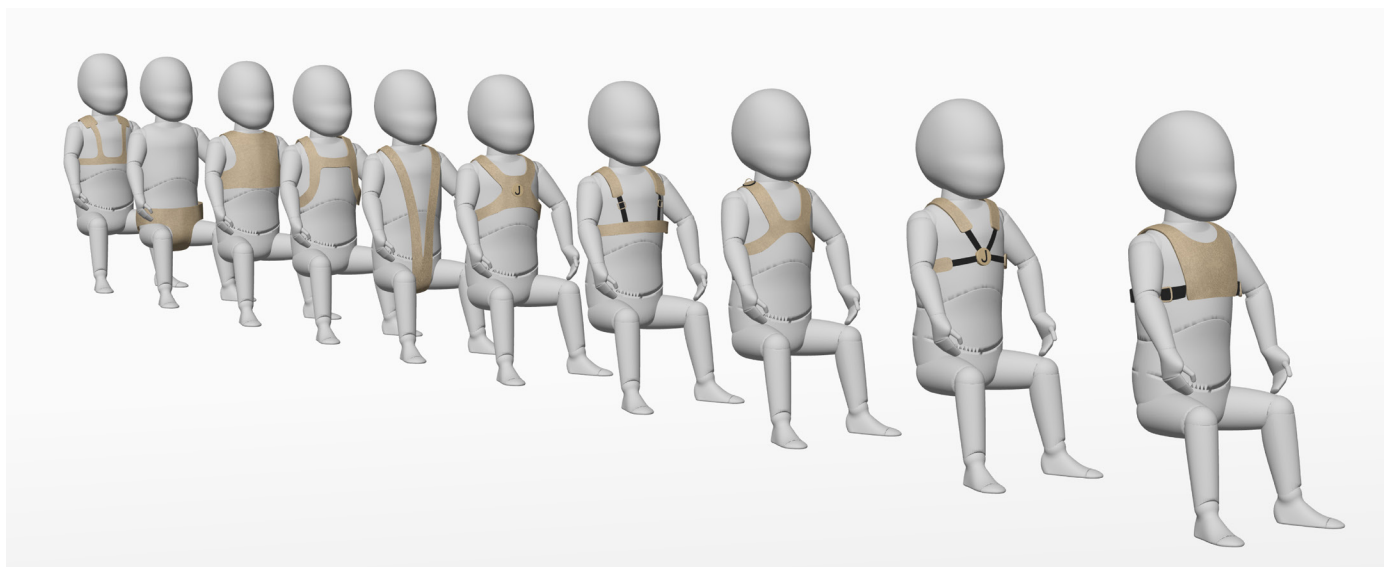


Figure 4.15: Gravity Sketch Iterations

Defining Connections

The best possible way to see how connection points could influence the movement freedom and behaviour of the child, would be to test with children. However, due to the limited time frame of the project and the ethical process user testing with children requires, this was not feasible. This section explores different ways how the decision was made to have two connection points on the sides.

Safety

In the previous 2 prototypes, there was one connection point placed on the back. Not only was this perceived as uncomfortable and inconvenient by the parents, it would also provide less safety for the child. In Figure 4.16, a schematic top view shows the difference between having one or two connection points. For this example, the connection with the chairs is taken as a fixed point.

The top view shows how one point could allow the child to hang over the side of the seat. With two connection points, hanging to one side would always be limited due to the point on the opposite side. Furthermore, two points would provide redundancy. If one point were to fail, a second would still be able to keep the child from completely being detached.

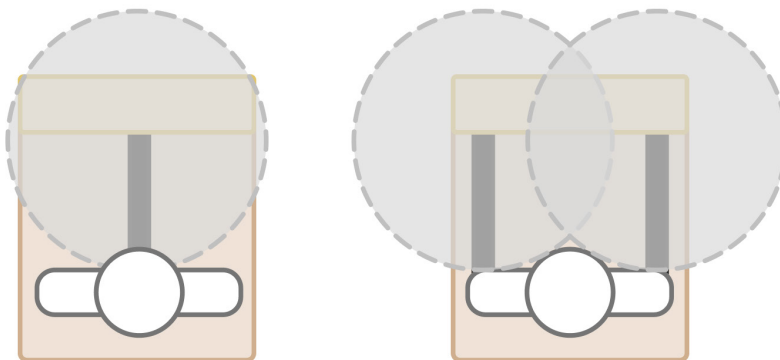


Figure 4.16: Schematic top view connection points

Mobility

To test behaviour and mobility in a seat, some personal tests were done by using parts of suspenders (Figures 4.17 and 4.18) and an office chair.



Figure 4.17: Suspenders used in mobility testing



Figure 4.18: Suspenders used in mobility testing

Six different tests were conducted (Figure 4.19). Two tests were done with one connection in the back at two different lengths, seen in figure 4.18. Two tests were done with two connections on the shoulders, at the same two lengths. Finally, two tests were done with two connection points on the sides, with the smaller straps. A complete overview of observed behaviour and postures is shown in Appendix O.



The connection in the back occasionally pressed uncomfortably on the spine. Furthermore, both in the longer and shorter configuration a lot of movement freedom was observed. This amount of sideways movement is likely too much, as I was able to put most of my body over the sides and armrest. Lastly, when pulled, the sweater pushes uncomfortably into the throat.



The connections on the shoulder also gave too much freedom in the longer configuration. The shorter showed to be much more promising. However, two unwanted behaviours were observed.

Because of the upwards pulling, I was inclined to start hanging in my seat. Furthermore, because of the connection on the shoulder, it significantly impacts the range of motion of the arms. Important to note that this might be caused by the sleeves.



The connections on the side immediately felt more secure, but also a bit more restricting. Especially rotation was restricted. However, the arms, legs and upper body were quite free to move. Furthermore, no uncomfortable strain or pressure is put on the body when pulled.

Figure 4.19: Mobility Behaviour Testing



Figure 4.20: Testing 3D print connections

Additionally, to test the 3D printed connection made for the second prototype, three new ones were printed and sewn to the shoulders and back of a sweater (Figure 4.20). The rotation worked correctly. However, I noticed that the connection in the back indeed was not comfortable while leaning back. As a child is much smaller, they would likely even feel more discomfort.

Concluding Analogy

Based on the safety provided by two points compared to one, and the discomfort felt by the connection on the back, either two points on the side or on the shoulders were considered.

However, the lack of arm movement, the tendency to slide down and hang, and the lack of pelvis support found with the shoulder connection, made the side connections the best option. Finally, to give an analogy, it makes sense for the parent. When holding a child on your lap, you would not hold them by their shoulders, but by their waist. Resultingly, the decision was made to include two waist connections in the final prototype.

4.5 Prototyping for evaluation

Two iterations of prototypes were made to be able to communicate and evaluate the final concept (Figures 4.21 and 4.22). Prototype 1 was a first iteration with available hardware and for practicing patterns and sewing. The insights from Prototype 1 were used in creating Prototype 2, which consists of 3D printed parts and a much more finalised appearance in fabrics and cushioning. The prototyping journey will be explained separately for the hardware and for the soft goods.



Figure 4.21: Prototype 1



Figure 4.22: Prototype 2



Designing the hardware

Buckles & Connectors

Taking the current 5 point harness as a starting point and introducing adjusters (Figure 4.23), would cover a significant portion of the child's stomach, and would not be comfortable. Therefore, a new part was modelled and 3D-printed, combining both the connector and buckle into one. (Figure 4.24)



Figure 4.23: Original parts

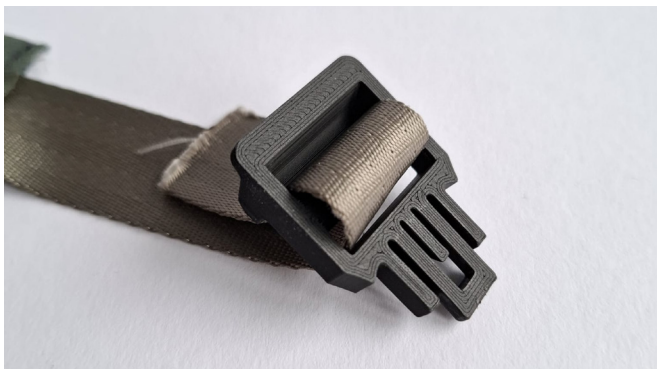


Figure 4.24: Prototype 1 3D printed connector

Another issue found with current harnesses, is that all of them have the connector attached to the crotch restraint. In the new interaction, putting on the harness would be much easier for the parent if the connector was attached to one of the sides. Then, the harness could first be put around the waist, before connecting the crotch strap. To present a functioning prototype for evaluating the interaction, a new connector had to be designed (Figure 4.25), the design of the connector was inspired by the work of ABE 3D (2025). Prototype 2 also has a D-ring attached to the webbing (Figure 4.26).



Figure 4.25: Prototype 2 3D printed connector



Figure 4.26: Prototype 2 D-Ring

Buckle Exploded View

After many iterations of adjusting tolerances and varying layer heights, the final design was finished. Figure 4.28 shows an exploded view of the 3D printed buckle. The assembled product is seen in Figure 4.27, showing the connected and disconnected stages.

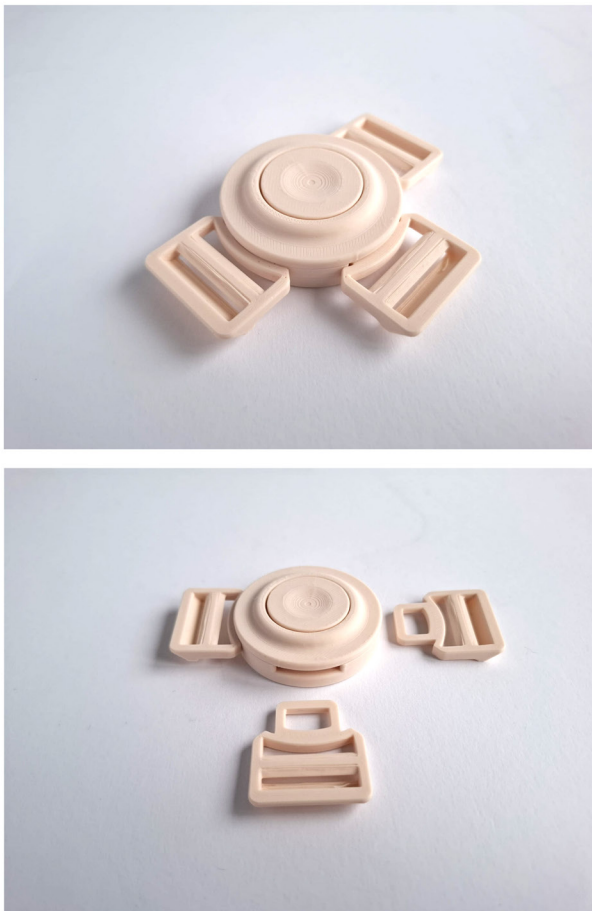


Figure 4.27: Final Buckle Assembled



Figure 4.28: Final Buckle Exploded View

Detailing - Shape

To prevent the design of the buckle being perceived as belonging to a military or animal harness, the design should be child-like, and fit Joolz' portfolio. The ideation session seen in Figure 4.29 showed a round shape without extra logos

or edges would likely fit best, in being perceived as friendly and child-like. It also resembles the harnesses currently used in Joolz products, ensuring a good fit, and increasing chances of customer acceptance.

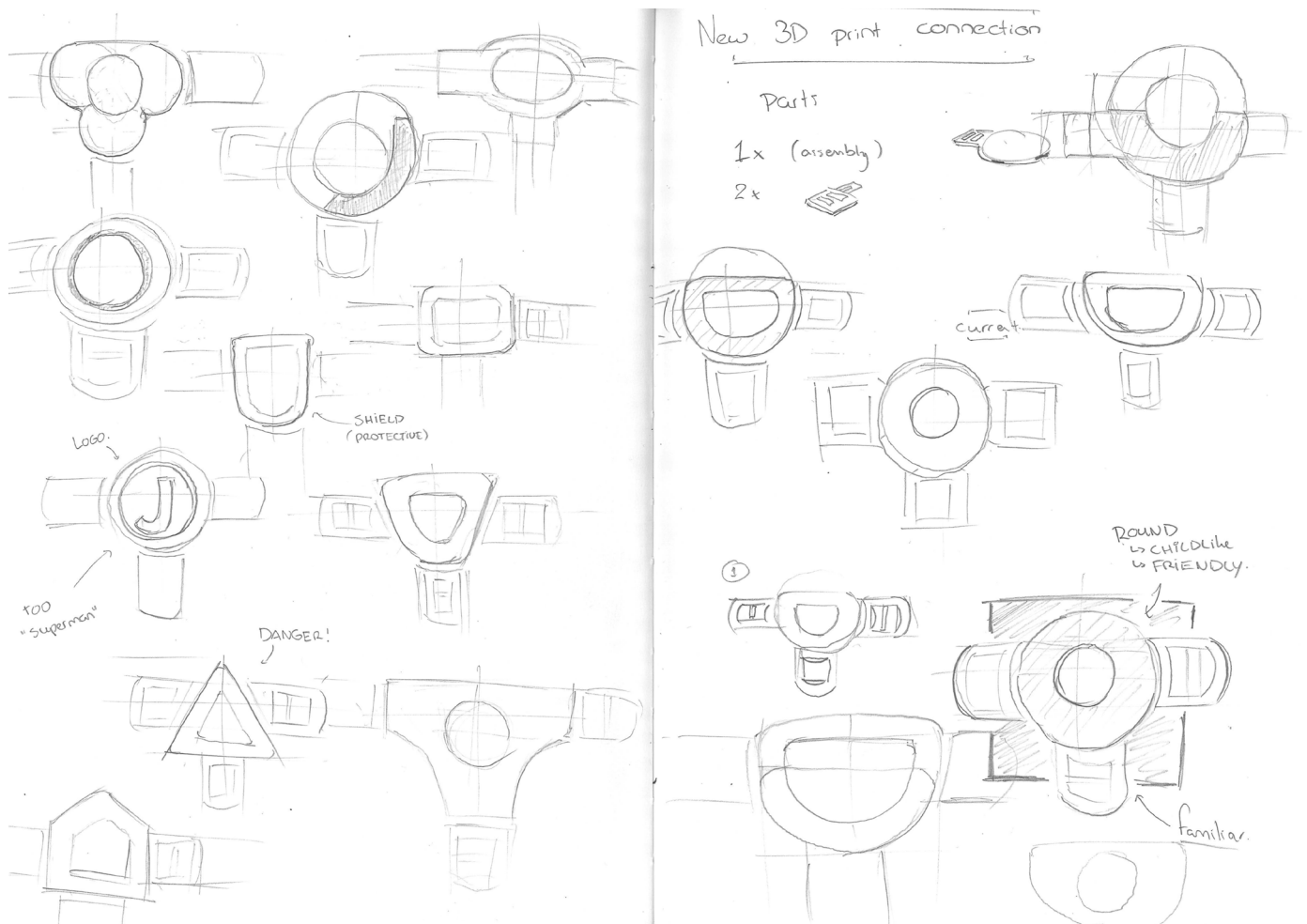


Figure 4.29: Design Drawing Buckle shapes

Detailing - Colour

Before printing, a colour test was done to see what filaments I had would best fit the Joolz style. The design should fit with Joolz' current colour portfolio. Within Joolz' current portfolio we can identify earthy colours, somewhat playful, yet still showing luxury and elegance.

Several colour combinations were printed, and placed on two of Joolz' popular stroller colours (Figure 4.30). Based on this analysis, a selection was made as shown in Figure 4.31.

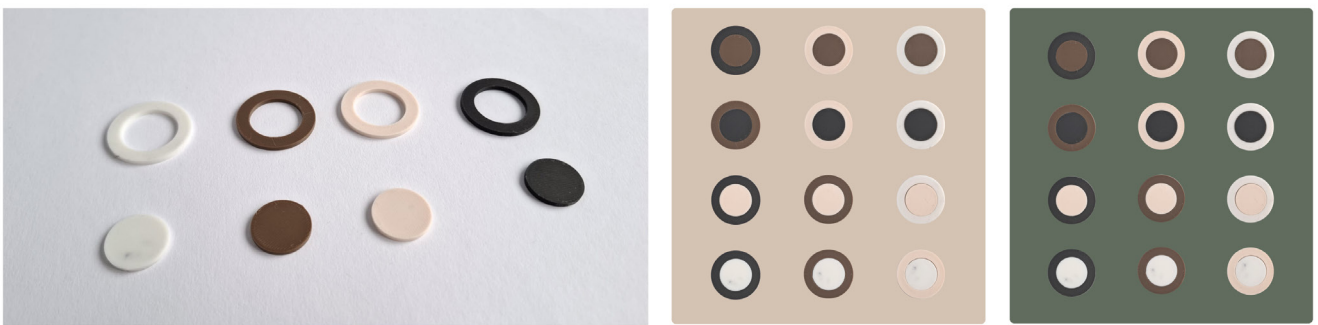


Figure 4.30: Colour Analysis

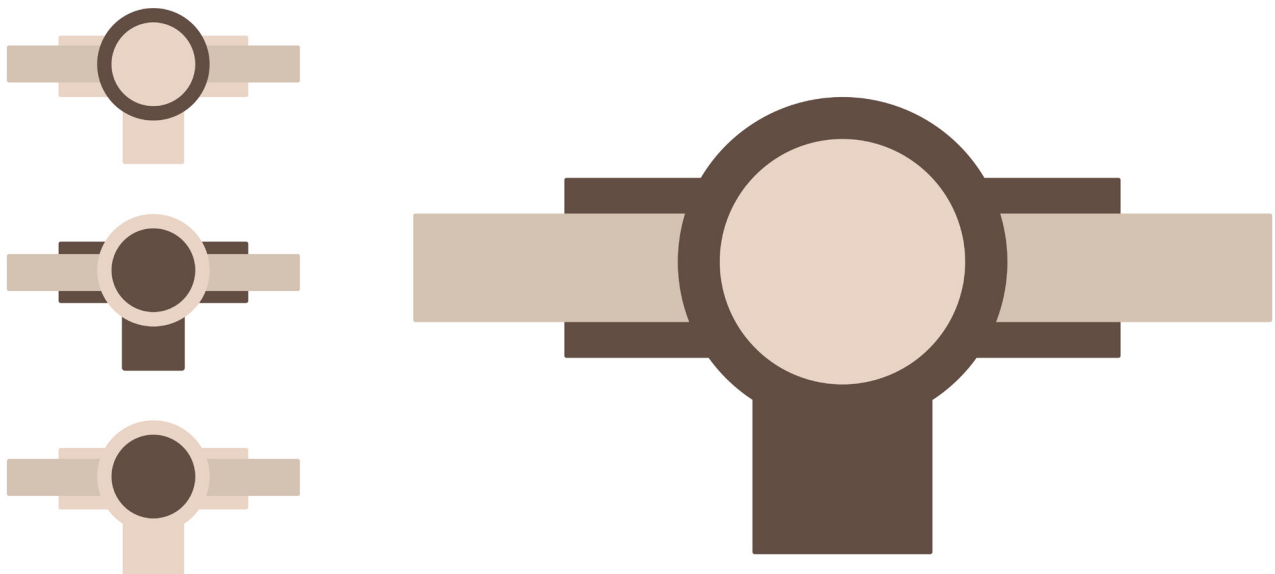


Figure 4.31: Colour Selection

Designing the soft goods

Experimenting

Before starting on the two prototypes, some sketches and putting together parts found around the workshop lead to a few important insights for the development of the concept:

- The design should have a crotch strap, to prevent the harness from sliding upwards.
- All connections and adjustment should be in the front for child comfort and parent convenience.
- Both sides should be adjustable, keeping a symmetric image, and allows tightening without constant readjustment of the harness nor pulling the child in one direction.
- As seen in figure 4.32, attaching the crotch strap in the back only to the webbing, can cause uneven tightening without the parent noticing. Continuing the cushioning around the back would prevent this from happening.



Figure 4.32: Experimenting with soft goods

Determining Dimensions

The dimensions for Prototype 1 are shown in Figure 4.33. The reasoning for these dimensions can be found in Appendix P.

These dimension were used to create the patterns seen in figure 4.34. For the first prototype, each pattern was used for two pieces of fabric, which were sewn together and turned inside out. Through a deliberately left opening in the waist fabric, the crotch pad was put in and sewn in place.

For the second prototype, the pattern width was increased, from 4 to 6cm. Furthermore, slightly more attention was given to the edges. To visually smoothen the transition from fabric to webbing, rounded edges were added. Additionally, small tabs of fabric were added, to be folded inward and sewn shut in the end, creating a cleaner edge. And to improve the comfort for the child, and create a more luxurious feel, cushioning was added on the inside of the fabric. Before sewing them together, each layer of fabric was sewn to a thin layer of foam.

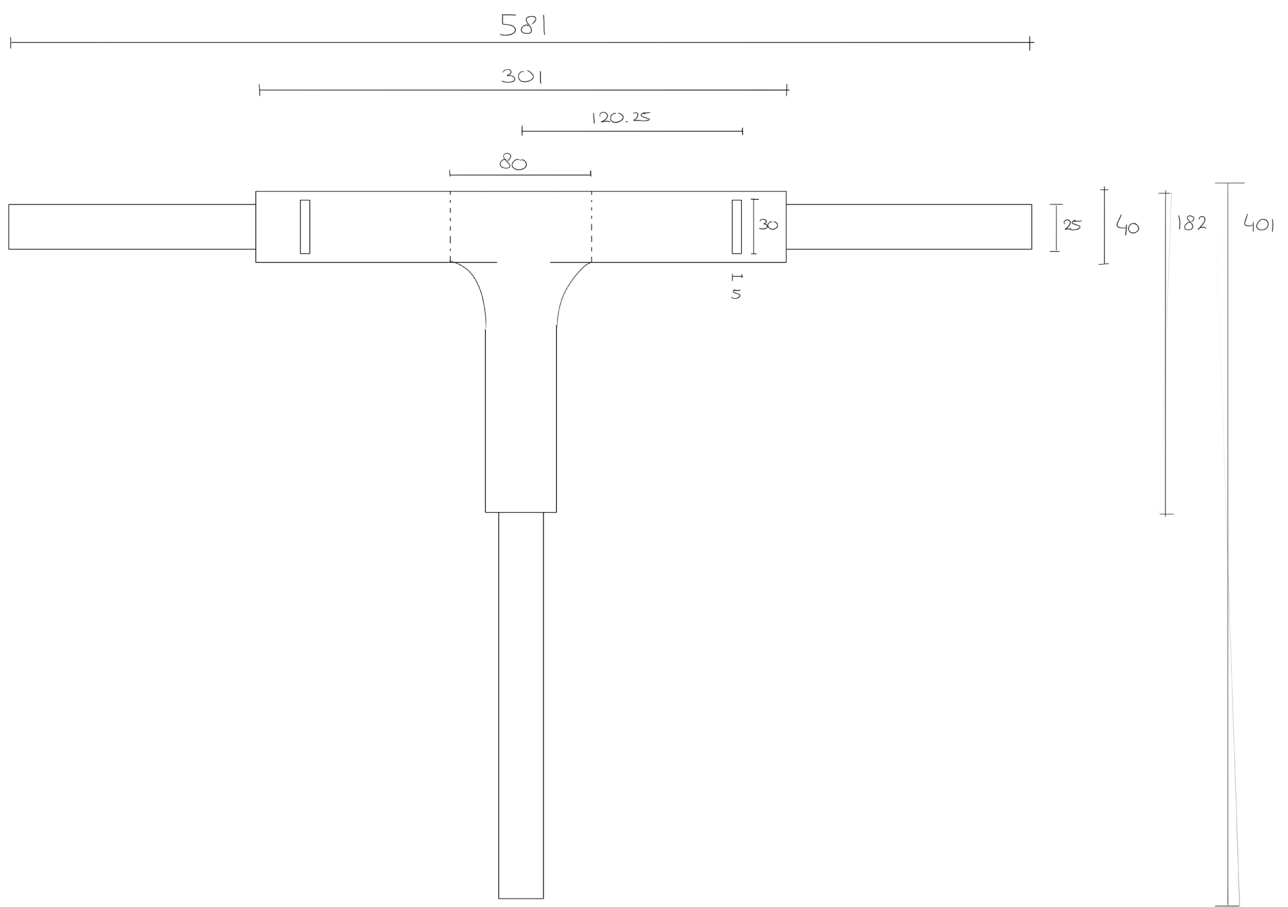


Figure 4.33: Dimensions Prototype 1

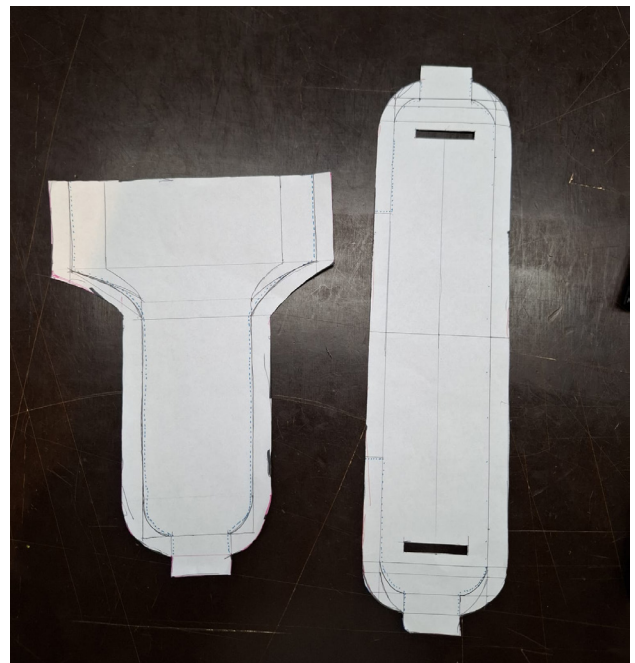
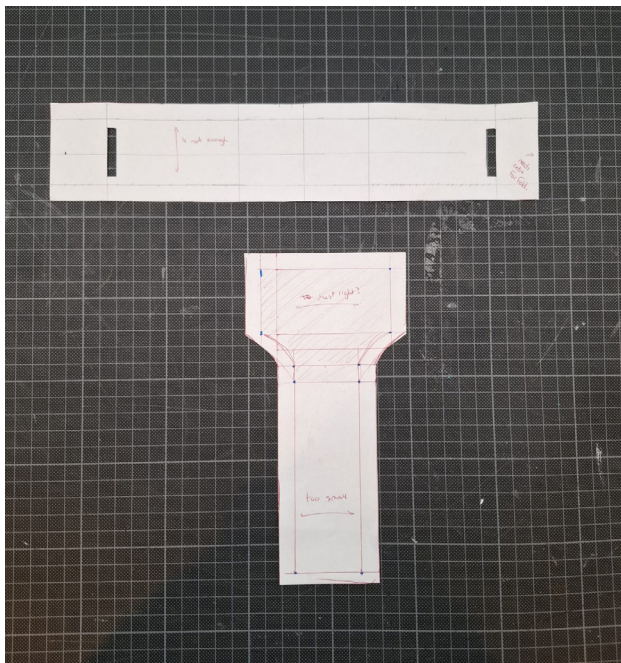


Figure 4.34: Soft goods patterns (left Prototype 1, right Prototype 2)

4.6 Evaluation

Prototype 2 was used in two different evaluation sessions. The first evaluation concerns a compliance review at Joolz, where various standards were discussed. The second evaluation was with participant 1 from Chapter 2.5, who was asked for feedback on the final concept and prototype.

Compliance Review

Standards

Throughout this project, only European standards were taken into account, which did not seem to specifically state requirements for the harness. Figure 4.35 shows some of the standards the current prototype does not comply with. When taking into account US and AU standards, there needs to be an upper torso restraint, which the prototype does not have.

The standards are also designed specifically to restrain and protect, not to give movement freedom. From a conceptual standpoint, there should be room to move beyond the standards. However, the concept must still address the same underlying risks and hazards, even if not according to the traditional solutions.

Standard	Requirements not met
EU	Restraint system can not be used without the crotch restraint. Without 5 points unlikely to pass rotational test.
US	Restraint system should have a restraint for the torso.
AU	Restraint system should be a five point harness The crotch restraint needs to be permanently fixed to the stroller.

Figure 4.35: Standards

Concept Risks

Regardless of any standards, the primary goal for a stroller harness is to securely restrain the child. It must prevent injuries from fall, climbing or sliding out. Secondly, it should maintain the child in a safe and stable seating position. Even though the concept presents benefits for motor development as argued throughout the thesis, it may not be to the detriment of the child’s safety.

The most important risks created by the concept, which should be investigated further, include:

A lack of stability increasing the risk for slouching or submarining into unsafe positions, which might obstruct breathing, especially when asleep.

Too much movement freedom might encourage them to stand up, which is a major cause for injuries.

Risk for dynamic forces. On one hand the increased forces on the child (e.g. in a corner) on the other the forces the child puts on the stroller. A moving child increases the risks of a stroller tipping over.

Parent Feedback

Critique

The parent was not excited by the prototype, and did not see themselves using it for their child.

First of all, they argued having two separate connections would create a more difficult user experience than the current singular button to disconnect the harness.

They always use the entire 5 point harness. Their child tends to pull herself up and forward with the bumper bar. The parent would rather have her sitting against the backrest.

The participant also wondered if the crotch padding in the prototype should not be thinner if the child is to sit on it, or whether it should be wider in the back.

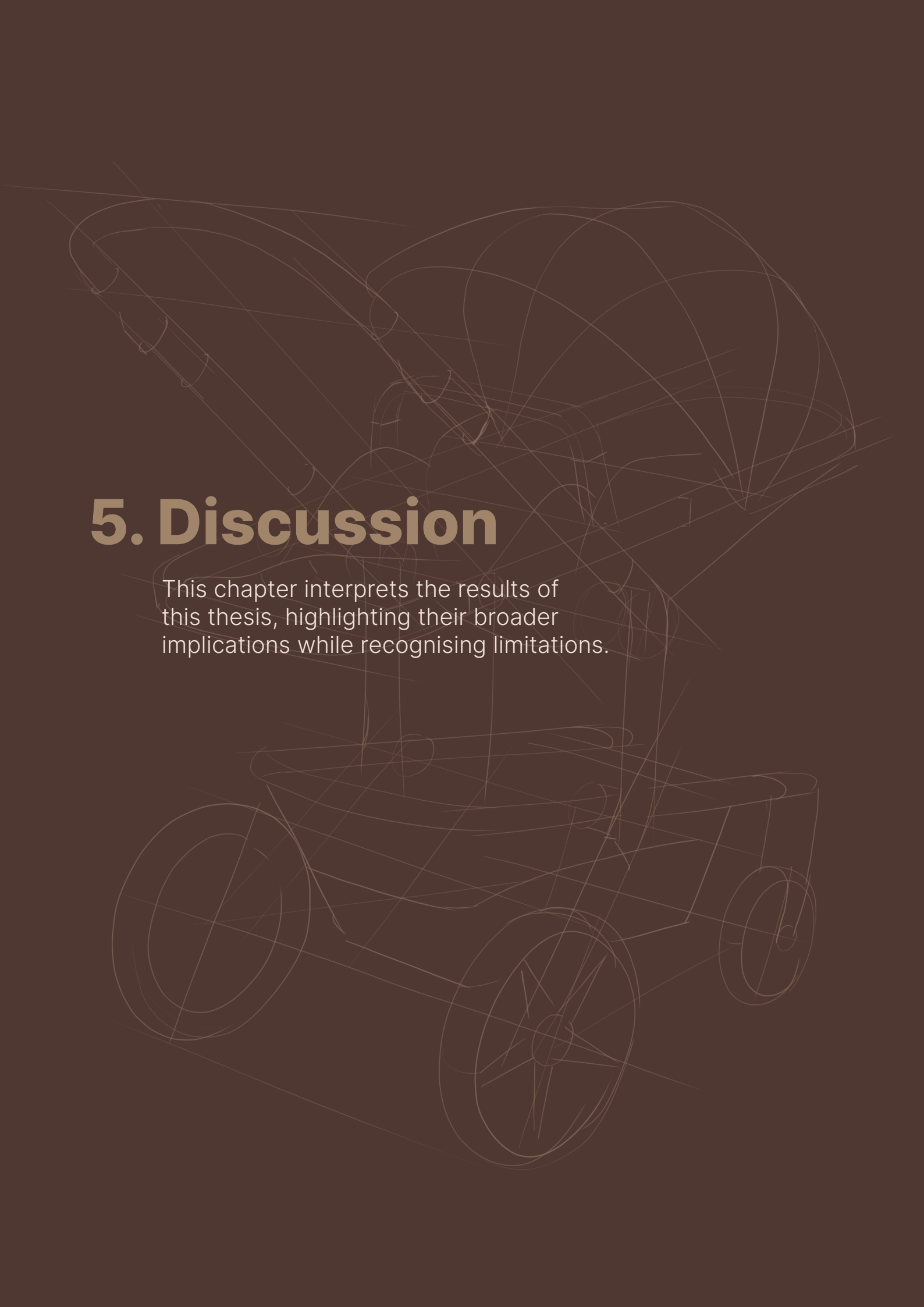
Because their child is unable to walk yet, they do not see the added value of an easy in and out of the stroller. For the parent, putting your child into a five point harness also provides a sense of calmness, knowing their child is not able to lean anywhere.

Potential

However, they did understand where the concept is coming from.

They specifically see added value for children who already can walk, and go in and out of a buggy when at an amusement park or in the woods. Then it would be pleasant to just having to put them in the stroller.

Finally, they did like the harness to be universal. Their Tripp Trapp eating chair does not come with a harness, but she could definitely see something like the prototype in that use case.



5. Discussion

This chapter interprets the results of this thesis, highlighting their broader implications while recognising limitations.

5.1 Implications

Research

This thesis provides several implications for the research field. The literature review provides an insight into the current relevant ergonomic research topics in the stroller industry. Building on these topics, this thesis presents ways of translating them into design opportunities, identifying possible solutions for further design research

Besides the literature review, this thesis presents qualitative data from interviews with various stakeholders. Furthermore, it includes observations of stroller use for both the parent and child's behaviour. Due to the broad exploration,

insights which might not have been used in the concept development could still be of interest to other researchers and designers.

Through the research, ergonomics has not been identified as just physical fit, but related to movement and motor development. In doing so, this thesis discovers a lack of scientific evidence relating child posture and physical activity to long term effects to motor development. This lack of evidence is not just significant in the context of strollers, but in child care as a whole. Further investigation would be needed to realise ways of promoting motor development.

Joolz

As defined in Chapter 2.7 Joolz aims to create a better world for both parent and child. That is exactly what this design tries to achieve, by improving children's well-being and making the parent's life easier. Furthermore, making the harness universal for other seating devices could work according to Joolz' other pillar, sustainability. Imagine only needing one harness for all your sitting devices.

However, due to the limited conceptual level of the prototype, it is difficult to propose a specific business case for the company. It still depends on a variety of factors. On one hand, selling the harness as a separate accessory could lower the costs and risks. It would require minimal change to Joolz' current portfolio. Furthermore it implies parents get to choose whether they would like

the harness or keep the current one. And having the harness as an accessory might be different compliance wise, in that the responsibility lies more with the parent opting for the less safe option.

On the other hand, making the concept the new standard harness that comes with all strollers, would come with significant investment costs. But it could also have a larger desired impact as users will be forced to use the harness.

In its current state the design is not ready to be sold. However, it does provide a new perspective on restraint systems in strollers. In the end, the goal for this concept is to inspire.

Stroller Industry

Over the course of history strollers developed in accessibility, safety, portability and luggage space. However, Sehat & Nirmal (2017) argued innovation in strollers had plateaued. More recent innovations include circularity, sustainable materials or use of electronics, but no inherent change to the use of strollers itself. This thesis tries to present a concept which breaks through this plateau. It envisions a future where a stroller is not just a fixed human transport unit, but a portable place for movement and exploration. Instead of the harness being seen as a restricting safety obligation, it is an extended part of the interaction with the stroller. However, this vision can only be reached through balancing safety and mobility. The concept should not exist to the detriment of child safety. At its current state, it does not provide the perfect answer and would not comply with current standards, but it takes a small step in the right direction.

Furthermore, we should be aware of other negative behavioural effects. As stated by Michalska et al. (2025), the fear of prone sleeping had caused parents to avoid prone time for their children altogether. The acceptance of the concept presented by this thesis depends on the underlying argument that restriction affects motor development. There is a small possibility that parents may prioritise motor development over their child's safety, and start avoiding the use of harnesses altogether, which should be avoided at all costs.

5.2 Limitations

Research

Due to a lack of sufficient relevant results for the search strings used in the literature review, a less systematic method has been used to find additional sources. This highly influences the replicability of the research method, and allows room for subjectivity and bias. Through this subjectivity, it is possible some relevant sources were overlooked, which could have created an unbalanced view of the literature space. Furthermore, due to limited scientific and peer-reviewed literature, a significant part of the research consists of grey literature, influencing reliability. This lack of literature could be the result of the ethical and privacy constraints around testing with children or the difficulty in measuring long-term effects on children's development. Moreover, some measurements lacked in the anthropometric data, which were estimated based on data that was available. However, these estimations were rough calculations and further measurements are needed.

Scope

Framing the project also came with its limitations. As seen in Chapter 3, multiple decisions had to be made in analysing the research and defining design opportunities. Besides some holistic criteria such as alignment with the research and potential value to Joolz, these decisions were largely based on interest and intuition. Furthermore, to make these choices knots had to be cut, significantly affecting the time

The front-end user research similarly had its limitations. Firstly, the broad exploration at the start of the project reduced the time available to dive deeper into a specific area. Secondly, to better understand the stakeholders and support the broad exploration, a preference was given to qualitative approaches. This provided in-depth insights, but lacks in sample size and breadth of the research compared to quantitative methods. The semi-structured interviews allowed flexible exploration of the topics, but were limited by possible interviewer bias and low validity. With this low number of participants, it is also important to consider the cultural and geographic limitations. Finally, even though it could help provide a new perspective, another limitation for the project might have been my personal lack of experience with children and the use of strollers.

to elaborate directions further or make more substantiated decisions. To help make these choices, experiments were held with ChatGPT as a conversation partner and relate the research to the defined directions. These limitations do not necessarily affect the current outcome of the project, but other defined directions could have led to other interesting concepts. However, they could not have been investigated further within the timespan of the project.

The chosen scope, focusing on improving motor development for children through movement space in a stroller is based on assumptions which could not be fully validated within the scope of this project. The previous section already discusses the limited amount of scientific sources. Even the Health Council of the Netherlands (2022b) did an extensive literature review and found not enough evidence to state physical activity promotes motor development at ages 0 to 4. Furthermore, Hudson (1966) argues through studies of North American Indian cradle boards, that restriction does not affect the age at which children learn to walk. He explains this through isometric exercise of the muscles, in which no limb movement occurs.

Concept

Given the time constraints of the project, the concept could not be extensively validated. Some evaluation was done with parents, but more testing is needed to determine perception and acceptance and to compare the new harness concept to the current interaction. As seen in the evaluations at the 9 months fair, parents see movement freedom as a benefit of the concept, but are wary of the amount of support it gives. Besides the caregivers, experts should also be consulted to further evaluate the concept on the support for the child. Furthermore, due to ethical limitations, testing with children was unfeasible. This made it difficult to understand how children would react to a new harness or to the given movement freedom. Currently the target group has been limited to 9 to 18 months, for the scope of the project and the perceived impact as defined in chapter 3.4, but the harness would likely also be used by other children. This means the harness would require more adjustability or would have to make use of a sizing system.

Although a cradleboard comes with other risks of overheating, or hip dysplasia, the paper proposes an interesting counterargument to the scope of the project, and should be investigated further. Finally, the concept focuses on stroller use. However, as argued by the occupational therapists, the time in a stroller spent in a stroller should already be limited. This raises the question how large the impact would be of providing movement freedom in a stroller. Perhaps a larger effect on overall motor development could be achieved through considering the context outside of strollers, or even taking a step back and consider child care as a whole.

Additionally, the concept focuses on the use of strollers. However, as argued by the occupational therapists, the time spent in a stroller should already be limited and advises taking breaks during use. This raises the question how large the impact would be of providing movement freedom in a stroller. Perhaps a larger effect on overall motor development could be achieved through considering the context outside of strollers, or even taking a step back and consider child care as a whole. In the scope of this project, no long term validation could be done on the effects of the harness. Besides the magnitude of the effects, it is also important to consider negative effects. Movement freedom and a lack of support might give way for improper postures, which could lead to asphyxiation or spinal deformation (Daams, 2024a)

Finally, for the scope of the project, the prototype has been made to a conceptual level, the technical feasibility and durability were underexplored. With safety being the most crucial part of a stroller harness, this should have priority in further exploration. As discussed in Chapter 4.6 changes have to be made to comply with the relevant standards, and the prototype should be evaluated according to these standards.

The current conceptual level of the design limits this type of testing, and lacks validation for usage in other strollers and types of seating devices. An important limitation for the harness, is that the seating device itself should also allow the movement freedom. The concept only would work when the child is not restricted by the seat itself.

5.3 Recommendations

Stroller Connection

Due to the conceptual level of the prototype, certain decisions have not yet been made, including the technical requirements for the connection of the harness to the seat. This firstly needs to be developed before further evaluation and to assist in substantiating a business case.

Anthropometric Data

Critical dimensions for the prototype were roughly estimated. Further measurements are needed to ensure a proper fit. Secondly, the concept was limited to the specific target group, but older children should also be considered in the next iteration. Especially because the parent in Chapter 4.6 saw the most value for children who already were able to walk around.

Motor Development vs Safety

As evaluated in Chapter 4.6, in its current state, the prototype would not comply with multiple standards. Even when disregarding the standards, the harness does not fulfil its primary purpose to provide safety and stability. Therefore, a redesign of the concept should be considered, giving higher priority to safety.

Further Evaluations

Due to ethical and time considerations, no final evaluations were arranged with children nor experts. Evaluations with experts is necessary to assess the effectiveness of the concept. Testing with children would help validate assumptions, to see how they would react to the given movement freedom.

Substantiating the Scope

A lack of literature was found on the effects of physical activity on motor development. Further research would be needed to substantiate the scope and argue for the prototype. This research should also include counterarguments such as the isometric muscle development seen in the study by Hudson (1966).

Quantitative data

Due to the qualitative research approaches, the sample sizes were very limited. More research is advised with a focus on quantitative data with larger sample sizes. Using statistics and numbers to show the delay in motor development or current stroller and harness use would help justify the concept and give more direction for specific requirements. Furthermore, it would enable a better prediction of the perceived impact of design choices.

Sharing information

As argued in Chapter 2.8, it is important to consider where parents get their information from. Further investigation is recommended on how to bring the underlying ergonomic knowledge and theory to the parents. The product would likely be more successful if consumers are aware of the reasoning behind it.

6. Conclusion

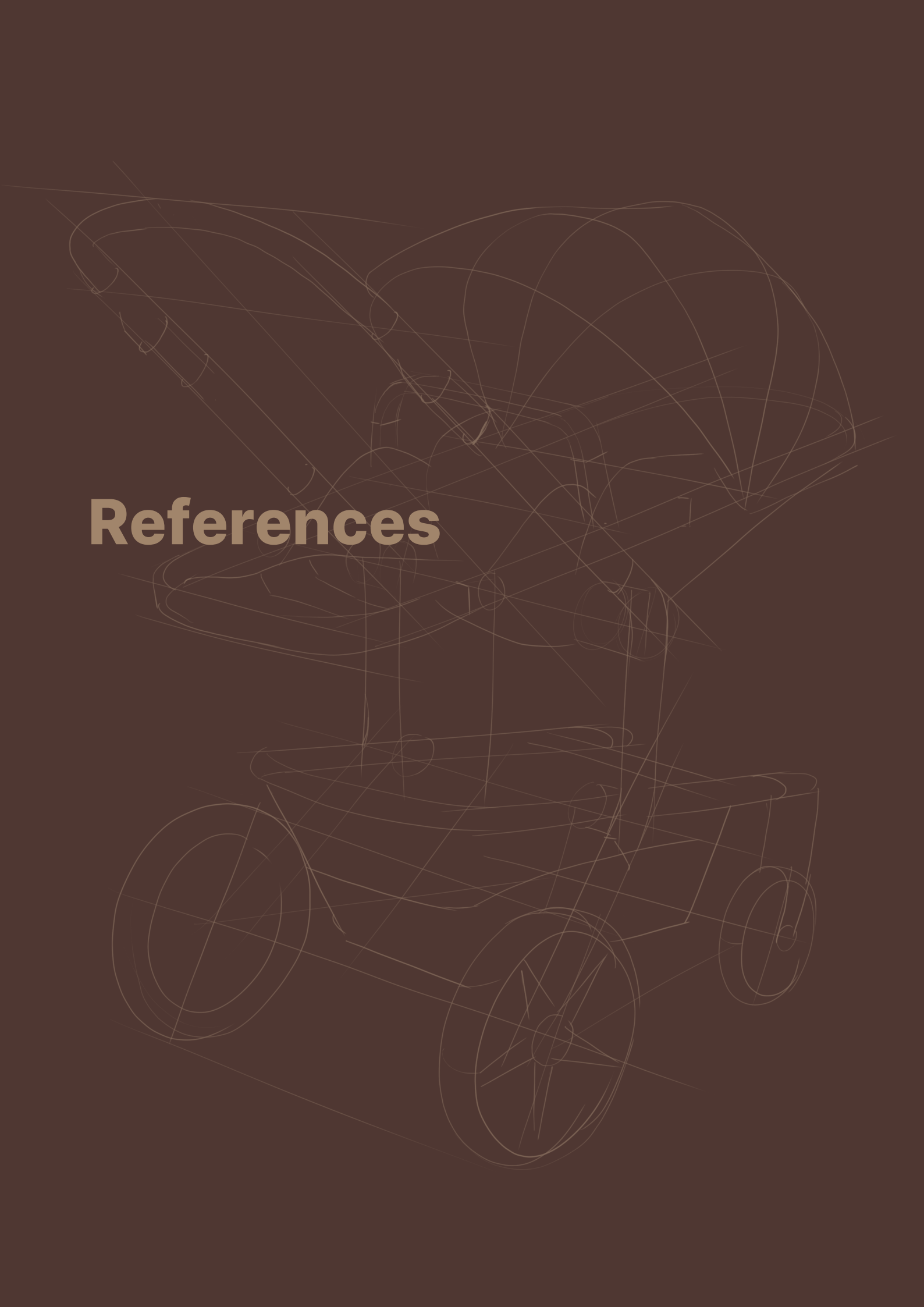
This thesis set out to investigate children's ergonomics within the stroller industry. Through a combination of research methods, the findings highlighted concerns regarding the overuse of infant sitting devices and their impact on children's motor development.

As a result, a design goal was formed to improve this motor development through a new harness design, which redefines the parent-child interaction and offers both mobility and safety for the child.

The concept was demonstrated and evaluated through prototypes with both parents and compliance experts. These evaluations indicated there is room for improvement and further development.

In the end, the aim of this thesis is not to present a finalised product, but to provide an innovative perspective on stroller ergonomics and restraint systems, and to inspire further design exploration supporting children's movement and development.

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Appendices



Appendix A - Project Brief



Personal Project Brief – IDE Master Graduation Project

Name student Max Hessels

Student number 5275997

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Investigating the gap between design vision and user practice in the stroller industry

Project title

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

This project aims to investigate how comfort strollers are perceived and used in everyday life and to explore opportunities for ergonomic improvement. This includes analysing both the correct posture and comfort of the child, and the usability for the caregiver. The focus lies on children ranging from 9 months to 4 years. Children within this age group grow rapidly and are constantly changing, and so do their needs.

Regarding other stakeholders (figure 1), particularly the users and retailers, it is important to consider that 'ergonomic' sells. Parents and caregivers usually want what is best for their child, and therefore are drawn to products that seem to offer comfort and support. However, it is not always clear whether their decision-making is based on evidence, marketing claims, or personal perception.

Considering Joolz and its competitors, they are often influenced by one another, following certain ergonomic trends. A recent example is a backrest that can be angled independently of the seat. Many designs claim ergonomic benefits, but the actual evidence and long-term value for children are not always clear.

This creates opportunities for the project to explore the vision and scientific support behind ergonomic strollers, and relate this to how they are experienced by the child as well as perceived and used by their caregiver.

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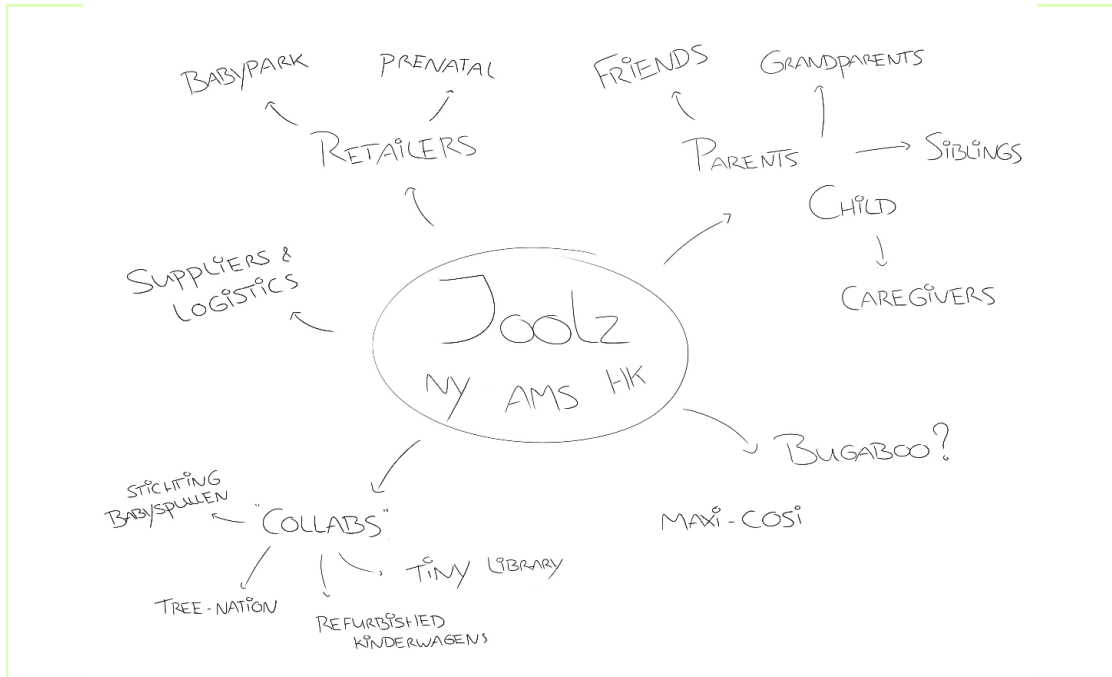


image / figure 1 Joolz Stakeholder Map V1

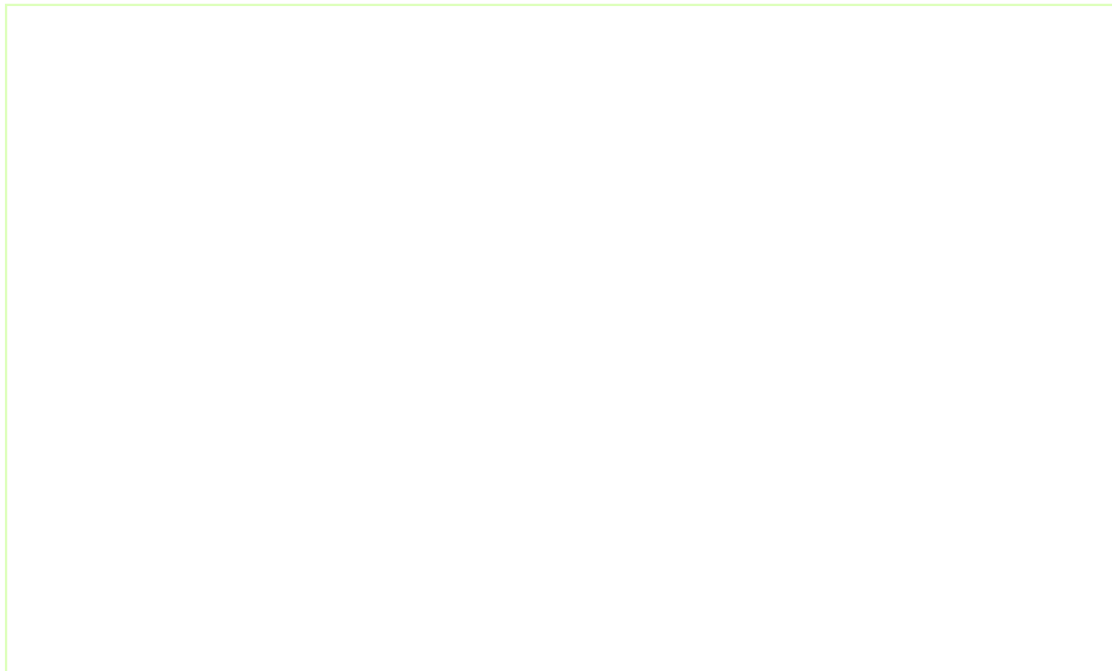


image / figure 2



Personal Project Brief – IDE Master Graduation Project

Problem Definition

*What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)*

The main focus of this project lies in bridging the gap between design vision and actual practice in the stroller industry. Stroller brands emphasize their ergonomic designs, while it is unclear how these features are used in daily life by both child and parent. For example, many brands offer a buggy where the back and footrest can lay flat, to allow for proper sleeping position. However, keeping the footrest horizontal with a vertical backrest could create uncomfortable posture, negatively affecting the health of the child.

Parents are motivated to choose what seems best for their child, however the information they rely on is likely influenced by marketing, perception or advice from others. This could result in their decision-making process being disconnected from the actual underlying ergonomic principles.

This creates two opportunities for Joolz and this project. Firstly, to gain a better understanding of how their current products are being used, and how certain ergonomic features are perceived amongst users. Secondly, to investigate what information parents base their decision making on, and how find better ways of communicating the value of the ergonomic design.

Assignment

*This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)
As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:*

Investigate the gap between design vision and actual practice in the stroller industry and design a conceptual prototype to ergonomically improve Joolz' comfort strollers for both child and parent.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The project would start with both literature and observational research. This would help gain an understanding of the ergonomic principles and what the current general consensus is amongst researchers about the correct posture and safety of the child. Furthermore, it would create a better picture of how both Joolz' as well as competitors' products are being used. This would be supported by questionnaires and interviews.

This research will be used in developing a conceptual stroller chair design, so following this exploratory phase is a decision moment to define what specific direction to focus on. Through sketches and prototypes, this direction will be explored. The prototypes will assist in evaluating ideas and test assumptions, rather than for aesthetic or presentation purposes.

The end goal for this project would be an overview of the knowledge gained, together with a conceptual design of the stroller chair, evaluated with end users through various prototypes.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting, mid-term evaluation meeting, green light meeting and graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	29-09-2025
Mid-term evaluation	24-11-2025
Green light meeting	30-01-2025
Graduation ceremony	02-03-2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	☐
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

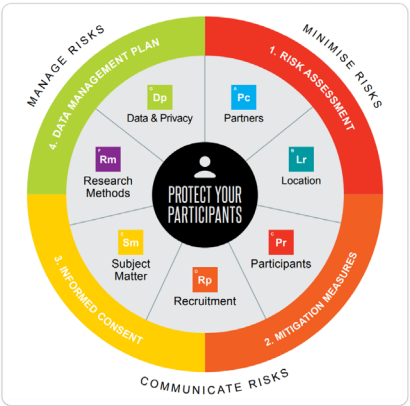
Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

When I visited Joolz during Cases on Tour, I became intrigued by their products, their vision and the open atmosphere at the company. Their focus on physical products would allow me to make use of my existing drawing & prototyping skills, while increasing my knowledge of materials and manufacturing. Through my work as a sailing instructor & scouts leader, I have some experience with working with older children (ages 7-18), but I am very excited to see what it would be like to work with this target group and, of course, their parents.

Skills I would like to build on in this project are reflecting on a weekly basis, keeping a daily diary, making use of visualisations like sketches and renders, and 3D-printed prototypes. I would also like to increase my prototyping skills and start with prototypes as early as possible.

I also have some learning ambitions for this project. One is to not get stuck after the analysis phase, and keep scheduling meetings, so that I keep having deadlines to work towards. Furthermore, I would like to gain more knowledge on materials .

Appendix B - Risk Planning Session



0A Pc	Partners & collaboration Is there anything about my funder, internship provider or research partner that participants should be aware of? For example, might there be repercussions if my partners see the raw data?
0B Lr	Location risks Does the location of my research (whether it's physical or online) bring any potential risks? For example might my research put participants at risk from a non-democratic regime? Or does it influence what might be considered "reasonable compensation"?
0C Pr	Participant risks Are there any possible risks specific to my participants? For example, are they legally able to provide informed consent? Or might my research run the risk of triggering an investigation of them by an authority?
0D Rp	Recruiting participants Is it OK for me to use that old conference attendance list to recruit participants? Or is there some legal or customary entity I have to go through to contact my participants?
0E Sm	Subject matter Does my research need Medical Ethics approval? Could the research potentially put my participants in physical or emotional danger?
0F Rm	Research methods Might my participants object to something that I'm doing? For example am I observing them without them knowing – either physically or online? Or what about that dataset I want to use – did the participants agree for it to be reused?
0G Dp	Data and Privacy What kinds of problems could participants face if their identity was somehow linked to the data they are providing? Am I potentially putting them in danger – even after the research has been published?

	Risk Assessment				Mitigation Measures					
Pc	Partners: Joost Supervisor Mentor HREC HSE advisor	Partners should not have access to raw data, only anonymized data or conclusions drawn	Research might indirectly make use of confidential data provided by Joost	Besides HREC, HSE advisor must approve any prototype	DO I NEED ANYONE ELSE RESEARCH TO ASSIST ME?	Keep any personal data to a minimum and only store on personal storage, not online	Anonymize any personal data, especially things like pictures	Only present or report anonymized data to any of the partners	Do not share or transfer any confidential data fr...	Have a woman present to provide a more comfortable atmosphere
Lr	Location will be in the Netherlands	Tests will be done indoors in a safe environment	How will participants get to location, or would this be at their homes	As participant home would create comfortable environment, but difficult to present, and requires extra attention for privacy	Risk of participants experiencing emotional stress from environment	Be aware of surroundings when walking with stroller, empty room needed	Testing seat with child should be as safe as possible → low to the ground, stable etc.	Make experience as comfortable as possible to also account for emotional impact	COMPENSATION FOR PARTICIPATION? (travel expenses)	
Pr	Children are vulnerable and not able to provide consent for participation	Parents might not feel comfortable with testing on their children	Children could have various risks: - Filling - Finger pinching - Fiddling/twisting - Sufocation or choking	Power imbalance between adult researcher and young child		Seek guardians consent and allow them to monitor activity	obtain and monitor participants assent	Have a prototype inspected by HSE advisor	Have measures to respond to any distress or discomfort	
Rp	Are participants from my own circle, or could this be arranged through Joost?	Risk of having a too small or too similar group	Participants I know might be biased or might be hesitant to critique	Would it be ethical to get participants contact info through someone else	Participant I do not know might have a higher chance of feeling uncomfortable	Explain to participant that critique is what I'm after, its even more useful	Carefully consider who to have as participant and how to contact them			
Sm	Risk of emotional distress for the child, due to raw experimental environment	Be aware of sharing Joost confidential data	Study does involve sensitive data relating to children			Allow parent to monitor activity and comfort child if needed	Sensitive data should be minimized as short as possible			
Rm	Participants should not be deceived or unaware of any recording without their knowledge	Study will make use of a not CE certified prototype	be aware of data techniques that could result in biased outcomes	Child could experience emotional or physical discomfort	Parent could experience physical discomfort	Have a signed device report for the prototype	Adhere to European standards for childrens products, to also ensure safety	Don't do any testing on an elevation, to prevent risk of falling for child	Keep weight as low as possible, if prototype is to be carried by the parent	
Dp	Personal data could result in the participants being ID-ified	Contact information will be gathered, highly personal	If possible, I would like video recordings, so I can focus on the study and testing	Screenshots from video are likely to be taken	research is used in Master Thesis, published publicly	Any data used in the research should be carefully anonymized (e.g. no names, names, serialize game, unsorted pictures)	outline/blur any images made of participants	Keep any personal data to a minimum. Provide only range for participant age (no specifics)		

	Informed Consent				Data Management Plan				
Pc	Inform about the types of data gathered (e.g. recordings, demographics)	Communicate the risks of the data gathered	Have Consent form approved by supervisory team	Include who will be able to access the data	Only publish anonymised data	Delete gathered personal data, after anonymisation or after drawing conclusions	Only store data on personal laptops, not cloud, perhaps with a password	Only I will have access to raw data from the research	
Lr	Explain where and how the test will be done	Show the measures that have been taken to ensure safety			If at home, be aware of visual recordings, and its privacy implications	Who will be present at location? Any other passerby that might be able to see			
Pr	Respect dissent from both parent and child	Both parent or child can withdraw at any moment	Carefully explain risks the child might be exposed to	Inform about all measures taken for safety	Be extra careful with privacy for the children	Do not use any personal names	Have participants check the anonymised data that will be published?	Allow participants to access data, or request removal	
Rp	Perhaps even explain here I will not be offended by any critique	Be sure to provide an email I will still have access to after graduation			Keep any contact information of the participants private	Delete any personal contact information after the study			
Sm	Explain how sensitive data is collected and stored	Mention the risk of substance use	Explain the risks of mental & physical discomfort and how this has been mitigated	What data is collected?	Carefully consider where to store data,	Don't share sensitive data via email	Maintain data as short as possible	Be aware of having data in online clouds, including iGms	
Rm	Carefully explain how the data is collected	Explain the device has been approved by a safety advisor	Show measures taken to mitigate any discomfort		Do not use any external techniques to analyse data, to prevent bias and chance of re-identification				
Dp	Explain how data is anonymised	Explain how and when and what data is to be deleted	Mention how the data is included in the report, which is publicly published	Explain how Joost might use the anonymised data / report	Carefully consider how the published report could have a small chance of giving more media attention	After usage, contact information is to be deleted	If approved, the made videos should be deleted after analysis	Before publishing, anonymised data is to be checked by participants for approval	Necessary to collect personal data (age, gender?)

Appendix C - Interview Questions

Questions roughly used for the employee interviews (Chapter 2.3)

- Waar zoeken klanten naar in kinderwagens?
- Wat voor trends & functies zie je?
- Hoeveel weet je over ergonomie?
- Welke merken of stoelen zouden ergonomisch gezien beter zijn voor het kind
- en waarom?
- Hoe wordt ergonomie geadverteerd?
- Zijn er ook klanten die vragen naar de ergonomie voor het kind?

Questions roughly used for the parent interviews (Chapter 2.5)

Algemeen:

- Welke kinderwagen hebben jullie? En dan met wieg of met stoel?
- Hoelang hebben jullie die al?
- Zou ik misschien een foto van kunnen maken?
- Als ik mag vragen hoe oud is uw kind?

Kopen:

Hoe en waar hebben jullie hem gekocht?

- Was het een snelle aankoop?
- Waar zochten jullie naar, nog specifieke functie?
- Hebben jullie ook accessoires bij gekocht of gekregen?

Ergonomie:

- Wat weten jullie over ergonomie en de positie en zitting van het kind?
- Weten jullie bijvoorbeeld wanneer te wisselen naar een stoel
- Waar deze info vandaan?

Gebruik:

- Hoe vaak gebruiken jullie de wagen?
- In wat voor situaties, hoe ziet een gemiddeld dagje eruit?
- En als jullie niet gebruiken waar staat ie dan?
- Zijn er ook negatieve dingen aan de wagen?
- Hebben jullie nagedacht over wat jullie na gebruik met de wagen willen doen?

Questions roughly used for at the Nine Month Fair (Chapter 4.3)

Parents:

- Mag ik wat vragen, student ontwerpen, op zoek naar feedback
- Vindt u het goed als ik wat dingetjes opschrijf?
- Heeft u kinderen, verwacht u een kind?
- Heeft u ervaring met het vastzetten van kinderen, met bijv. gordeltjes?
- Wat zijn de stappen van het kind in de wagen zetten?
- Wat gaat er dan handig/onhandig?
- Hoe zou u het vinden als het harnas los van de wagen aangetrokken kan worden? pak visual/Prototype
- Wat voor gevoel krijgt u hierbij? En ik probeer het te verbeteren, dus wees vooral kritisch en geef tips.
- Wat denkt u over de veiligheid? Waarom?

Companies & Observations:

- wat is er op het gebied van vastzetten, bewegingsvrijheid, en veiligheid, nog nieuwe innovaties?
- hoeveel bewegingsvrijheid heeft een kind nodig?
- "Zit dat dan niet te strak" / "Heeft het kind wel genoeg bewegingsruimte"

Appendix D - Ethical Consent Form

Informatie

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd *Investigating the gap between design vision and user practice in the stroller industry*. Dit onderzoek wordt uitgevoerd door Max Hessels van de TU Delft namens het bedrijf Joolz, als onderdeel van een afstudeerproject voor de master Integrated Product Design van de faculteit Industrial Design Engineering.

Het doel van dit onderzoek is een beter beeld te krijgen van het aankoopproces en gebruik van kinderwagens, met een focus op ergonomie, en zal ongeveer 30-45 minuten in beslag nemen. De data (in anonieme vorm) zal gebruikt worden voor het beter begrijpen van gebruikers van kinderwagens. Dit is onderdeel van een afstudeerproject, wat aan het eind gepubliceerd wordt in de publieke Repository van TU Delft. U wordt gevraagd om een aantal vragen te beantwoorden, zowel verbaal als een meer interactief element wat bestaat uit het plaatsen van plaatjes op een vel papier.

Zoals bij elke online activiteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. Voor dit onderzoek vragen wij om toestemming om geluidsopnames te maken en afbeeldingen van de kinderwagen. We minimaliseren de risico's door geen persoonlijke namen te noemen en in de gemaakte afbeeldingen u of uw leefomgeving onherkenbaar te maken. Verder zullen geluidopnames of transcripties niet gedeeld worden, ook niet met TU Delft of Joolz, en puur gebruikt worden voor het maken van notities, om conclusies te trekken, en om in geschreven vorm gebruikt te worden in het eindverslag.

Uw deelname aan dit onderzoek is volledig vrijwillig, en **u kunt zich elk moment terugtrekken zonder reden op te geven**. U bent ook vrij om vragen niet te beantwoorden. De gemaakte afbeeldingen zullen binnen een week onherkenbaar gemaakt worden en de originele verwijderd. De gemaakte geluidsopnames of transcripties zullen uiterlijk 02/03/2026 worden verwijderd. U heeft het recht om toegang te vragen tot deze data, en indien gewenst verzoeken om deze te verwijderen.

Contact:

Max Hessels –



Toestemmingsverklaring

1. Ik heb de informatie over het onderzoek gedateerd [20/10/2025] gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.

JA / NEE

2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.

JA / NEE

3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent:

JA / NEE

- een interview gedocumenteerd d.m.v. geluidopnames en afbeeldingen.
- van de audio wordt een transcriptie gemaakt, en beiden worden niet gedeeld en voor het einde van het project (02/03/2026) verwijderd.
- in de afbeeldingen zal indien van toepassing zowel u als uw leefomgeving onherkenbaar worden gemaakt, en het origineel binnen een week verwijderd worden.

4. Hierbij geef ik specifiek toestemming voor het maken van:

- Afbeeldingen

JA / NEE

- Geluidopnames

JA / NEE

5. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. Stappen die genomen worden om dit risico te minimaliseren zijn:

JA / NEE

- het niet documenteren van namen
- het niet delen van audiobestanden of transcripties
- het verwijderen van de persoonlijk identificeerbare informatie na gebruik
- het anoniem maken van afbeeldingen

6. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals [*bijvoorbeeld naam, woonplaats*], niet gedeeld worden buiten de onderzoeker. JA / NEE

7. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor: JA / NEE

- het afstudeer rapport, welke publiek gepubliceerd wordt in de TU Delft Repository
- de publiek toegankelijke eindpresentatie van de afstudeerder
- indirect voor het ontwikkelen van een ontwerp concept, welke mogelijk verder ontwikkeld wordt door de opdrachtgever Joolz

Signatures

_____	_____	_____
Naam deelnemer	Handtekening	Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

_____	_____	_____
Naam onderzoeker	Handtekening	Datum

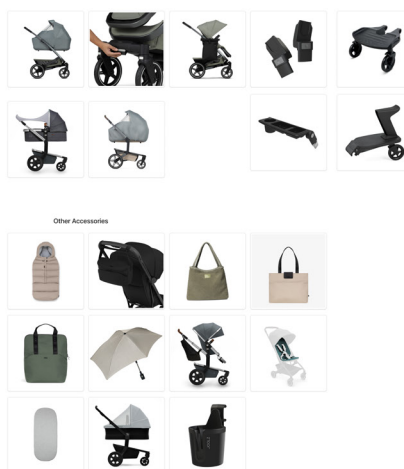
Contactgegevens van de onderzoeker voor verdere informatie:
Max Hessels, _____

Appendix E - Product Portfolios

Joolz Portfolio



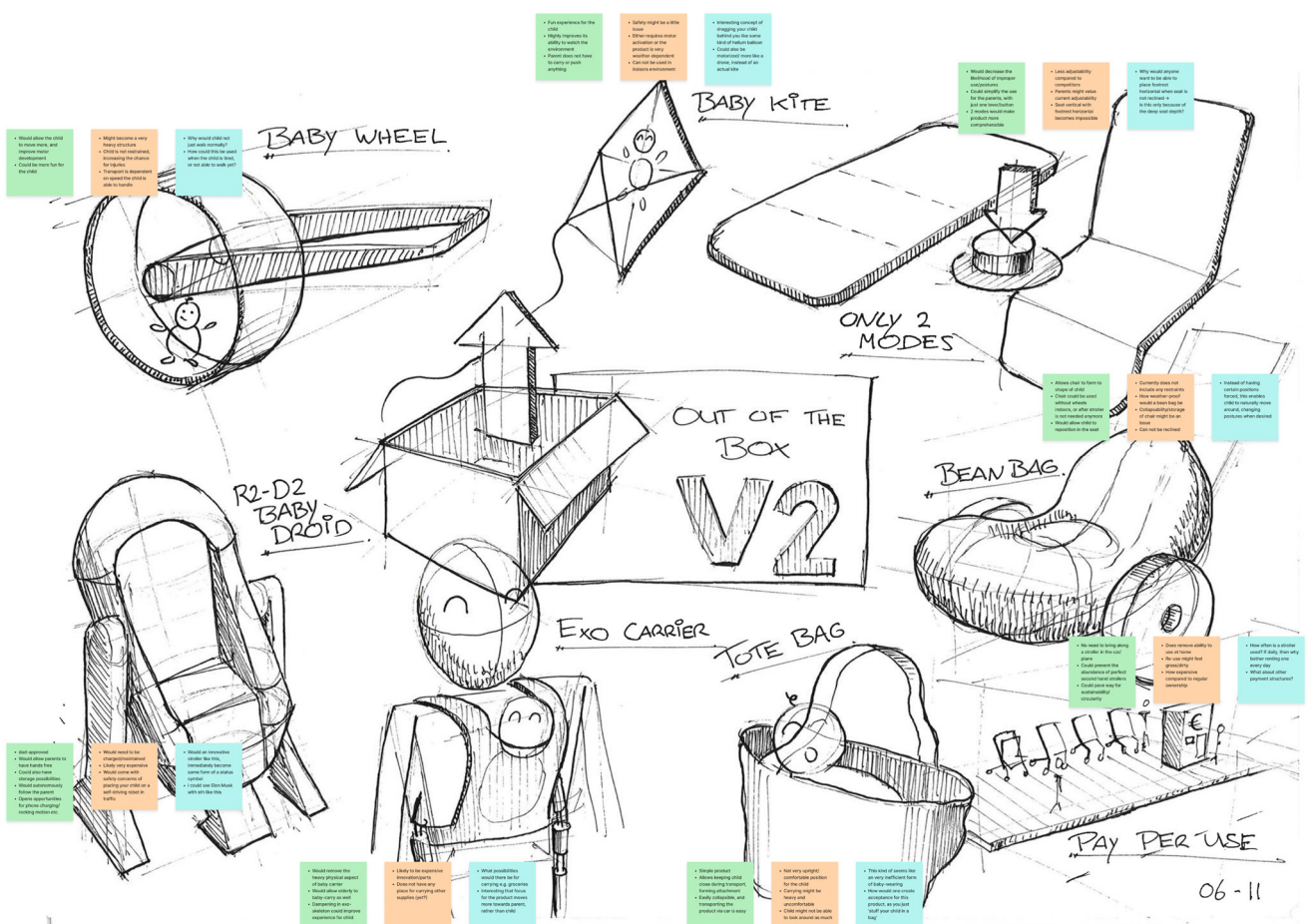
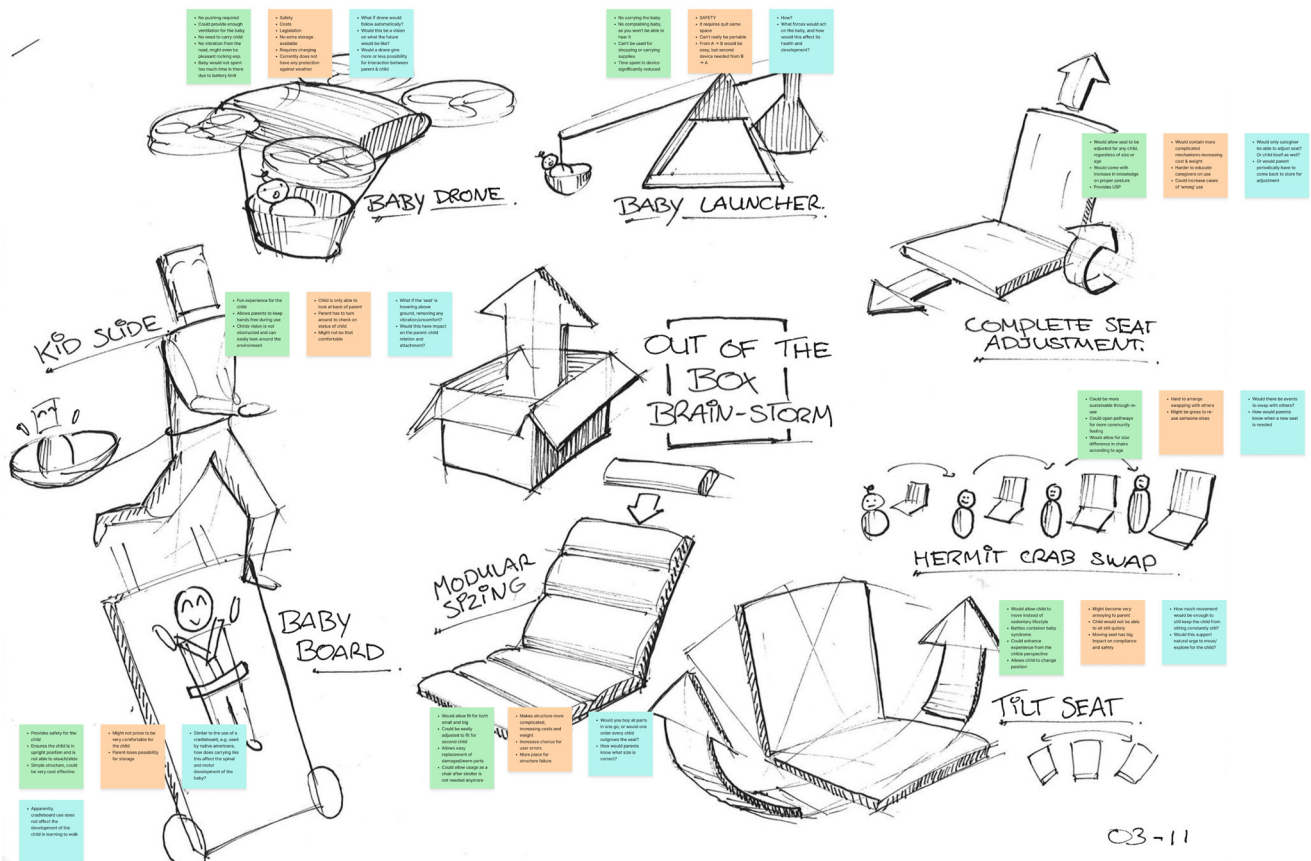
Accessories for Comfort Strollers



Some competitor Portfolios



Appendix F - Initial Sketches





Appendix G - Problem Areas

Growing Children

Children grow and develop at a rapid pace. However, an 8 month old and a 3 year old use the same stroller. This leads to uncomfortable positions for children small and big. Proper sitting is simply about sitting in a seat which fits. Through modular, adjustable or shape-morphing seats, a proper fit could be ensured. Additionally, another option could be a product-service-system, consisting of multiple sizes. Such a system could have sustainable benefits through the reuse of seats.

Research Results



- Literature shows the rapid development in children, and addresses their change in size and needs
- Interesting concepts are shown (e.g. Nomi chair)
- Concerns about the overuse of strollers at older ages



- 6 months is too young to transition from cot to seat
- Impossible thing about strollers is that an 8 month old and a 3 year old child should use the same seat
- Current seats are often too deep, with the harness too far forward, allowing the child to slump
- Furthermore, the footrest is often too high



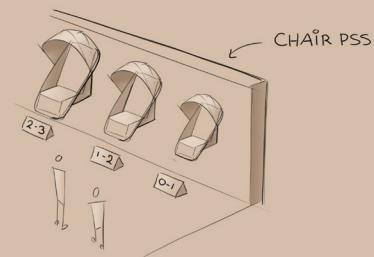
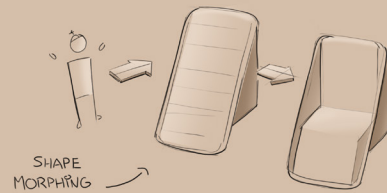
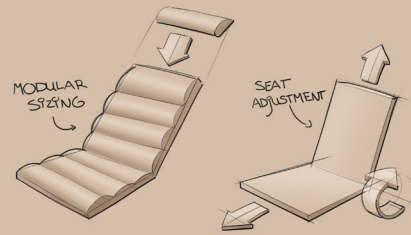
- Employees state child should be in seat after 6 months
- Ergonomics and comfort is not advertised, but is mentioned in sales pitches and conversations
- Important aspect of child's ergonomics are the deep seats and high backrest



- Stroller is bought with both cot & seat, transition is based on 6 month guideline, if child is able to sit, and child preference
- Cots used to be bigger
- Important aspects of stroller are a high backrest and adjustable footrest



- Multiple uncomfortable positions were observed, related to the length of the back, legs and specifically the thighs:



Futures

Through researching the past and present, possible futures of strollers can be envisioned. Portability of strollers is an important criterion for parents, what if you never even have to bring your stroller again, through a pay-per-use system? With current developments in e-strollers and robotics in general, a self-driving and self-balancing stroller might not be that far-fetched. However, a stroller is besides functional, an emotional product. An exoskeleton could assist in babywearing, to create a bond and attachment with your child.

Research Results



- Over more recent years in stroller history, there has not been much functional innovation, with changes being more ornamental
- Future might be in modularity, sustainable materials or battery technology
- Would we have gone too far as humanity if we consider self-driving strollers?
- Recent literature draws attentions to possible health risks for infants due to vibration exposure



- A stroller remains a mode of transport, not a long term seating, however it transports more than just children, also goods, groceries, bags
- Knowledge on proper posture and raising children has been lost over the years, what could this mean for the future?



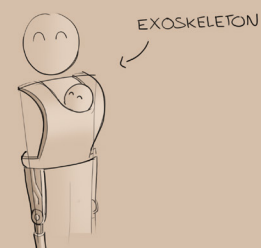
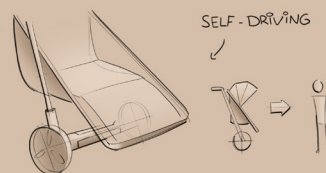
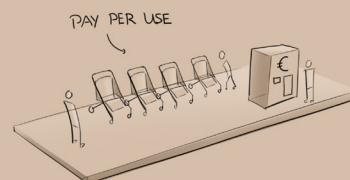
- Increasing trends in accessories and extra features (e.g. e-strollers, lighting, phone charging, phone holders, fans)
- Companies are following each other, 1 has something, others will follow



- Some parents really value forums and a community feel. They value other people's experiences
- Participants did opt for second-hand strollers, yet Marktplaats is full of them and thrift stores do not accept them anymore
- Even though parents look at functional requirements for their stroller, it is still an emotional product, related to raising your own child.



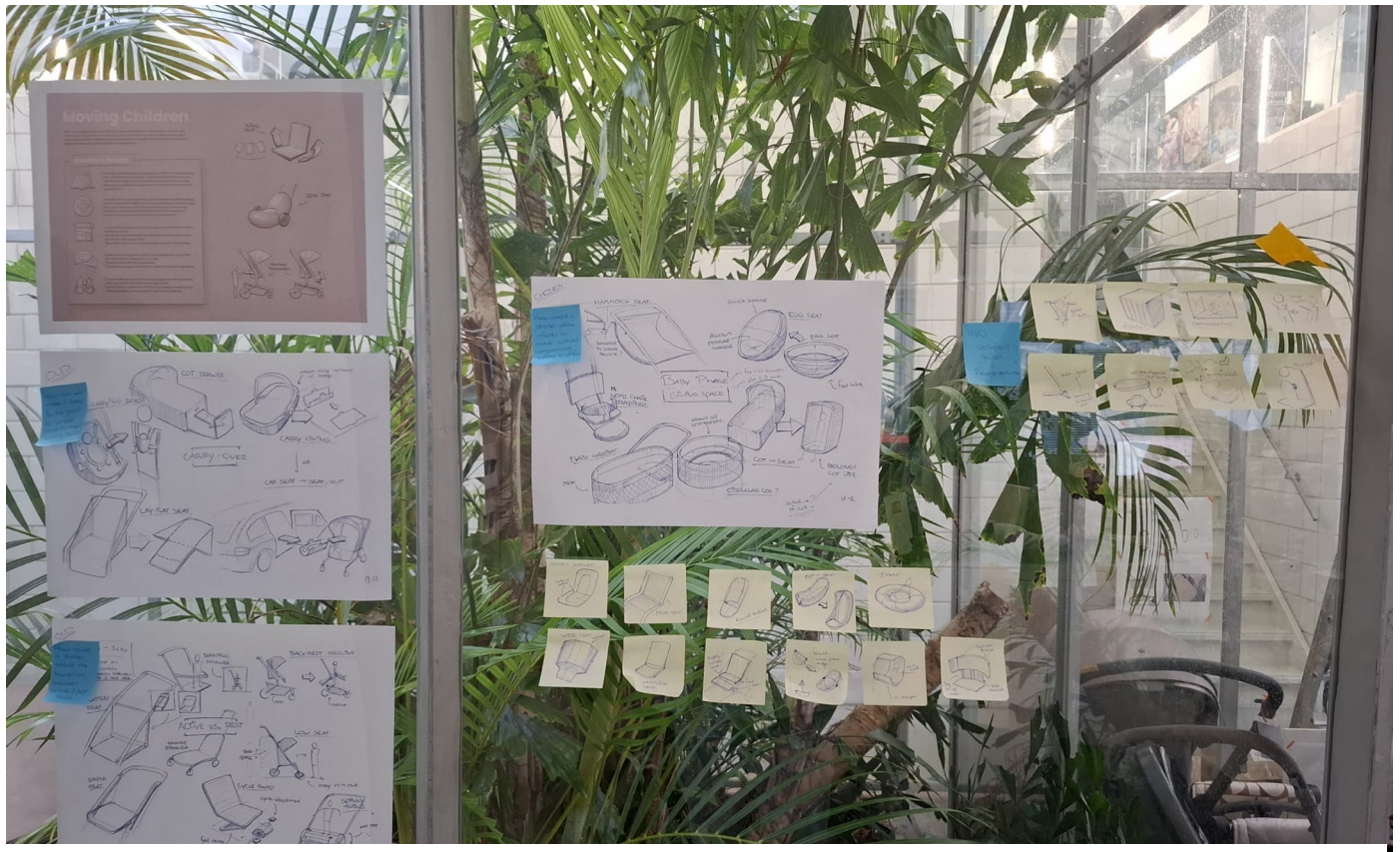
- Seen the bumper bar used for various accessories (e.g. fans or steering wheel)
- Specifically when visiting Blijdorp, there is a possibility to rent a stroller for a day, to use during your visit

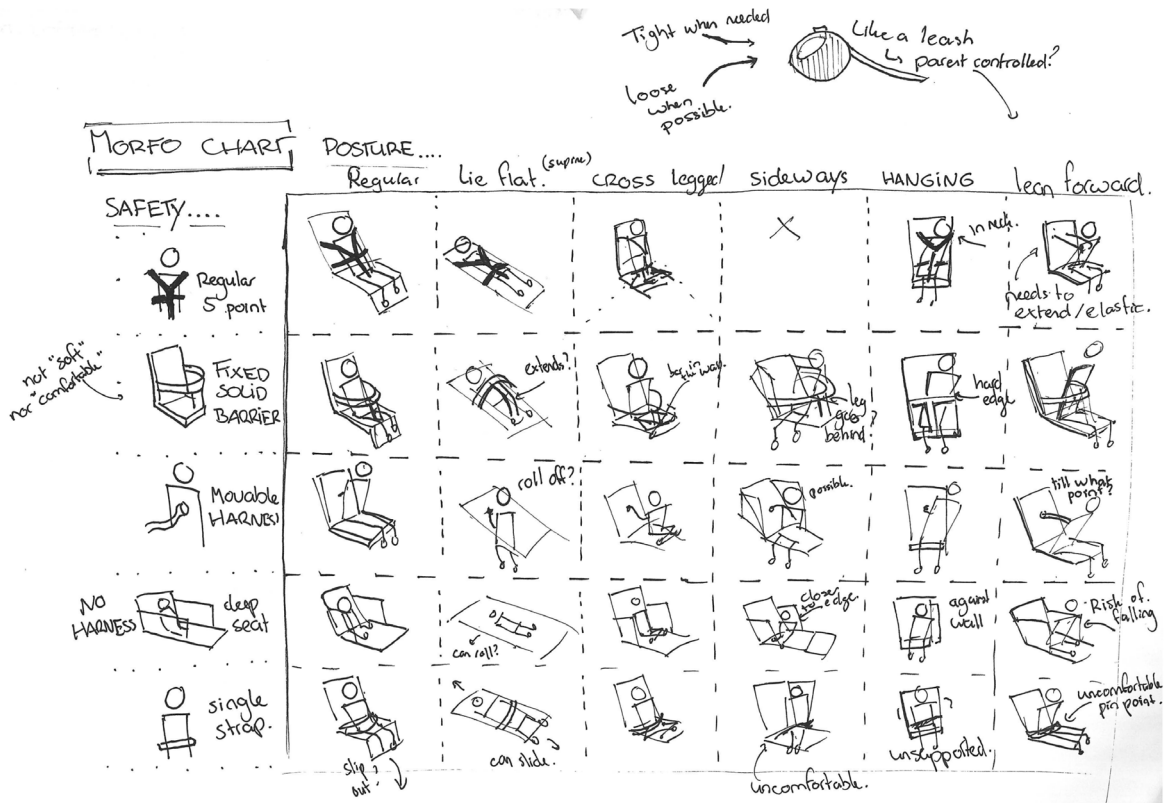
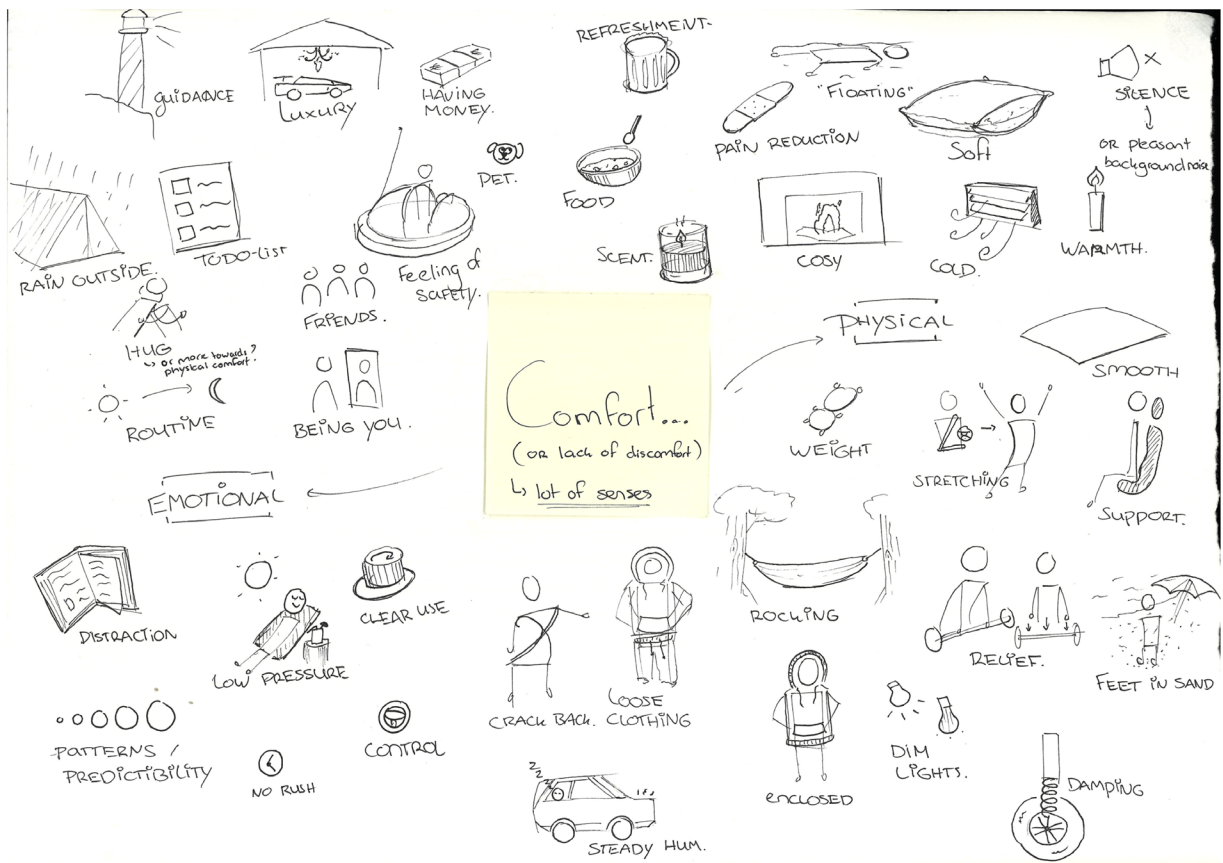


Appendix H - Problem Areas Evaluation

	Growing Children	Moving Children	Futures
Research Alignment	+ Multiple concepts shown for grow-with-me products. + Occupational therapist confirmed its weird that a 8 month old and 3 year old should both fit the same stroller. + Current seats are often too deep and the footrest too high, which was also observed in the study. - No real evidence could be found for negative effects of being too big or small for stroller.	+ Supported in literature, term 'container babies'. + Recent guidelines by WHO and Dutch health council have been developed promoting daily physical activity. + Occupational therapist confirmed problem, and stated natural urge and benefits for children to move. + Children were observed taking all kinds of positions and postures in strollers, showing urge to move. - Real evidence remains unclear, although multiple sources mention this problem area.	+ No real functional innovation over the years, could be time for something new. + Rise in use of electronics in strollers. - No real grounding in the research, very speculative problem area
Value to Joolz	+ Having a more adjustable seat could provide a unique selling point. + Using different sizes of chairs or modular parts could increase touchpoints and engagement with customers. - Adjustability mechanics would be harder to implement while fitting the clean Joolz design style. - Commonly addressed problem, which might be difficult to actually implement a solution for. - As mentioned by Joolz designer: "the boring option"	+ As mentioned by Joolz designer, "the more interesting option". + Could provide a unique standpoint and vision in the industry. + More creative problem, which could lead to more unique results or innovative designs. - Might not be a great fit as strollers are part of the problem, best option would still be to spend as little time in the stroller as possible.	+ Could provide a very creative insight into the future of strollers. + If done correctly, it could prepare Joolz for a possible future, putting them ahead of their competitors. - High possibility the end result might be more of a nice vision, and not of real use to the company. - As industry stayed relatively similar in their products, something different might not fit the company.
Potential User Impact	+ Child would be able to comfortably fit in a stroller, adjusted to their size. + Proper fit could also have other physical benefits, some state wrong posture could lead to spinal deformations. - Would require more knowledge and responsibility for parent to choose the right seat or adjust to the right dimension, leaving more room for user error.	+ Child needs movement not only to develop physically, but also to stimulate the brain. + Child might feel more comfortable and less restricted. - Unclear how big the problem is, and how effective a change in strollers/transport could have - Solutions in this area might cause an overactive restless child, undesired by the parent.	+ Likely will make the life of the parent easier or would have positive effect on sustainability. - Area is too vague to assess potential user impact. - Resulting impact of vision will likely remain just a guess.
Project Feasibility	+ Clear problem area to explore and design for. + Likely doable in the given time frame - Would require expertise on embodiment, likely a concept won't be enough as a project goal. - A bit more straightforward engineering task, less design freedom.	+ Interesting and uncommon problem to design for in this context. + With a concept as end goal, it fits the project brief. - A bit more vague and difficult to design for. - Solution likely difficult to evaluate without children to see their behaviour	+ Could be a very creative project, not restricted to current the current market and available technology. - Will likely be an entirely different type of project, very future vision, conceptual or critical design focused. - Possibly difficult to realise a working prototype

Appendix I - Ideation Inspiration





Appendix J - Concept prototypes

Concept 1:

Main Questions:

How big does it have to be to provide enough space for movement?

How big does it feel when walking behind it or seeing it from a distance

How big can it be, based on sidewalk width?

Research:

Anthropometric data

Sidewalk measurements taken:

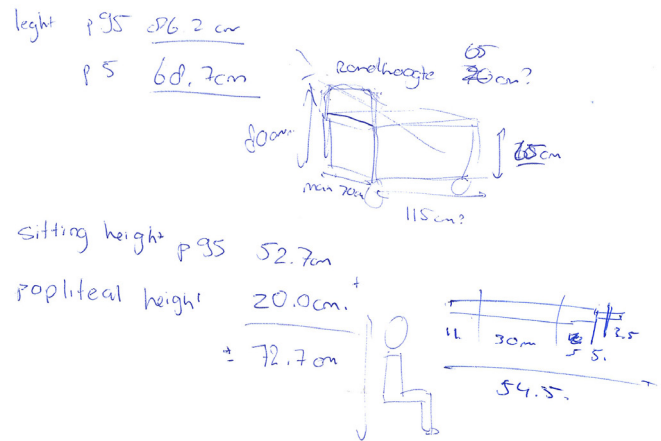
Total width: 170cm

Walkable width: 150cm

Walkable width with light pole: 120cm

Don't forget any overhanging shrubbery

Prototyping:



Evaluation:

Based on personal opinion, the prototype does not seem excessively large in an outside context.

Furthermore, one could consider if lying down is really necessary for the child.

Further evaluations should be done in testing parents' perception of the prototype and its size.

Concept 2:

Main Questions:

How does a car seatbelt work?

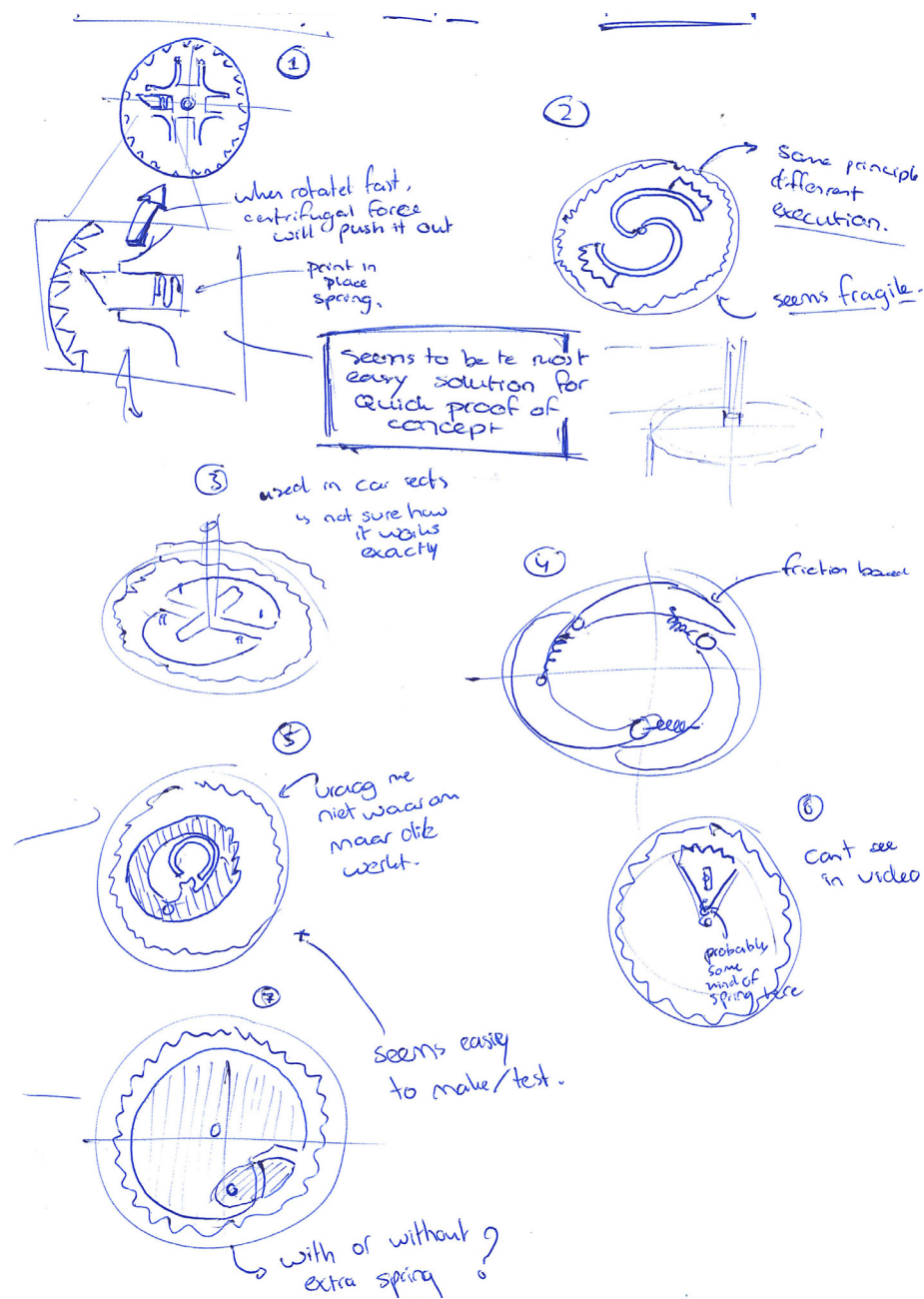
How could I make a version to be used as a proof of concept?

How could this be applied in the context of a stroller?

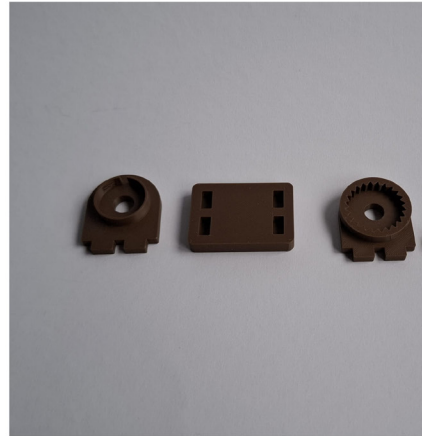
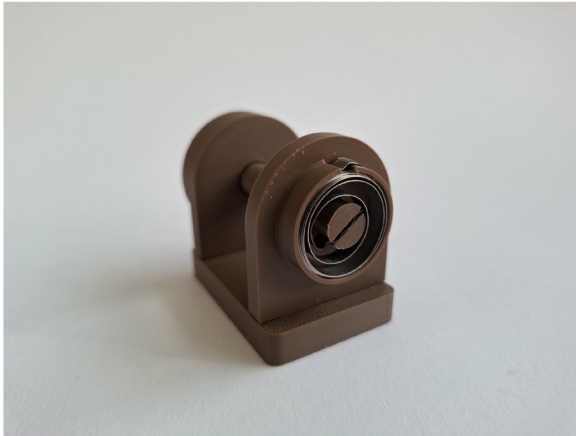
Research:

Youtube videos and existing patents were consulted to learn about existing seatbelt mechanisms.

Prototyping:



Retracting:



Brake Mechanism Testing:



Evaluation:

Retracting is properly functioning, but none of the brakes are. Currently orientation plays a huge role in mechanisms 1 & 2, as gravity will pull them down in their locked state, even without the centripetal force from pulling the belt. The spring in mechanism 3 is too stiff to be activated, and the spring-like functioning of mechanism 4 is too fragile and broke during use. Further prototyping is required to balance all the forces and strengths needed.

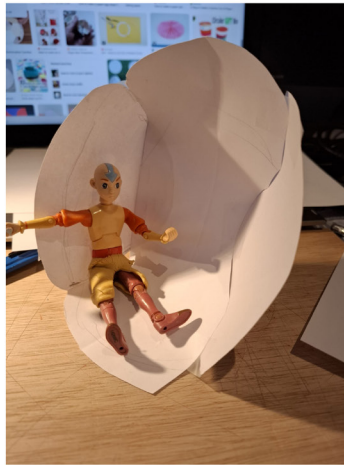
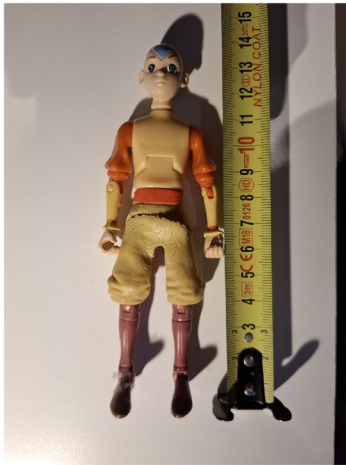
Concept 3:

Main Questions:

How big would the seat have to be to account for different postures?

What kind of positions could this shape allow?

Prototyping:



Evaluation:

Some quick attempts were made to construct an egg-like shape, to get a feel of shapes and dimensions. An articulated toy was used to portray different positions. However, this figure does not accurately represent the proportions of the target group.

Taking the figure's size of 14cm and the mean size of the target group of 77cm, would mean a scale of 1:5.5. The total width of the seat is 12cm. Using the scale would result in a real life seat width of 66cm, just within the maximum width of 70cm (based on sidewalk width).

Appendix K - Design Sprint

Graduation in a day!

Planning:

9:00 - 11:00, nodige onderzoek, pop vragen, sw model vragen

11:15 - 12:30, brainstormen, gewoon knallen, misschien dmv vr bril

13:30 - 14:00, idee uitzoeken om verder mee te gaan

14:00 - 14:30, materiaal bij elkaar sprokkelen, wat er bij Joolz ligt

14:30 - 16:30 keihard prototypen

16:30 - 17:00 feedback vragen (IS HEEL KORT, anders doorschuiven naar donderdag)

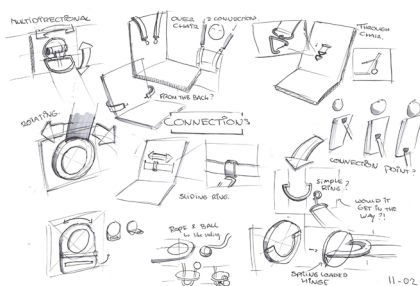
Field Research



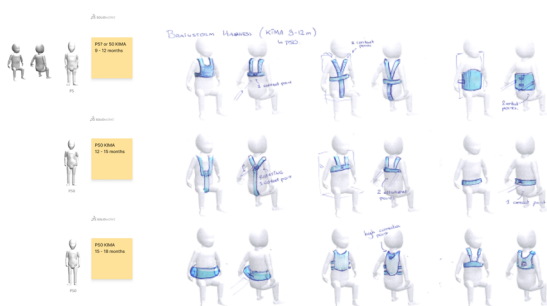
Brainstorm



Brainstorm Connections



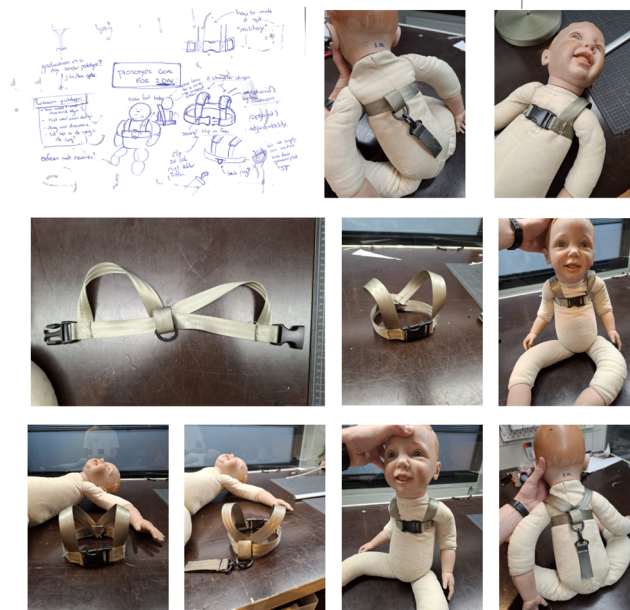
Brainstorm Harness



Online Research



Prototyping (With Weighted Doll, representing a 1 year old)



Evaluation (PMI)



Appendix L - Results 9 months fair

Parent	Topic	Current Harness Use	New Concept	Prototype Specific	Other Comments
P1		- Adjusting straps is quite a hassle when winter jacket is taken off or put on. - In the car seat, the straps tend to twist. - Adjusting the straps in chair is not very easy with the sliding bar buckle. - No jacket problem in car seat as this is taken off for safety, due to the play in the thick fabric of the clothing.	- Would be safe in a stroller seat, but not sure when used in a car seat. - Connection in the back would seem uncomfortable for the child. - How protected would the neck be as it is not supported and could flop around? - How easily can the harness be disconnected, for example in car seat, when car hits the water?	Material seems hard and has some sharp edges, perhaps some silicon type material would be better.	- After mentioning connection on the shoulders: - Would seem an easier interaction for the parent, compared to moving the kid forward to access their back. - Could also provide a bit more neck support.
P2		- Using button is quick and easy to open. 5 point harness provides safety. - Does not have issue of child sitting against the harness. - Tripp-Trapp chair harness is bad, as child did sit against/on the harness, and they have come up with own way to fix this.	- The woman first impression was not very convenient, but the other (likely her mother) did find it clever, she stated it's currently a hassle. - Could not really explain why? (first on then having to get in the seat) - Convenience depends on connection . - How would the harness adjust to with or without a jacket? - How safe would it be? You don't want child to turn around, but head can still flop forward.	- Not very convenient to have connection on the back. - Is very thick, will be uncomfortable for the child. - Also on the sides would not seem comfortable. - How does the connection work? Just click it in there? - Best would be if the connection part is in the chair, and not on the back of the child, almost like an isofix, just click in.	- Child does need movement freedom, to play and be able to interact with stuff - Constant use of car seat is pitiful, child shouldn't be in there all day. Stroller with car seat is fine for a small shopping, but not day at the fair.
P3		- Child takes off the harness by themselves (currently 2 years old). - Current use is only convenient if the child cooperates. - Have stopped using the harness.	- If it is a vest, the child is also able to undo zippers already. - Entire vest would seem a bit too much for a stroller, more something for a car seat. - A connection in the back might not be comfortable.	- The connection would definitely be felt in the back. - Her child is already picky, and would definitely notice that. - How would the vest be adjustable and fit all sizes? - A vest might cause a trapped feeling, the child should still be able to sit nice and relaxed.	
P4		Her child crawls out of the harness themselves, however, this only started at an older age.			They were in a hurry
P5		- Current situation is kind of annoying, especially when in a hurry. - Having all these separate straps make connecting and adjusting take longer. - Sometimes the connection is upside down, so it doesn't work. - At the fair, they only used the bottom connections to give the child some movement freedom.	- How would a vest like harness work, both in summer in just a shirt, and in winter with a thick jacket or sweater. - Their child tends to get hot easily, how breathable would the vest be? - Quite a nifty idea as child wants to be able to move.	- Would such a connection be only suited for one specific stroller or company, or could it be used for different brands? - Perhaps it could make use of the existing holes in the seat?	Currently your are kind of stuck with a stroller brand, everything you buy tends to be from the same brand.
P6		- Currently quite easy to use, likes that all harness points can be used separately, and that you don't have to click in two points together. - Often do not use the harness straps on the sides, but this does cause the child to sit a bit slumped. However, they do not mind this hanging in the seat.	- Good idea as it provides movement freedom. - Undoing the connection on the back would be difficult. Connection could be convenient, but disconnecting more challenging when the back is against the backrest. - How could the harness be adjustable?	- How high on the seat would the connection point be? - With the connection point, keep in mind that reclining the seat will change the position of the child relative to the backrest.	Maybe disconnecting could be done through a button on the stroller?

Company	Comments
Thule	- All brands have similar harnesses. - Swedish brand, so pretty safety focused. - Pelvis and shoulders should be fixed. 5 point harnesses are used for safety. - Movement freedom not that important compared to not being able to fall out of the stroller. - They have a new disconnect system for the harness (Magnet Buckle) which allows easy use and instead of pressing a button into the child, makes use of a pinching interacting. - No studies on time in a stroller, do have some advice on time in car seat. - Sleeping is done in flat position. - When young, the child is best placed in a cot. - Baby carrying is done in the M-position of the legs.

Appendix M - Observations 9 months fair

Observations

While walking around, pictures were taken of any innovative sitting devices or interesting harnesses presented by other companies. Special attention was given to harnesses used in bouncers. Both manually and machine operated bouncers were observed. The Elvie Rise one of the winners of the baby innovation awards 2026, can even turn into a bassinet. However, the lack of shoulder straps remained interesting, even if the bouncer was not a stationary sitting device.



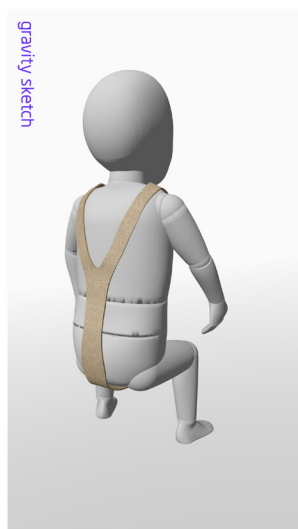
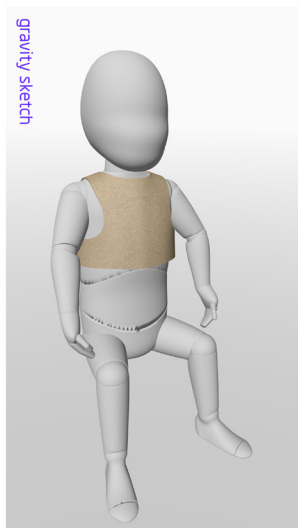
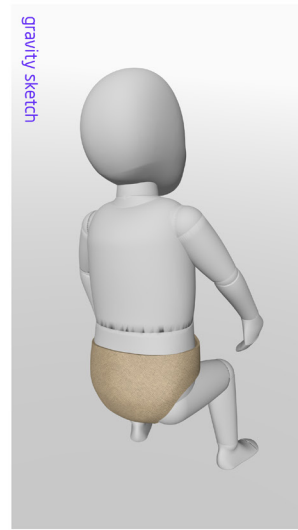
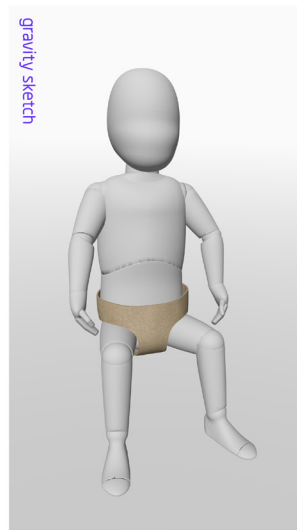
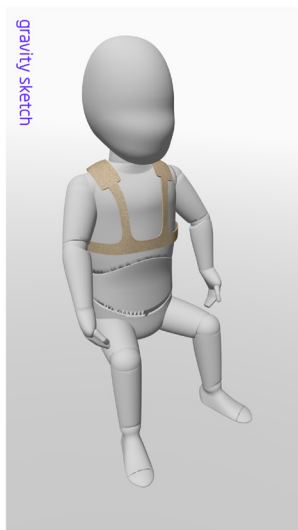
Other observations of harnesses standing out were a Cybex car seat, making use of only one big belt. And the JoeyBubbles Showeroo, meant for showering with your newborn.

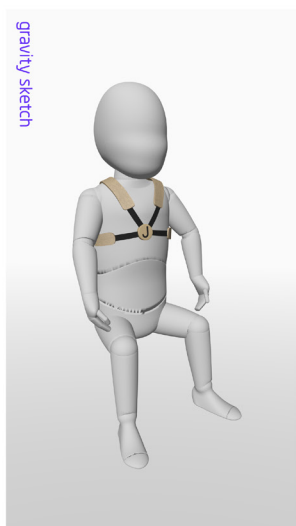
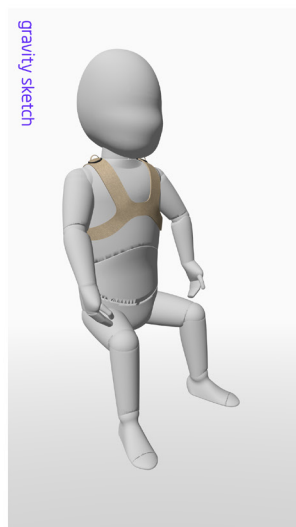


Finally, to gather some examples of existing vests for improving the prototype, were taken. This teddy fabric seems to be popular and was also seen as bags during the observations in Blijdorp.



Appendix N - Gravity Sketch Iterations





Appendix O - Connection Testing

Shoulders (Long & Short)



Sides (Long & Short)



Back (Long & Short)



3D printed on Back



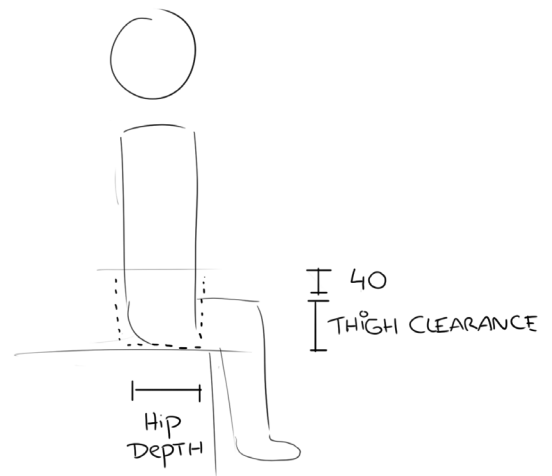
3D printed on Shoulders



Appendix P - Estimated Dimensions

The relevant dimensions were defined based on the anthropometric data from Chapter 2.7. The two measurements needed were: the waist circumference and the crotch length. Both measurements were not found in the available data. However, to approximate the waist circumference, the chest circumference was used, based on the similarity found in children's sizing guides for clothing (Kair, n.d.; Kids Around, n.d.).

To approximate the crotch length, both the hip depth and thigh clearance were used, combined with a distance of 4 cm from the top of the thigh to the waist, measured using the KIMA model.

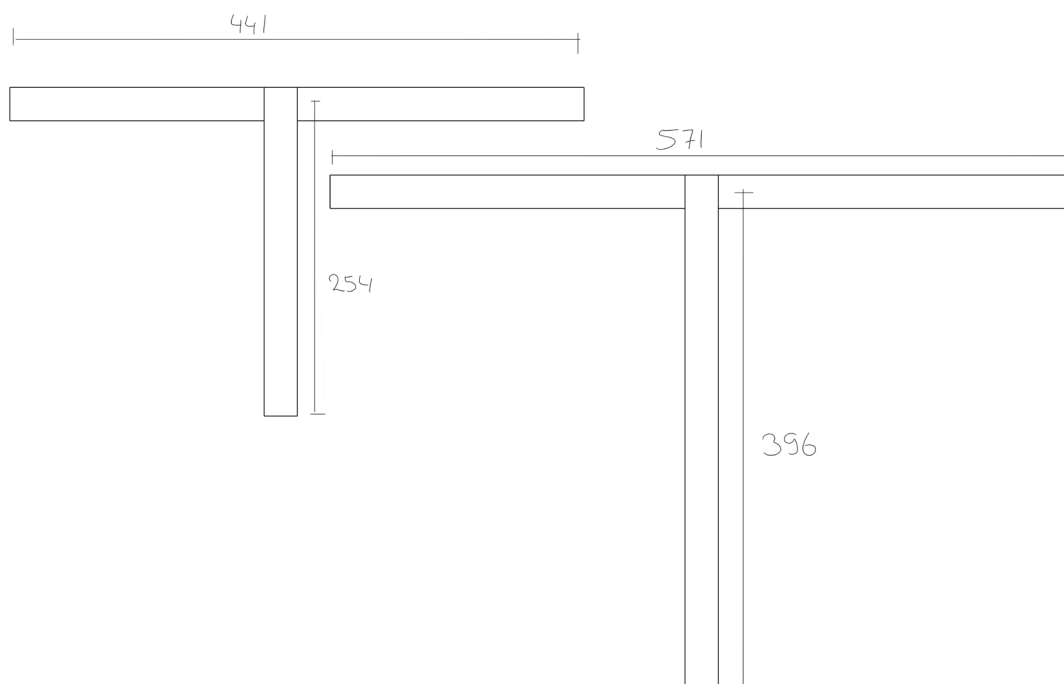


For the crotch length a margin of 3cm was taken to account for diapers and other clothing. For the waist circumference the raw data measured by Pardue (2019) was used by finding the mean difference in hip circumference for children 9-13 months with and without diaper, resulting in a value of 4.7cm.

This resulted in the following dimensions (seen below):

Waist circumference: **411** (=p5 chest circumference) to **571** (=p95 chest circumference + 47)

Crotch length: **252** (=p5 hip depth + 2*p5 thigh clearance + 2*40) to **396** (=p95 hip depth + 2*p95 thigh clearance + 2*40 + 30)



So now we have estimated the waist circumference to be between 411 and 571 mm.
And the crotch length between 252 and 396 mm

At the smallest size, the fabric should just touch the buckle. Therefore, to determine the lengths for the fabric, for both the waist circumference and the crotch length, the p5 value was subtracted by the width of the buckle (70mm).

waist pad: $441 - 70 - 70 = 301\text{mm}$

crotch pad: $252 - 70 = 182\text{mm}$

For the largest size, there should be sufficient webbing to go around the body. For the lengths of the webbing, from the p95 values, half of the connector was subtracted and a small tab of 4cm was added, to always have some webbing remaining:

waist webbing: $571 - 35 - 35 + 40 + 40 = 581\text{mm}$

crotch webbing: $369 - 35 + 40 = 401\text{mm}$

Finally, the point on the harness should be determined where it will be connected to the chair. The location of these points should be at the sides of the child. However, this position will slightly change relative to the waist circumference. This difference should be insignificant for the functioning of the product, therefore one location was chosen based on the mean circumference.

Taking the mean chest circumference of 481mm, the sides should be around $\frac{1}{4}$ of this value, at 120.25 from the centre.

Combined with a fabric thickness of 4cm the resulting dimensions are shown below and in Figure 4.33.

