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Brand and Concept Development of a Child Restraint System

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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Gothenburg, Sweden 2015

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Abstract

Child restraint systems in their modern form have existed since the 1960s and can therefore be considered a mature product. In such a market it becomes increasingly difficult to compete with innovative solutions, and smaller companies may have to focus on ways to distinguish themselves through other means.

This project aims to investigate ways to increase competitiveness of a small company on a market with much larger competitors by improving visual brand management and usability aspects of their products. This is achieved by performing a usability study, together with a statistical analysis of the semiotic characteristics of child restraint systems.

This knowledge was then translated into three concepts which aimed to incorporate the characteristics which were found to contribute most towards the total impression of a child restraint system. The concepts were then evaluated against existing products on the market to verify that the designs were successful and lastly a final concept was developed from the most desirable traits of these three concepts.

The results show that there seems to exist measurable correlations between different signs and an assumption can be made of how these dependencies can facilitate the creation of appealing products by having an impact on a customer's affective evaluation of the product.

Acknowledgments

We would like to begin this project report by acknowledging the people who have helped and supported us in our work. Their input and support has been essential to the success of this project.

We would like to thank the people at Axonkids for providing us with the opportunity to perform this project, with a special thank you to Tony Qvist, Daniel Johansson and Dennis Anderberg for sharing their knowledge of child restraint systems.

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Jon Sandström & Jonatan Bergström
Gothenburg, 2014

Contents

1. Introduction

This chapter introduces the "Branding and Concept Development of a Child Restraint System" master thesis project. It describes the background, problem definition, aim, goal and delimitations as well as the process of the project.

1.1. Background

Child restraint systems (CRSs) sold in Europe need to comply with United Nations regulations, with different requirements for different groups of CRSs depending on the weight of the intended passenger. Previously the weight limit for each of these groups has been specified by the seats weight alone. A recent revision to the standards for child restraint systems with ISOFIX connectors specifies the maximum weight as the combined weight of the seat and the child. This new set of regulations is commonly referred to as "i-Size". i-Size regulations also state that CRSs can only allow installation by ISOFIX connectors, not by the car's seat belts.

These new standards open up new possibilities for companies to change the appearance and features of their child restraint systems as the products now can be designed with only one specific type of fastening in mind. This can be utilized in order to reduce the perceived complexity of the product and also gives greater freedom for the aesthetical design and possibly new features as well. The market for child restraint systems is highly competitive with several international brands which makes it important for companies to be able to compete on many levels of product design.

Aesthetic qualities is something humans are drawn to and research show that it can also have a significant influence on our evaluation of a product (Page & Herr 2002). The same report also shows how brand strength has a similar effect and can have a positive effect on trust. Factors like these gives an indication on the importance of active management of visual brand in product design.

The project described in this report has been carried out in close collaboration with Axonkids, a Swedish manufacturer of child restraint systems under the brand name Axkid. The first Axkid CRS was released for sale in 2011 and six different models exist on the market today (2014). No formal usability study has been performed in the development of the current product line, nor do the products conform to a well-defined brand identity. Axonkids has expressed the wish to make improvements in both fields with future product releases.

1.2. Problem Description

This project is based on Axonkids ambition to improve their competitiveness on the market. A recent revision to CRS regulations known as i-Size which requires significant alterations to the current product range is used as an opportunity to revitalize the brand and its products.

1.2.1. I-Size

The design of today's CRSs is controlled by a number of standards in order to aid the integration of these products between car manufacturers and CRS manufacturers. These standards enable solutions such as the ISOFIX system for fastening the CRS to the car seat. United Nations Economic Commission for Europe (UNECE) is the governing body that publishes the regulations for these standards. On the ninth of July 2013 a new standard came into force and is known as "UNECE R129" or "i-Size". The i-Size standard is a new standard similar to the older UNECE R44 standard for child restraint systems but it has some significant differences. Some of these include mandatory side protection and ISOFIX fastening. This means that a CRS conforming to the i-Size standard will not have to support being installed and secured with the cars seat belts and thereby a simpler visual expression is possible by removing visual clutter and usability aspects can be optimized and simplified in order to only support one method of installation instead of two.

Another significant difference is that the maximum allowed weight is calculated by adding the weight of the child to the weight of the CRS. Previously, maximum weight was specified for the CRS and the child separately, dividing CRSs into different weight groups. For i-Size CRSs the maximum combined weight of the CRS and child is 33kg. For Axonkids this means that they cannot merely adapt their previous products to conform to the new standard since the current line of products can't comply with the weight restrictions of i-Size. A new design is needed in order to achieve this.

1.2.2. Market

Axonkids as a company is very small when compared with many of its competitors. Brands such as Maxi-Cosi is owned by the multinational parent company Dorel-Juvenile whose Europe division employs 1300 people in 13 countries (Maxi-cosi 2011). Other significant competitors include Britax, Cybex and Besafe all of which are significantly larger than Axonkids. There are also numerous other smaller companies which in total makes the market highly competitive. Although the automobile has been around since the late 1800s a patent for the first real child restraining system was filed first in 1962 by Leonard Rivkin. This means however that the concept of a CRS is over 50 years old and this in combination with widespread usage has made the CRS a highly mature product.

The maturity of the market also makes it increasingly important for companies to create products with unique features to distinguish themselves from the competition. Features that may once have been state of the art innovations may over time have turned into expectations. Good human factors in general have also become more of an expectation rather than an added bonus (Jordan 2000) and for a small brand such as Axonkids it becomes increasingly important not to fall behind in such fields, else they risk the loss of a significant number of customers. To further increase the competitiveness of a product on a market as saturated as that of child restraint systems, designers need to put further effort into enhancing the user experience. At the moment of purchase the factor that arguably matters the most is the visual aesthetics of the product, an area in which Axonkids has explicitly expressed a desire to enhance their competitiveness.

1.2.3. The Axkid Brand

Today the Axkid brand does not have a well formulated design philosophy. They use the slogan "safety shall be easy", but apart from this there are no documented core values or design philosophies. While the visual expression in their products can be considered to display some consistency between products this is more the result of a small design team rather than well formulated rules for the visual expression. The visual design and expression has not been a part of the development process from the beginning, but is rather a feature that was created after most of the construction of the CRS had already been made. It can be argued that due to how this process was carried out the commonalities in visual expression that do exist between different products in the company's portfolio may have came to be due to how the development was carried out rather than by a conscious decision.

This creates an opportunity for Axonkids to completely reinvent their visual identity without having to worry about consistency with the heritage of previous models. The fact that they only have one generation of CRSs also gives support to this idea.

The Axkid brand have also recently been the subject of bad publicity after one of their products failed a test made by the Swedish consumer magazine "Råd & Rön" (Berge 2013). This test put higher demands on safety than the tests devised by UNECE. In this test the ISOFIX connectors on the test chair failed due to the higher speed used in the test when compared to the standard tests. Although the chair was still approved according to regulations, Axonkids replaced the ISOFIX connectors to new more robust ones but the ordeal severely damaged the reputation of the brand, and especially their image on search results on the web. These events give yet another reason to clearly distinguish any new products visually from the model that suffered the negative publicity in an effort to further regain consumer trust.

1.2.4. Usability

Studies show that insufficient usability for CRSs can lead to use errors. These errors can be detrimental to the safety of the passenger as they can prevent essential functions of the CRS to perform the way they were intended (Klinich et al. 2014). These errors should if possible be prevented by improved usability of the CRS.

1.3. Project Aim and Goal

This project aims to design a new concept for a child restraint system which meet the requirements posed by the new i-Size standard. This concept will also be the starting point of a new brand image which has a strong foundation in customer expectations and wishes. The thought processes of potential customers will be carefully analyzed to identify and understand the underlying functions that leads them to make a choice. An exploration will be conducted regarding what expressions can be communicated to the customer through the product design and how these expressions can contribute to an attractive product. Shortcomings of existing products will be identified and suggestions for solutions for these will be presented.

Research questions:
• How should a CRS be designed for optimal ease of use and minimal risk of use error?
• What feelings should a CRS express in order to evoke a positive reaction in a potential customer?
• Do some expressions correlate to others and which expressions are most important for the total impression?
• How can this knowledge be translated into rules and guidelines that can strengthen the brand in the future?

The goal is to deliver one concept of a new CRS. The concept should be represented by a 3D model and visualizations that is to serve as a basis for further development and mechanical construction of the new product. Along with the digital representation a thorough description of the functionality and intended use of the CRS shall be provided. Furthermore, an explanation of what factors determine the visual expression of the CRS will be provided, including core values and design cues to be used in the development of new products.

1.4. Delimitations

One important part of the i-Size standard is the new weight requirements. The focus area of this project however is usability and visual expression, neither of which require a mechanical design of the product to be evaluated. As a result of this the weight of the new product cannot be evaluated. Weight can however be taken into account in development and evaluation of functional concepts, such that no unnecessary weight is added.

Although safety is arguably the most important aspect of a CRS, to evaluate the safety of a new concept, a physical prototype is needed for crash testing. Due to this, the responsibility of ensuring and optimizing crash safety is handed over completely to Axonkids. Safety can however be taken into consideration through usability factors, such as minimizing errors in

the installation of the CRS in the car, or child in the CRS, which could otherwise cause safety issues.

Child restraint systems come in many sizes for different sizes of children. i-Size regulations however only regard children up to approximately 4 years old (33kg combined weight of CRS and child), and as the new concept needs to adhere to these regulations, older (and heavier) children are outside the scope of this project.

1.5. Project Process

The process has followed the first steps in a generic product development process, which can be divided into four general phases: A planning phase, research phase, concept development phase and an evaluation phase (as seen in Figure 1) (Bligård 2011).

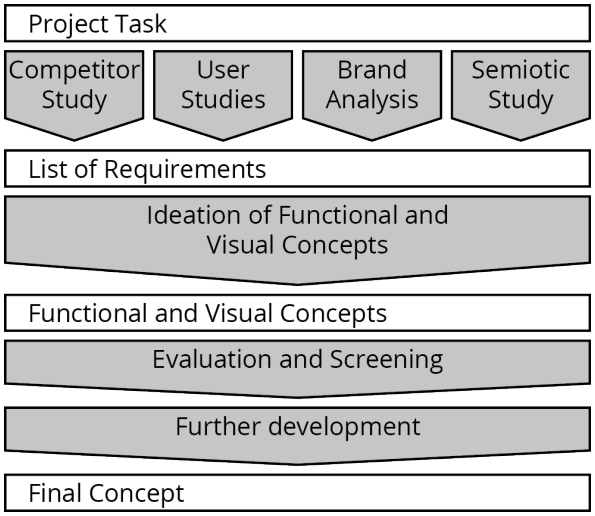

Figure 1. Project process.

The research phase consisted mainly of studying CRS regulations, identifying user requirements and a brand analysis, resulting in a list of requirements for use and functions of the product, as well as a number of desired visual expressions for the new concept. This could then be used in the concept development phase, resulting in three visual concepts and a long list of functional concepts. These concepts were then evaluated and screened, after which one concept was chosen for refinement, resulting in the final concept.

Throughout the process, the project group met with Axonkids periodically to present the work and to gather input for decisions needed to progress with the project.

1.6. Report Outline

This report describes the process and outcome of the project. The report structure follows the project chronologically, except where parts of the process was carried out simultaneously. The description of the project process is divided into chapters to let the reader focus on specific areas of interest.

• The first chapter introduces the project by describing the background, problem definition, aim, delimitations and process of the project.
• Chapter two offers an introduction to child restraints systems and their functions as well as the user of the product.
• Chapter three describes the methods used to identify usability issues for child restraint systems, as well as the execution and results of said methods.
• Chapter four describes the theory of brand identity and the methods used in this project for analyzing the Axkid brand and identifying the desired visual expression of the new concept.
• In chapter five, the results from chapter three and four are posed as a list of requirements on which the concept development was based upon.
• Chapter six describes the process of developing solutions for specific usability and user experience issues.
• Chapter seven describes the development of three concepts, and the properties and functions of these concepts. It goes on to describe the evaluation and screening of concepts, resulting in the final concept.
• In chapter eight the chosen technical solutions and design cues developed for the final concept is presented.
• Chapter nine discusses the final result, the methods used and process of the project and recommendations on further development for Axonkids.
• The tenth and final chapter presents the conclusions drawn from the project.

2. Child Restraint Systems

This chapter introduces child restraint systems, parts that make up a CRS and their functionality, and describes the three CRSs that were used as reference products.

2.1. CRS Components

Child restraint systems intended for the specific age span (0-4) are mostly similar in design and can be generalized into a list of common components.

2.1.1. Seat and Base

A CRS can either have a seat that is fixed to the base, or a seat that is separate from the base. The main reason for having a seat separate from the base is so that the seat can be tilted back while the base remains stationary. To allow the seat to tilt, it can either pivot around an axis or slide along a curved rail in the base.

2.1.2. Seat Installation

Child restraint systems are secured to the car seat by either using the car's seat belts or by ISOFIX connectors. Some CRSs allow installation by both methods of fastening. ISOFIX is an international standard for means of installing a CRS in a car, intended to lower the risk of installation error (Britax 2008). It consists of two anchor points inside the car seat, which connectors on the CRS attach to as seen in Figure 2.

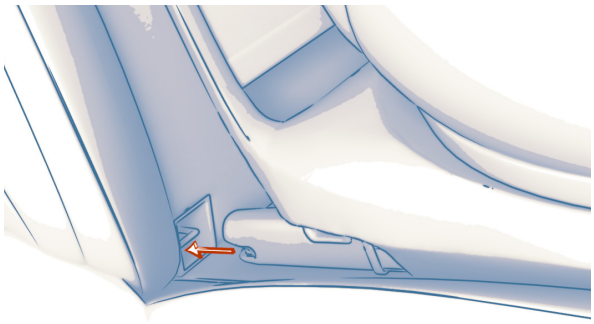

Figure 2. ISOFIX connectors and anchor points.

2.1.3. Anti-rotation Devices

In addition to a means of fastening the CRS in the car, some CRSs utilizes one or more anti-rotation devices. Examples of anti-rotation devices used for CRSs are a support leg extended down to the floor of the car, a top tether connecting the CRS to the top of the car seat or ceiling, rear-facing tether connecting the CRS to anchor points on the floor of the car and an anti-rotation brace which supports the CRS against the back of the car seat. The purpose of anti-rotation devices is to keep the CRS stable and minimize the rotation in the event of a crash.

2.1.4. Harness System

Most CRSs use the same type of harness system, a 5 point harness that connects on the front (as seen Figure 3). In most cases, three of the straps are fixed while the other two go

into the seat where they are connected to a tensioning belt. The tensioning belt protrudes from the seat and can be pulled to tighten the harness. Parts of the harness are often covered in padding to increase comfort for the child.

Figure 3. Typical harness system. A strap on the front of the seat is pulled to tighten the harness.

2.2. Seat Direction

CRSs can be intended for forward-facing (facing towards the direction of the car), rear-facing or both (often referred to as combination chairs). The National Society for Road Safety in Sweden recommends children up to 4 years of age ride rear-facing as this has been proven safer than forward-facing (NTF 2013). Sweden has the lowest traffic mortality rate for children, which could possibly be attributed to children riding rear-facing longer than in other countries (Trafikverket 2012). According to Tony Qvist[1] riding rear-facing up to 4 years is not possible for many CRSs as the legroom does not sufficiently accommodate taller children.

Combination chairs can be used rear-facing until the legroom is no longer enough, and then changed to a forward-facing position. Some combi chairs can be switched from rear-facing to forward-facing without detaching the CRS from the car seat by allowing the seat to both tilt and rotate relative to the base. Examples of such CRSs can be seen in Figure 4.

2.3. Reference Products

Three reference products were used in the project, both to draw inspiration from and to use for comparison when evaluating the new concept. One of the reference products was chosen because it is the latest model released by Axonkids for the intended age group. The other two products were chosen because they are the only two models available on the market with rotating seats, which Axonkids specified as a requested feature for the new concept.

The three CRSs were used in the project for the focus group and field testing, and were also disassembled so that their structural design and mechanisms could be studied.

For a list of properties and functions of the reference products, see Appendix I.

2.3.1. Reference Product A

Reference product A (hereafter referred to as Ref.A) is the Kidzofix model from Axkid, a combination chair for children weighing between 9 and 25 kg, depicted in Figure 4. It is mounted rear-facing by ISOFIX connectors and uses a support leg as well as rear-facing tethers to counter rotational forces. The support leg can be retracted so that it doesn't protrude under the base while being stored. When mounted forward-facing it uses the car's seat belts to secure it to the car seat and no additional anti-rotation devices are used. It features the conventional harness system with a tensioning belt protruding from the front. The headrest however has a unique functionality seen only on Axkid products. The headrest height is automatically set as the harness is tightened, which at the same time adjusts the height of the shoulder straps of the harness. The headrest height can then be fixed by a rotating lever on top of the headrest. The seat pivots on an axle attached to the back of the base, allowing the inclination to be set in three different angles, which can be unlocked by a lever on the front of the base. The textile cover for the seat and the headrest can be removed and machine washed.

2.3.2. Reference Product B

Reference product B (hereafter referred to as Ref.B) is the Dualfix model from Britax, a rotatable combination chair for children weighing up to 18 kg, depicted in Figure 4 it

1. Tony Qvist (CEO, Axonkids) interviewed 14-03-10.

is mounted in the car by ISOFIX connectors, and the seat can be rotated 360 degrees by operating a button on the front of the base. For anti-rotation devices it has a support leg and an anti-rotation brace. The support leg can be retracted and folded in under the base for easier transportation and storage. The ISOFIX connectors can be extended by pulling on a strap on the back of the base and retracted by pushing the base towards the car seat so that the anti-rotation brace sits up against the back of the car seat. It features a conventional harness system and the headrest height can be adjusted by unlocking it with a pull-strap on top of the headrest. The harness is attached to the headrest mechanism, such that the shoulder strap height is adjusted with the headrest. The seat can be reclined by pulling a lever on the front of the seat and pushing the seat back. To rotate from rear-facing to forward-facing the seat needs to be fully upright. To tilt the seat fully upright a button needs to be pressed to unlock the full range of tilt. Every part of textile cover, including shoulder and hip pads can be removed and machine washed.

2.3.3. Reference Product C

Reference product C (hereafter referred to as Ref.C) is the Sirona model from Cybex, a rotatable combination chair for children weighing up to 18 kg, depicted in Figure 4 It is in many ways similar to reference product B in terms of functionality but with some slight differences. The seat needs to be fully upright to be able to rotate, but no locking mechanism is present. The ISOFIX connectors can be extended and retracted for this CRS by pushing a button on each side of the base. The anti-rotation brace is removable as it is not needed for forward-facing operation. The headrest is adjusted by depressing a lever on the lower part of the headrest and pushing the headrest up or down.

Figure 4. Reference products. From top to bottom: Reference products A, B and C.

2.4. Target Group

The intended target group for CRSs is anyone who at some point needs to fasten a small child in car. This target group would consists mainly of a parent who owns a car and buys a CRS but also contains users which only use a CRS temporarily. The target group therefore varies in gender and life situation, which also gives the group a large age span.

Axkid CRSs are mainly sold in Nordic countries. This means for the development of a new concept that potential users petitioned for brand analysis or concept evaluation should be living in Nordic countries. This ensures that the product is designed for the intended target group.

Users of a CRS can be divided into two groups. Anyone who installs the CRS in a car, secures a child in the CRS or otherwise interacts with it can be viewed as the primary user, while the child who sits in the CRS can be regarded as a secondary user due to the low amount of interaction with the products functions. Different aspects of a CRS are important to different extents to the two users. An example of this is while comfort may be of highest concern for the child, the perceived comfort is of higher importance to the primary user.

2.5. Persona

A persona is a fictional individual, meant to represent a typical user (Baxter & Courage 2004). Two personas were created for this project in order to enhance the understanding of the mindset of the target users, and can be found in Appendix II. They were made to cover a relatively broad range of potential users and their needs, while also correspond to the pricing and typical customers as described by Axonkids.

2.6. Implications

This chapter has introduced the conditions as they were at the initiation of the project. The main challenge is to create a concept of a CRS that can compete with the large brands on the market. Since there is limited room for innovation a new product needs to be competitive in areas such as usability and aesthetics. To achieve this, research has to be made on the usage of similar products as well as how people perceive and judge CRSs. With the mindset that “form follows function” the project was continued with a usability study to better understand the needs of the user and what modern CRSs could provide for these needs.

3. Usability Research

This chapter describes the methods and executions thereof used to identify the user needs for the products as well as the usability issues found for the reference products.

3.1. Analyzed Products

The three reference products ref.A, ref.B and ref.C were instrumental in gathering knowledge about the CRS as a product. Ref.A due to its brand relevance, and ref.B and ref.C as they are the products on the market today which are closest to what Axonkids wishes of the final concept in terms of functionality, and therefore the main competitors. The differences between ref.B and ref.C are relatively small on a conceptual level. Due to the requirements of this project the delivered concept will also be very close to these products, which makes it even more important to study them in detail. Odds are that the customer's choice will greatly depend on the affective qualities of the products.

3.2. Methods and Execution

Much of the information regarding usage and usability was gathered in an exploratory fashion in the initial stage of the research phase. Open ended and spontaneous discussions with users and engineers were common throughout the project, but they were actively induced in the earlier stages. These were also complemented with more well defined and proven methods of usability research.

3.2.1. Interviews

Six semi-structured interviews were conducted during the information gathering period of the project. These included extensive interviews with experts and developers of CRSs, researchers, sales representatives from retailers, as well as parents and owners of CRSs. These interviews where not intended to produce any statistical data but rather to gather qualitative information from numerous heterogeneous sources and to create a comprehensive knowledge base of the product category.

3.2.2. Hierarchical Task Analysis

Although there exists a number of modern ways to carry out a task analysis, the Hierarchical Task Analysis (HTA) is a method with a long history that is still widely used today. Stanton (2006) describes the HTA as "a way of representing a system sub-goal hierarchy for extended analysis". The HTA creates a well-defined and structured representation of a system by splitting up tasks into multiple sub tasks and finally into actions that has to be performed in order to achieve the goal. This can be used on its own in order to better understand a product, however in this project it has mainly been used as a supporting tool for other methods.

HTA's were conducted on the reference CRSs for the following tasks: "Fasten child", "remove child", "install CRS", "remove CRS", "place textile cover" and "remove textile cover" (Appendix III).

3.2.3. Enhanced Cognitive Walkthrough

Cognitive Walkthrough is "a usability evaluation technique used to identify problems with a user interface and to suggest reasons for these problems" (Lewis & Wharton 1997). Since the method was developed it has become widely adopted and adapted into different varieties (Mahatody et. al 2010). One of these adaptations is the so called "Enhanced Cognitive Walkthrough" or ECW, which aims to be "a method that can better detect and identify given presumptive usability problems in an interface and also provide an overview of which types of problems exist and how serious these are" (Bligård & Osvalder 2013). The ECW can be used to closely examine the usability of a product and aid in identifying potential problems. Since the method does not require a physical representation of the product it can also be used in order to evaluate and compare concepts at an early stage in the development process. The ECW needs to be based on a task structure that can serve as the foundation for the analysis, where in the case of this project the HTA was used. ECW's were conducted for all of the corresponding HTA's (Appendix IV).

3.2.4. Predictive Use Error Analysis

Predictive use error analysis (PUEA) is a method used for identification and analysis of human errors in product interfaces and is based on "Action Error Analysis" (AEA), "Systematic Human Error Reduction and Prediction Approach" (SHERPA) and "Predictive Human Error Analysis" (PHEA). The purpose of PUEA is stated to be: "to counteract the deficiencies in AEA, SHERPA and PHEA. Better identify presumptive use errors and investigate these and also give a good overview of which types of use errors exist and how serious they are" (Bligård & Osvalder 2014). Similarly to ECW the analysis requires a task structure, where again the HTA could be used. The results from this method can also be used as a metric on usability when comparing concepts. The full material for the PUEA's can be found in Appendix V.

3.2.5. Focus Group

A focus group can be defined as "a research technique that collects data through group interaction on a topic determined by the researcher" (Morgan 1996). The design of a focus group with regards to its size and moderation greatly depends on the topics and goal of the group. Morgan (1996) describes that smaller groups can work better with emotionally charged topics with high level of involvement. Although there exists much information on how to design focus groups in literature it is important to note that this information describes guidelines rather than rules (Morgan 1997). A focus group that does not strictly follow these can still give much valuable information. In this project focus groups were not only used for collecting information but also to verify that we were approaching a saturated level of gathered information. In other words, it was used as a last stage in the information gathering process to see if there was any more data that could be extracted by utilizing a group instead of individuals.

3.2.6. Field test

The field testing conducted for this project consisted of studying the products in a real use context. It served as a means to examine if the usability issues identified in the interviews were present in the reference products. For each of the reference products, every function was tested to evaluate the severity of the issues. The task time of functions such as removing the textile cover could be measured to see if the functions of a particular CRS were superior to others. Functions related to cars, such as installing the CRS were tested with the reference products in a car (Figure 5).

Figure 5. Reference product B test fitted in a Mini Cooper.

3.3. Findings

The results from the usability research phase were documented as potential problems as well as existing problems related to Ref.A which needed to be addressed. These were also categorized into the three groups priority one (P1), priority two (P2) and user experience (UX) issues. The P1 category is defined as the most severe issues which for example can be safety related. The P2 category are rather annoyances or have a small but significant impact on performance. The UX issues fall outside these categories and mostly have an impact on how people perceive and react to the product in an affective sense. Unless stated otherwise the following issues refer to Ref.A.

3.3.1. Priority One Issues

The following issues were considered of highest importance.

Limited Support for Removal of Absorbent Materials

Small children are often high maintenance due to the mess they can cause to their surroundings. Spilled liquids and mud together with accidents involving vomit and urine etc. makes it necessary to facilitate simple cleaning of the CRS. Ref.A had a block of soft foam glued to the bottom of the chair as well as shoulder pads attached with Torx screws, which limits the ability to remove and clean absorbent materials.

Complicated Procedure for Removal of Textile Cover

The sequence of actions required to remove and attach the textile cover of Ref.A are documented in the HTA seen in appendix HTA. This is a complicated procedure that when timed took 3 minutes (removal of cover) to complete for a person who were completely familiar with the sequence. No formal testing was conducted on how long this would take for someone unfamiliar with the product since the authors of this paper failed to complete this task themselves without guidance. Due to this fact it was deemed on spot that formal testing would be unnecessary as large changes had to be made and a comparison with Ref.A had little purpose in this regard.

Another even more severe shortcoming of this procedure was that in order to remove the cover, the user also had to detach the belts. This has the consequence that when the belts are attached again it puts a responsibility on the user to get the routing of the belts correct. If this is done improperly it may have a severe impact on the safety of the product.

High Belt Friction

It became clear during interviews that tensioning of Ref.A's harness requires an amount of force that for some users is difficult or uncomfortable to produce. This can be attributed to friction generated when the belt is sliding across different surfaces inside the chair, but also due to the fact that the harness requires a substantial amount of tension to fit snug against the child. In three studies conducted on CRS installation, the harness was insufficiently tightened in 48% to 59% of installations (Klinich et al. 2014). Brown et al. (2009) suggests the high amount of force needed to tighten the harness may contribute to these installation errors.

Harness Operation

The operation of tightening the harness on Ref.A requires the user to apply a vertical force on the belt strap with one arm extended out from the body (Figure 6). This is a relatively

weak position which may contribute to the high percentage of incorrect installations as described by Brown et al. (2009).

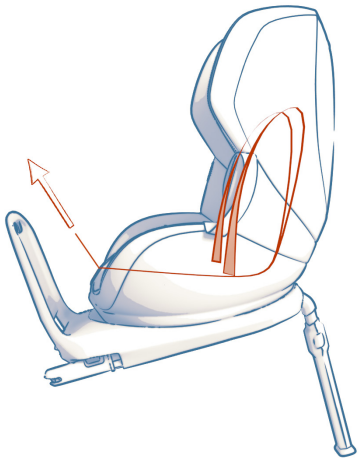

Figure 6. Force used to tighten the harness.

No Indication of Proper Harness Tension

As previously stated improper tensioning of the belt harness is a frequent error that users make which can also be detrimental to the safety of the child passenger. Klinich et al. (2014) suggests the high frequency of this type of error may be due to a lack of feedback, i.e. the user does not know if the harness is sufficiently tightened. None of the reference products utilize any kind of tension indication to aid the user.

Dust & Gravel Management

Owners of Ref.C has experienced issues with particles falling in between the seat and the base of the CRS, and into the mechanical parts. This had to be prevented at a later stage by changing the original design of the textile cover in order to cover up the gap. The effectiveness of such a solution is unclear but it does have an impact on the intended aesthetics. A better solution may be achieved by planning for this at an earlier stage in the development process.

Prevention of Unintended Liquid Containment

In an interview with a parent it became clear that some CRSs has a design which can collect liquids in places that are difficult to rinse, such as screw holes and other cavities. This may lead to unwanted odors that can be difficult to get rid of.

Prevention of Incorrect Inclination Angle

When a child is fastened in the chair the angle of the back has an important impact on injury prevention. In the case of a child sitting in a rearward facing position, the strain in the neck will increase relative to the angle of the back-rest on the CRS (Figure 7). Insufficient inclination can however lead to a situation where the child's head tips forward when falling asleep which potentially have even more severe consequences in case of an impact. According to Tony Qvist[11] at Axonkids the recommended lowest angle is 25°.

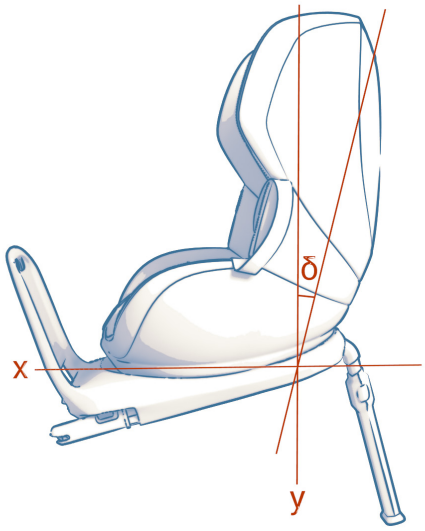

Figure 7. Angle of recline, δ.

The problem with limiting this angle or trying to give an indication of a correct angle is that the car seat on which the CRS is being mounted may have an angle of its own that can differ between different car models. The CRS may also be installed when the car is standing in a slope making it difficult to measure the relative angle to the car itself.

Infant Passenger Accommodation

One requirement for the new product is that it should accommodate a passenger that is between newborn and approximately 4 years

1. Tony Qvist (CEO, Axonkids) interviewed 14-03-10.

old. For every size of the child the straps of the harness needs to be situated at the height of the passenger's shoulders, and the harness buckle needs to be close to the passenger's groin. If these requirements are not fulfilled the child occupant will not be safely secured to the CRS. To accommodate for older passengers, CRSs are usually not suited for newborn babies, and are not recommended for passengers less than 6 months old.

3.3.2. Priority Two Issues

• The ISOFIX arms lock button is hidden underneath the seat having a negative impact on discoverability.
• The ISOFIX connectors use a push action to release the locks, which is not consistent with the pull action that is used to move the seat away from the car seat. This combination requires the user to "grab" the seat with their arms and drag it away while simultaneously using their hands to unlock the ISOFIX connectors (Figure 8).
• The CRS is big and heavy which makes it awkward to transport and move from different vehicles. It also requires a large space to store.
• The instructions for the headrest support brake reads "PULL DOWN-UP ONE "CLICK"-TURN BRAKE". The lack of context and indications what these instructions refer to combined with incorrect grammar makes this nearly impossible to comprehend. What it intends to describe is the following procedure: Pull the headrest down with the belt strap (PULL DOWN), then release the belt lock and let the headrest go up one step which is indicated with a "click" as an auditory feedback (UP ONE "CLICK"). Finally the user locks the headrest in place by turning a lever hidden behind the headrest. (TURN BRAKE).
• The product requires two hands to undo the belts. One to hold the locking mechanism open and another to pull the belts. Any changes made to this cannot neglect the impact this may have on the safety of the product, i.e. a mechanism that is always locked by default is safer than one that can be either locked or unlocked.
• The lever that unlocks the seat to allow it to tilt is located underneath the seat and can be difficult to reach.
• The support leg has two adjustment points instead of only one which makes it more complex to use and increases visual clutter.

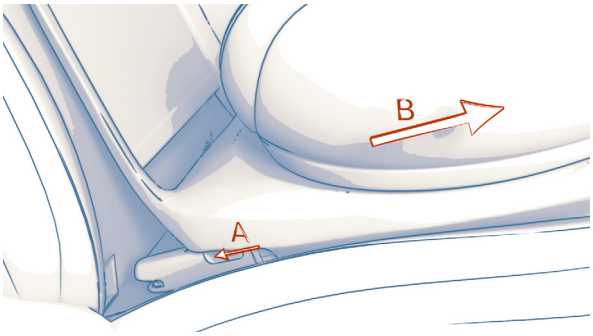

Figure 8. The button on the ISOFIX connector is first pushed to release it from the anchor point, after which force is applied to the connector in the opposite direction.

3.3.3. User Experience Issues

Ref.A is fairly good at providing feedback to the user with some exceptions like the headrest lock which has a feeling of low quality to it. With added functionality for seat manipulation it becomes even more important to give the user sufficient feedback. During interviews and tests many users expressed a slight distrust towards the products that used a rotating seat. This lack of trust seemed to stem from a conservative mindset where unconventional solutions were met with suspicion. Veryzer (1998) describes this as "lack of familiarity" and identifies it as a factor that increases customer resistance towards a product. The theory on diffusion of innovations would classify this mindset as that of the late majority (Rogers 2003). Since there is a large group of potential users that may have this type of reserved attitude, it becomes important to work with the user experience in order to regain such inherent loss of trust. In a rotating seat it is therefore essential to achieve a high level of quality feedback from the rotation mechanism to "prove" to the user that the product is safe.

Other ways of improving the apparent safety of the product include:

- Showing metal - One competitor CRS hid the metal in the buckle which made some people complain that it did not feel safe with a buckle without metal. Since metal is often associated with rigidity this effect could also potentially be used elsewhere.
- Reduce wobbliness - Ref.A has a particularly wobbly headrest which gives the expression of low quality and reduced safety. In general, all parts in the product should have a distinct and rigid position unless they are intended to move.
- The ISOFIX arms on Ref.A had a section where only a metal plate provided the thickness of the entire part. Although this may be completely safe it does not necessarily communicate this safety to the user. These ISOFIX arms have since been upgraded to better ones.

There were also some issues on the Ref.A that reduced the overall feeling of quality. Some of these were related to the textile cover of the product. The cover on the reference sample is made from sanded polyester fabric which has a texture (and sound produced when touched) that was described as somewhat less pleasant and less modern by some of the interviewed. The textile is also very stiff which makes it difficult to create a good fitting cover, and instead creates creases and folds which has a negative effect on the overall impression. Close to the belt buckle as well as where the belt straps connect to the seat there are openings in the cover where soft foam is exposed which gives a very dated impression.

There are also many visual elements which are questionable on Ref.A. Graphical elements have no visual coherence as some tags are made from rubber and others made from fabric. There is no apparent color palette and typefaces differ almost everywhere. Some tags seems do not contribute with any valuable information and together with other visual annoyances such as the loose belt strap at the front, these factors combine into a cluttered visual appearance when compared to much of the competition. Some of the visual clutter produced by for example tags for belt routing and other indications and adaptations will not be necessary thanks to the new i-Size standard.

Another annoyance that was frequently brought up during interviews was how the belts and the buckle tended to have a default position that placed them underneath the occupant when fastening the child. This forces the user to reach in below the child and search for the parts for the buckle. Many manufacturers have partially solved this by placing attachment points at the sides of the seat where the user can place the belts prior to lifting the child in place.

4. Brand Research

This chapter describes the theory of brand identity and semiotics as well as the methods used to find the desired visual expression and develop core values and design cues for the new concept.

4.1. Theory

The scientific theories described in this chapter primarily concern the affective evaluation of products. Here primary focus is the visual attributes of product design, the way the user process visual information and how this can be used to create competitive products.

4.1.1. Visual Brand

Aesthetics is an important factor which has a clear influence over customers decisions when buying new products (Veryzer 1998). The visual medium is an attention grabber and the marketing teams all over the world go to great lengths to outdo the competition (Figure 9). To develop and maintain brand recognition Karjalainen (2007) mentions attractiveness and strategic meaning creation as important aspects. Page & Herr (2002) describes how "liking" judgments are not clearly connected to brand strength, however "quality" judgments seem to have a stronger connection. In other words a customer may not like the design of a product just because it belongs to a certain brand, but it will affect the perceived quality of the product. In order for these factors to take effect the customer still has to recognize that the product belongs to a certain brand. This can be achieved with so called "design cues".

Figure 9. Times Square: An example of brands competing for attention.

Karjalainen (2007) gives a description of several categories of design cues. There are the value-based and the artificial design cues. Value based cues have a semantic relation to the brands "core values" and design features can be used to evoke associations to support brand values. If such an associative quality is missing, the design cue can be labeled as "artificial". Design features in this category can be said to be semiotic signs with symbolic reference to the brand. They don't have any specific value associated to them but nevertheless has become closely related to the brand over time due to consistent use. Karjalainen (2007) gives the kidney-shaped grille of BMW as an example of an artificial design cue.

In this project the goal is to create a foundation on which Axkid can build a long term brand strategy for their visual design. In order to achieve this focus is put on the evaluation of different signs and design cues and their impact on the affective judgments of a consumer.

4.1.2. Semiotics

Products and artefacts can be said to have signs that gives descriptions towards different aspects of its characteristics This could be related for example to its usage, origin, value etc. Semiotics describes the nature of these signs and how they can function. Monö (1997) divides the study of semiotics into syntax (how the sign relates and interact to other signs), pragmatics (how the sign is affected by cultural contexts such as time period, geography or ethnicity) and semantics (what the sign communicates, or its "message").

In the context of this project the syntax of a sign is relevant since the final product will be compared to competitor products by the customer, and signs which on their own communicate one thing may have a different meaning when it's displayed next to others. Therefore it is of importance to evaluate the concepts against a variety of other products on the market.

The pragmatics of a sign is closely related to who the target group is. For example, people with different backgrounds or social status may have different views on what the sign communicates or what value they attribute to it.

The semantics of different signs is what communicates meaning in a product. Convex shapes and soft textiles may for example communicate comfort to the beholder. Peirce (1894) described the so called "sign triad" (Figure 10) which gives a model on how a sign is processed.

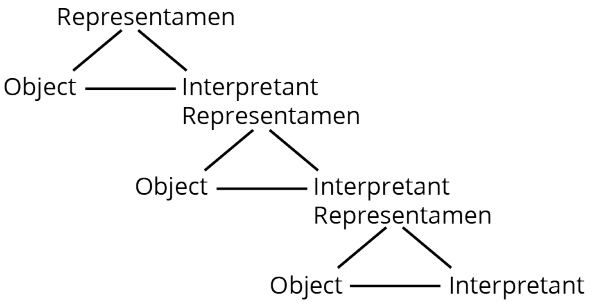

Figure 10. Peirce's sign triad and semiosis.

In Peirce's model the "representamen" can be described as the perceptible object, or the sign vehicle. In the case of an illness this could be for example the action of sneezing, or feeling sick. The "object" is what the sign vehicle represents, which in the case of an illness then would be the disease itself. There are however three different types of relations between a sign and its object. If the sign resembles the object the relationship is defined as being "iconic". A portrait is for example an iconic sign of whomever it depicts, and a scale model of a boat is a sign for the real boat. The relationship can also be indexical if the sign is itself affected by the object. This is the case for our example with the illness, but could also be for example an alcohol thermometer where the expansion of the liquid is an indexical sign for warm weather.

Finally a sign can be a symbol if it is a rule or convention that creates the reference. Examples of symbolic signs are the wedding ring as a sign for marriage, or numerical digits and roman numerals as a sign for their corresponding numbers.

The final part of the sign triad is the "interpretant". This is the meaning of the sign or a person's interpretation of it. Peirce (1894) also describes how the interpretant can itself become a new representamen, or in other words, the conclusion or interpretation of a sign can itself represent something new. This leads to an unbounded spiral of further conclusions and thoughts. This process is known as semiosis and is a key concept in the visual expression analysis of this project.

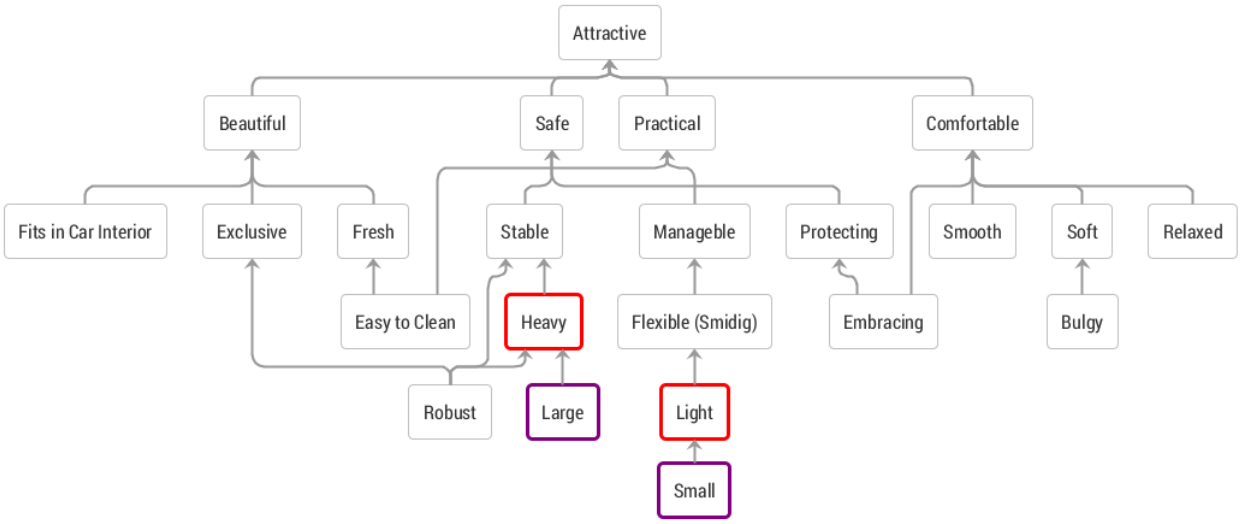

Figure 11. Semiotic network of expressions used to describe CRS's.

4.2. Methods

The purpose of the chosen methods was to generate a representation describing the importance of different signs and their interdependence. The idea was to be able to motivate future design decisions with something more substantial than solely the personal preference of the designer.

4.2.1. Interviews

The main target for the branding related interviews was to collect information on how people evaluate CRSs and to identify factors which may have an influence over the total impression. To achieve this a total of six interviews were carried out, where the interviewee was asked to describe a set of nine different CRSs. In order to facilitate the process and to help the interviewee to formulate descriptive statements, pictures were shown with three products on each, since it is easier to make comparative statements, e.g. A looks more comfortable than B. For each statement the user was asked to try to explain what led them to their conclusion, in an effort to backtrack possible semiosis processes. One researcher led the interview while the other documented which adjectives were being used to describe the products. The images where shown in different randomized orders for each interview and each CRS was shown next to every other at least once for every interviewee, effectively showing every product multiple times in order to extract as much information as possible.

4.2.2. Semantic network

The process of semiosis (Peirce 1894) where the interpretant of one sign becomes the representamen of another is not necessarily a single-track train of thought. It is not difficult to imagine that this process is branched and that one sign can lead to multiple independent interpretations. These thought processes and semantic relationships can be described with a semantic network. A semantic network is a form of knowledge representation that can be defined as "a graph structure for representing knowledge in patterns of interconnected nodes and arcs" (Sowa 2014). Such networks have been used for a long time in many different areas ranging from computer science to philosophy, psychology and linguistics (Sowa 2014).

In this project a semantic network was created in order to gain a comprehensive overview of how people tend to evaluate the quality and attractiveness of a specific type of product (Figure 11). The goal was to capture the process of semiosis and document it.

4.2.3. Web Survey I

The analysis of semiosis and how the different adjectives are connected was done through a manual method, and is therefore sensitive for subjective bias. Further, the connections shown in Figure 11 are not weighted and therefore it can be difficult to know what should be prioritized when evaluating concepts. These

problems can potentially be diminished by making a statistical analysis of peoples preferences and choices.

Design

The survey was conducted by constructing a web form where the test subject were shown a series of pictures of CRSs that exists on the market today. Each CRS that was included in the study was chosen from the same category as Ref.A and comprised a total of nine products where all the reference products also were included. For each picture the respondents were required to rate the displayed CRS on a scale from 1 to 10 for how well it's appearance corresponded to a set of 20 expressions, plus their total impression of the product.

The pictures of the CRSs were taken from approximately the same angle, a three quarter view of the seat. Most CRSs come in different color combinations due to the subjective nature of color preference and the relatively low price of producing different versions of textile covers. Humans also have a tendency to project the sometimes irrational concept of "beautiful is better" on everything from people to products (Dion et. al 1972, Tractinsky et. al 2000), and the subjectivity of beauty in colors may therefore have an effect on the rest of the design of the product. Because of this, all pictures included in the web form were desaturated to intentionally remove potential bias from color preferences. This may seem strange since the aim of the survey in fact was to try to measure the influence and interplay between expressions, many of which are subjective, but by removing color as a factor the results should be more focused and clear. It should be noted that color value, or material brightness may still have this type of influence over the results.

Research indicates that the order in which information is presented in a form may have a significant impact on the results of the survey. Krosnick & Alwin (1987) demonstrated how response order could alter response margins by 17%. In order to minimize such effects the order with which the respondents were presented the different CRSs were randomized together with the order of the list of expressions. The respondents were also asked about their age, gender and whether they were a parent or not.

The survey can be found in Appendix IX.

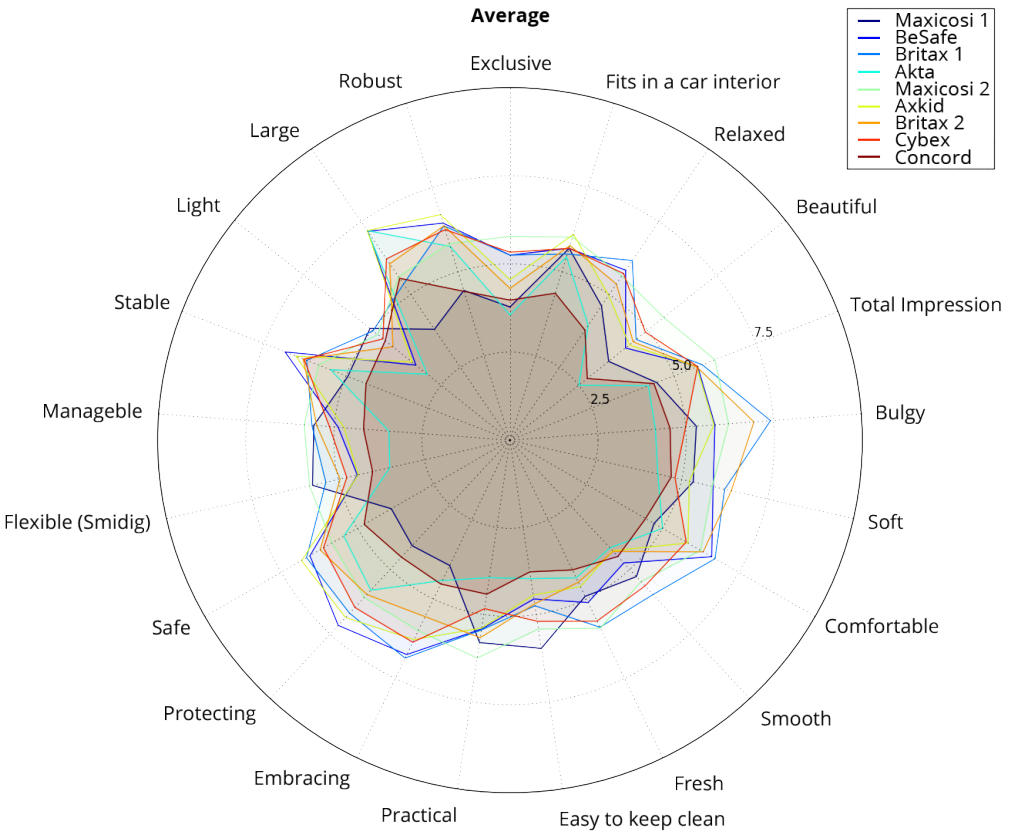

Figure 12. Survey results.

Analysis

The results from the survey was analyzed programmatically in order to maximize the amount of knowledge that could be extracted from the data. For example, by filtering the results for parents, and certain age groups an analysis can be made on the pragmatic aspects of certain signs.

Profile plotting

The average rating for each CRS on each of the adjectives were calculated and plotted with a spider chart (Figure 12). Since the scales on the test only went from one to ten without having any indication of what those values means there is a high probability that different people will interpret those scales differently. Some respondents used the full scale, while others stayed in the mid section of the scale, not giving any high or low scores. This does not necessarily mean that they do not think that any of the products were beautiful, but may be because a seven to them may have the same relative value as a ten has to another person. Neither person is right or wrong but they may merely have interpreted the scales differently. This is a potential source of error since the respondents who stays within a narrow span on the scale will not have as much influence over the final result as someone who utilized the full span. This source of error should however be reduced when using a sufficiently large sample size.

Correlation

By choosing two different expressions from the survey and using their respective scales from one to ten as X and Y axes a graph can be constructed. This graph is then populated with data in the form of dots. Each dot corresponds to one answer from one respondent concerning one specific CRS where the X and Y values are the scores that respondent gave the product. This graph can be analyzed by calculating the Pearson correlation coefficient to identify potential linear correlations. The Pearson correlation coefficient receives a value of one from a set of points with perfect linear dependence, If no linear correlation exists it is zero and in the case of an inverse linear correlation it will be negative (Figure 13). A manual review of the scatter plots was also made to search for non-linear correlations. By calculating all the Pearson correlation coefficients, a correlation diagram can be constructed (Figure 14). This diagram makes it easier to find the strongest correlations. While there may exist general correlation between these concepts this survey only identifies the correlations that exists for the CRSs in the sample set.

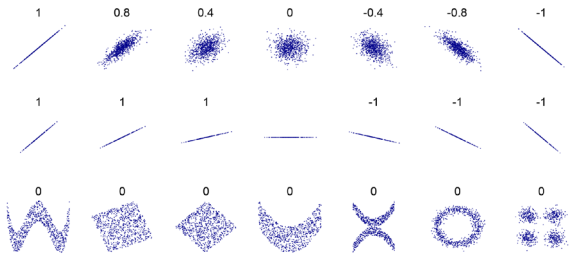

Figure 13. Pearson correlation.

Stronger correlations would indicate a stronger association between the two attributes. This is supported both by the nature of semiosis where one attribute can signify another, for example robustness might signify safety. This model can also be motivated by the following statement by Mark Hassenzahl (2003): “An apparent product character is a cognitive structure. It represents product attributes and relations that specify the co-variation of attributes. It allows inferences beyond the merely perceived. For example, a product with a simple user interface may also be thought of as easy to operate, although the user has no actual hands-on experience”. Such co-variations can become readable in the correlation plot, and can then be utilized in the design process.

Execution

Given the current state of the Axkid brand, the strategy for reinventing the brand that was decided on was to first study how consumers formulate and create abstractions for the idea of a child safety seat in their own mind. By gaining a better understanding of what concepts and features a consumer considers when evaluating a CRS, the new core values and visual identity can be designed to cater to the demands and desires of the consumers. Hassenzahl (2003) describes how products have certain features that are chosen by the

designer with the intention to create a certain product character. He gives an example that an online banking system may have an intended character of “trustworthy”, “sober” and “clear”. These characteristics often comes from the designer or from the core values of the brand. In this project the aim is to identify which characteristics are the most relevant and important for a CRS through analysis rather than qualified guesswork or already existing core values.

To achieve this a series studies was performed in order to cover as much as possible of the relevant aspects of what constitutes the design of a child restraint system. In the first step a number of Child restraint systems in roughly the same category as the Axkid Kidzofix were chosen to serve as a reference group. These were picked based on their apparent popularity and/or uniqueness, with the intent to create a diverse subset of products that were still comparable to each other.

Pictures of these were then presented in interviews to users as described in the methods section of this chapter. This produced a list of adjectives that people spontaneously used when comparing and describing CRSs. By analyzing these adjectives it is possible to try and recreate the semiosis process in the interviewed subject. By then linking these together a semiotic network could be constructed, where different identified semiosis processes were linked together and thereby the network can

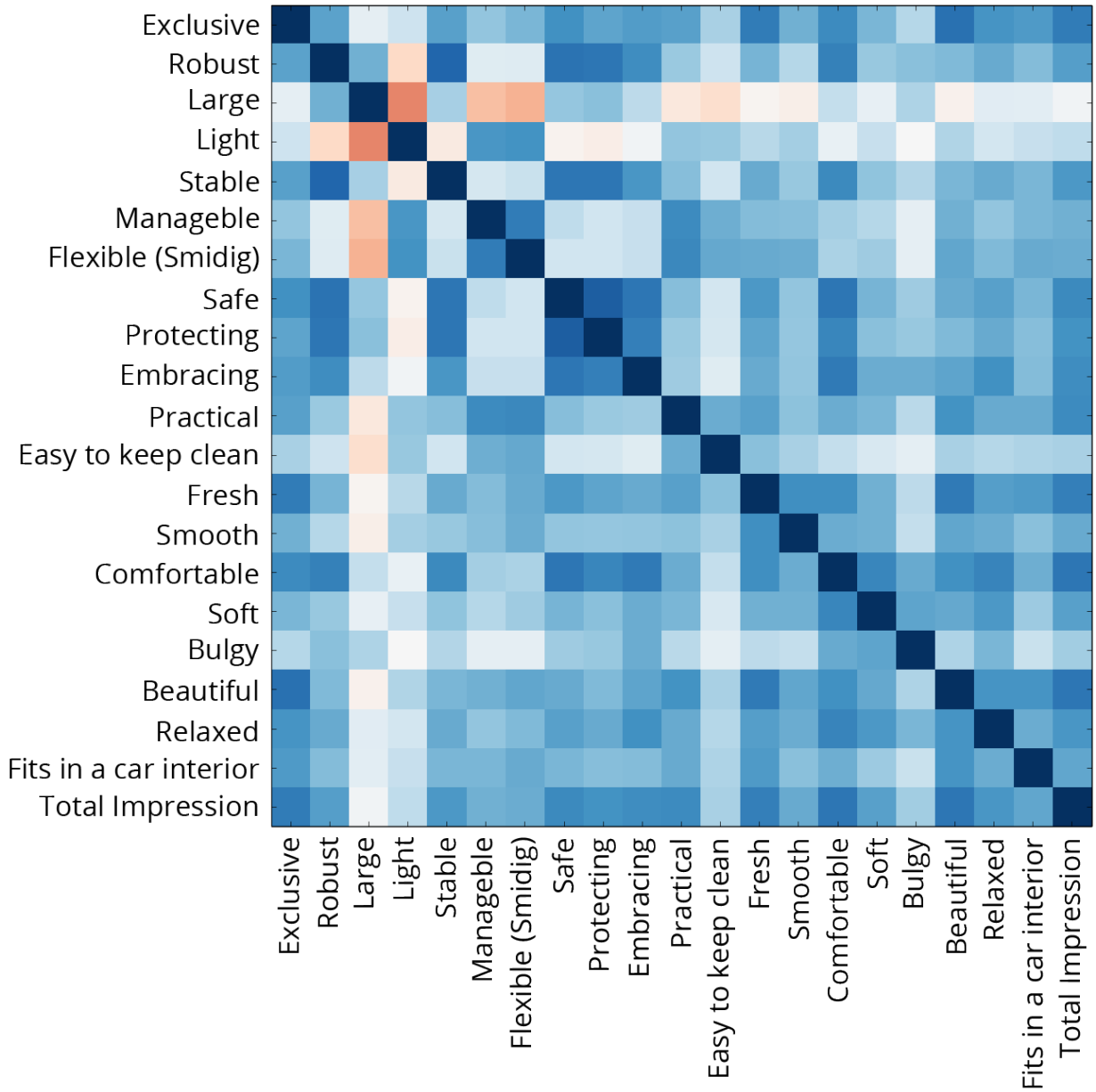

Figure 14. Correlation between visual expressions found in the survey. Blue indicates positive correlation while red indicates negative correlation.

serve as an abstraction for different thoughts and reflections happening in the mind of a consumer. This type of semiotic network has the potential to become very large and unmanageable due to the unbounded nature of semiosis. The list of adjectives had to be modified by removing words that were considered synonymous or very close in meaning.

The main purpose of reducing the size of the semiotic network was to achieve something that could also be tested and verified with a more quantitative approach. This was done by using same adjectives that constituted the semiotic network to design a web survey as described in the methods section of this chapter. From the survey a correlation matrix was produced which serves several purposes. Firstly, the semiotic network was compared to the correlation matrix in order to verify that connections existed where predicted. The semiotic network predicts that if there exists a relationship between two words this should also be visible in the correlation matrix. The purpose is not to identify all possible semiotic connections for every individual but rather the ones that are statistically most relevant.

4.3. Chapter Discussion

The methods which has been used seems to work well and give usable results but there is also room for improvement. The motivation for using linear correlation is simply that when manually inspecting the scatter plots it seemed reasonable to use linear correlation as a metric. There are however many options to linear correlation that could be explored with regression analysis in order to search for e.g. quadratic correlations. In reality, as noted by Schütte (2005) feelings are not necessarily either linear or quadratic but may potentially have much more complex dependence patterns and therefore it is important to keep in mind that these efforts to measure correlations are estimations. This is also why the scatter plots were inspected manually to make sure that no false conclusions were made. Another verification of the apparent linearity of the data was made by comparing the Pearson correlation to Spearman's rank correlation. The maximum difference rP - rS for all word pairs was 0.061 which means that an assumption of linearity is as correct as the broader assumption of a monotonic relationship which Spearman correlation measures.
Another way to potentially improve the method is to investigate if it is possible to switch from arbitrary scales to more absolute scales in the web survey. Since people may have slightly different interpretations of the scale this will result in a lower correlation coefficient as the values are more spread out because of this factor. This effect should not have too much of an impact on the conclusions drawn as long as this factor is fairly uniform for all adjectives which were studied. Any way to improve this should however also improve the conditions for a subsequent correlation analysis.

Another risk to be aware of is that participants of a survey may not be representative of the intended target group.

It is also important to constantly keep in mind the fact that correlation does not imply causation. The correlation matrix should only be used as a supporting tool which can aid the designer when drawing conclusions and making decisions, not as a conclusive result that governs the decisions.

5. Requirement Specification

The results of the usability and brand research were translated into a list of requirements. These requirements have been separated into requirements derived from regulations for child restraint systems, requirements and wishes posed by Axonkids and requirements found in the usability research phase. This chapter will present their significance in development of the concepts. The list of requirements can be viewed in its entirety in Appendix X.

5.1. Regulations

Regulation UNECE R129 (2014) pose a large amount of requirements that need to be satisfied in order for a CRS to be approved. Many of these requirements regard the structural integrity in a car crash and the testing thereof, and as described in "1.4. Delimitations" have not been considered in this project. Requirements from the regulations that were deemed important to the project consist of maximum allowed weight and outer dimensions of the CRS, means of installation in the car, required components and their placement.

5.2. Requests from Axonkids

In the original project description written by Axonkids, some specific requirements were presented, consisting of both wishes and demands on the new product. These requirements mainly regarded functionality such as being able to recline and rotate the seat in relation to the base and a wish to implement the existing solution for automatic headrest height adjustment that can be found on previous Axkid seats. Another requirement was to maximize the lifetime of the new product by accommodating use for children both younger and older than for previous Axkid models.

5.3. Usability Requirements

Many of the usability issues that were found for Ref.A resulted in requirements of improved usability for the functions those issues were related to for the new product. Especially important were issues connected to risk of injury. To be able to measure a difference in usability, the requirements were stated as a need for improvement compared to Ref.A. For functions such as seat rotation that Ref.A does not feature, the comparison was made with reference products B or C.

6. Concept Documentation & Ideation

Based on usability issues found in the usability research and the requirements they resulted in, solution suggestions were developed for each of the issues. This chapter describes the methods used in the development, how they were used and the resulting solutions.

6.1. Methods and Execution

Much of the ideation process involved open discussions within the project group or with engineers at Essiq or Axonkids. Quick and simple sketches or other representations were evaluated continuously and problems and solutions were documented. Some problems required greater attention and were therefore allocated more time. Many problems identified during discussions, interviews and focus group also had suggested solutions ready from the research phase. Due to the scope of this project, the general structure of the concepts followed existing market solutions. By sticking to proven concepts for the general form, the project could draw knowledge from Axonkids and feasibility would be secured. Exotic concepts however would require significant safety and crash studies and were therefore not considered.

6.1.1. Development

The main research phase produced a list of potential and existing problems as well as questions. These were tackled one by one with different methods, including brainstorming, discussions within the project group, discussions with experts and users, as well as individual reflection and problem solving over time. Much of this work was carried out in an exploratory fashion, first focusing on generating ideas, and then do a basic screening of these. This screening process removed concepts which were deemed to be unfeasible, but kept those which showed some kind of potential. Some of these concepts may have had problems of their own, but were not necessarily discarded because of this since those could possibly be solved at a later time.

6.1.2. Brainstorming

While there exists well defined instructions on how an efficient brainstorming session should be carried out these normally require large groups with approximately 12 participants with diverse backgrounds. Since a proper brainstorming session would be difficult to arrange the fundamental principles of brainstorming were instead used in order to generate ideas. Alex Osborn, the original author of the method (Osborn 1963) states that the most important factors to generate new ideas are to avoid criticism of ideas, aim to generate large quantities of ideas, build upon the ideas of others and to encourage wild and exaggerated ideas. These tactics were used when trying to solve problems and the ideas were written down for further evaluation at a later stage.

6.2. General Concepts

The following concepts describe general solutions and properties that are required for the final concept.

6.2.1. CRS Fastening and Stabilization

In accordance with the requirements the new CRS must use ISOFIX fasteners for installation. It is not only required for i-Size approval, it is also safer compared to conventional installation methods, as fewer installation errors are made. In a study conducted by the Munich Institute for Vehicle Safety the frequency of installation error was 93% lower for a CRS with ISOFIX fasteners compared to a CRS with conventional car seat belt fastening (Langwieder et al. 2003).

Regulation UNECE R129 (2014) states that an anti-rotation device is required, consisting of either a support leg or a top tether (Figure 15). According to Langwieder et al. (2003) a top tether is only suitable for forward-facing CRSs, whereas a support leg is suitable for both forward-facing and rear-facing. A support leg should therefore be fitted to the front of the base, and needs to be adjustable such that it is supported by the floor of the car (UNECE R129 2014).

To prevent rotation of the CRS in case of a crash from the rear, an additional anti-rotation device is required. This device consists of a brace connected to the back of the base that sits against the back of the car seat to prevent backwards rotation of the CRS. Rear-facing tethers could be used for the same purpose but was decided against by Axonkids. A vehicle fitted with ISOFIX anchor points is not guaranteed to also be fitted with anchor points for rear-facing tethers, while an anti-rotation brace can be used in any vehicle. Another benefit of the brace is that it can protect the seat back from the child passengers feet to avoid staining or damage.

When the CRS is mounted forward-facing, the back of the CRS seat is close enough to the back of the car seat for the brace to be redundant. The brace could therefore be made removable to reduce weight when it is not needed.

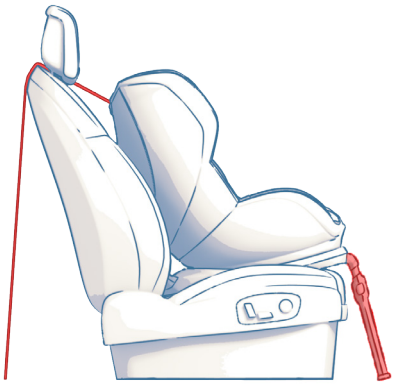

Figure 15. Top tether strap and support leg.

6.2.2. Seat Angle and Rotation

One of the requirements stated by Axonkids is that the seat should be able to rotate in reference to the base. Being able to rotate the seat is arguably more mechanically complex, resulting in a heavier CRS, but it does also result in several positive functionalities. Such a functionality is the ability to place and fasten the child with the seat rotated towards the user, which increases visibility and access to the seat. This increased access should reduce the physical strain of tightening the harness as the tensioning belt is pulled towards the user instead of to the left or right. It also reduces the distance that has to be reached inside the car in order to reach the tensioning belt.

To achieve a stable expression, the contact between the seat and the base should appear as solid as possible. To achieve this the surface of the bottom of the seat is made spherical, with a corresponding surface on the base. This spherical surface allows the seat to always appear in full contact with the base, regardless of its rotation or incline. The diameter and origin of the sphere determines how much the seat moves laterally when reclining the seat. For a certain angle of recline, the seat moves more for a larger diameter of the sphere, and less for a smaller diameter. With a rotating seat the axis on which it rotates needs to be considered. To ease installing the child, the angle of the seat should be as upright as possible when rotated 90 degrees (Figure 16). The horizontal position of the axis also needs to be considered, as when rear-facing, the leg room should be maximized and when forward-facing the seat should be as far back as possible.

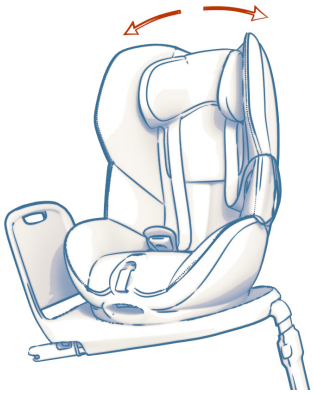

Figure 16. Angle of the seat when rotated.

6.2.3. Seat Transportation and Storage

It was observed in the field test that the ease of carrying a CRS depends on how the CRS is carried and the CRSs center of gravity in relation to the hand placement of the user. A center of gravity lower than the user's hands was found preferable as one with a center of gravity above the carrying points tend to exert a rotational force on the hands of the one carrying it. Additional to a low center of gravity, carrying handles can ease transportation by providing easier gripping of the CRS.

To reduce the volume of the CRS for storage when not in use, any anti-rotation device and ISOFIX fasteners should be retractable. To further improve ease of transportation the support leg needs to stay in the retracted position such that it doesn't extend by itself when lifting the CRS.

The amount of parts that can be detached from the CRS should be minimized to prevent misplacing parts of the CRS when transporting it to and from storage or between cars.

6.2.4. Textile Cover

An important function of any CRS is the ability to remove the textile cover for cleaning (according to the interviews). In case a liquid or other staining substance is spilled upon the textile cover, it could potentially soak through it and contaminate other parts than the textile cover itself. It is therefore necessary that every part of fabric or padding is removable. Every soft part of the CRS should also be machine washable, to ease the task of cleaning them for the user.

It is crucial that the harness does not need to be detached in order to remove the textile cover, as the users potential lack of knowledge of how to assemble them again could result in an incorrect routing of the belts. This could lead to reduced effectiveness of the harness in case of a crash.

To minimize the time and complexity of removing the textile cover, it should be performed in as few operations as possible. As removing the textile cover is a function not often used (according to the interviews), the operations should preferably have a high level of guessability (Jordan 1998). In order to be guessable, it needs to offer clues to the necessary operations. An example of such a clue is a visible zipper as seen in Figure 17.

Figure 17. A visible zipper on the back of reference product C indicates how the textile cover can be removed.

6.3. Function Specific Concepts

The following concepts are solutions for new functions or improvements for existing functions of the CRS. For some of them, several alternatives are posed, of which one or a combination of solutions were considered for implementation.

6.3.1. Seat Angle And Rotation Adjustment

There are many different possible alternatives for the positioning of interfaces for seat angle and rotation adjustment and how they work together. On existing products it is common to control the inclination from a mechanism at the front of the seat between the legs of the child. On Ref.C, the designers have chosen to combine the rotation and inclination locks into the same lever. The following solutions regard three different positions for the interface, as seen in Figure 18.

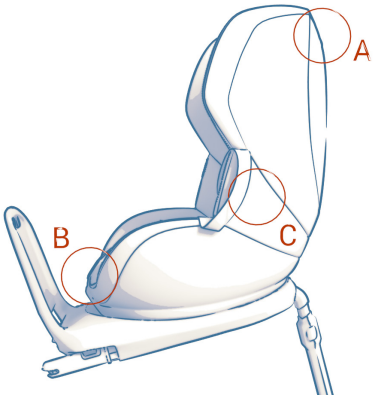

Figure 18. Positioning of interfaces.

Position A - Backside of backrest

This is an alternative position that is unusual in the products on the market today. One reason for this could be the distance between the locking mechanisms which are located just underneath the occupant and the lever which would have to positioned on the very top of the backrest. The lower on the backrest the placement is the more difficult it will be to reach when the CRS is facing the direction of travel, as the lever would be facing the backrest of the passenger seat. If executed properly this is however a viable placement for a lever, but there are several design choices that can make it fail, the first being the action with which the lever is used. The goal is to make the action of rotating or tilting the seat a one handed operation. This means that the action for unlocking the mechanism should also allow the user to grip and manipulate the seats position. Field testing identified two ways of doing this, one being to grasp the top rim of the backrest and pinching this to unlock, and the other to pull a handle upwards using the top rim as a support for the palm. Both of these effectively gives the user a firm grip on the chair while at the same time unlocking the mechanism. These concepts would have to rely on a wire that stretches from the lever/handle to the locking mechanism itself, which puts high demands on the quality on the wire since any elongation over time due to tension will have to be minimized.

Position B - Front

This position is popular on many of the chairs on todays market, which also has a positive effect on compatibility. This is a term used by Jordan (1998) which refers to that if the usage of a product is consistent with other similar products or objects it will be easier for the user to learn the new product. This however only applies to users with previous experience with such a CRS. Parallels could also be made with office chairs where levers for height control and inclination often are put underneath the chair. Another advantage of this position is that it's fairly easy to reach from both a forward and rearward facing position and it's symmetric placement makes it equally reachable regardless of which side of the car the CRS is mounted on. The same concepts for manipulation as described for Position A holds True for Position B, i.e. the user should get a good grip of the seat while simultaneously unlocking the mechanism.

Position C - Side of Seat

Here the interface is placed on the side of the seat which is the easiest position to reach, however this only holds true for one orientation. If the seat is facing forward and the lever is placed on the side facing the user, the same lever will be difficult to reach when the seat is put in a rearward facing orientation. To be able to compete with position A and B the interface needs to have a symmetric copy on the opposite side of the seat. This however introduces added mechanical complexity and weight.

Alternative 1 - Combined Interface

Combining the interfaces for rotation and inclination has some distinct advantages. A combined locking mechanism may somewhat reduce mechanical complexity and weight and

it allows for a cleaner design. There are however also some disadvantages. While combining the interfaces can lower the perceived complexity of the product it can also cause confusion as it has a negative effect on the guessability of the product (Jordan 1998). The seriousness of this problem depends on how this feature is implemented. An existing CRS system uses a combined interface where the user has to set the chair in a specific reclined position before they can rotate the chair. This has a major negative impact on the guessability of the product. One way to aid the user and improve guessability is by improving what Jordan (1998) refers to as the explicitness of the product. This can for example be done by implementing affordances which is a term used by Donald Norman (2002) to describe properties of an object that indicate possible actions to the user. This may be more difficult to achieve with a combined interface than with two separate ones as clues and affordances are more easily misunderstood.

Alternative 2 - Separate Interfaces

When the interfaces for rotation and inclination are separated, it has to be decided which interface should have what function. To provide compatibility, the seat angle adjustment position should coincide with other CRSs, i.e. on the front of the seat. This however may be countered by the fact that it is inappropriate to use position A for rotation as it would rotate to face away from the user which may then be difficult to reach. Position B on the other hand will face forward towards the user and therefore be easily accessible. The lack of compatibility is likely a minor problem in relation to this.

6.3.2. Seat Angle Indication

Some models of CRSs indicate if the seat has been reclined to an appropriate angle. The indicators work by the same principle a spirit level works, measuring the angle of the seat relative to the ground. The angle indication is supposed to inform the user that because the angle of the car seat varies for different car models, the base of the CRS may need to be propped up to change the angle. If the car is parked on unlevel ground when the indicator is read, the user could interpret the indication as a need to adjust the inclination to an inappropriate angle. As the angle indicator could give a false reading, it should not be implemented for the new concept.

Another type of angle indicator commonly appears between the seat and the base, indicating the angle between them. However, an inappropriate angle of recline for the seat relative the base should ideally be physically impossible to be set, making an angle indicator redundant from a safety standpoint.

6.3.3. Support Leg Adjustment

The distance from the floor to the top of the seat is different for different car models. According to UNECE R129 (2014) the support leg needs to be adjustable between a span of 285 and 540mm below the bottom of the base. As stated in “6.2.3. Seat Transportation and Storage” the support leg needs to be attached to the base in a way that allows it to fold under the base for transportation and storage. To allow the support leg to extend and retract, a common solution is for the support leg to consist of two metal profiles, where one fit inside the other. To set the support leg to a specific length, a locking mechanism is required. The interface for the locking mechanism can be designed in a few different ways.

The interface for the locking mechanism is most easily mounted on whichever profile is the outer one. As a consequence, if the lower profile is chosen as the outer, one-handed installation becomes impossible since one hand has to lift the CRS while the other pulls the leg down in order to securely fasten the CRS. If the lower profile instead is inside the upper, releasing the locking mechanism will extend the leg by gravity pulling the lower profile down, allowing one hand to both lift the CRS and extend the leg, i.e. one handed installation. If the lower profile is outside releasing the user can both unlock and retract the support leg, allowing one handed removal of the CRS.

The following alternatives are similar in function, with mainly cosmetic differences.

Alternative 1 - Pinch Grip

For this solution, the inner metal profile of the support leg has holes on both sides evenly spaced along the span of adjustment. The locking mechanism consists of metal pins that are spring loaded so that they are pushed into the holes, preventing movement of the outer profile. The metal pins are attached to a lever on each side such that they move out of the holes when the lever is depressed with a pinching grip.

Alternative 2 - Push Button

This solution works similar to alternative 1, but the inner profile has both columns of holes on the same side, facing the driving direction. The locking mechanism works the same way but with both pins and levers on the same side of the profile, connected to one push button for releasing the lock. This solution makes the support leg thicker, which could make it stand out further in a folded position.

6.3.4. Headrest Adjustment

To allow a range of heights for the passenger of the CRS, the headrest height and the height of the shoulder straps of the harness need to be adjustable. During interviews it was found that if adjustment is not easy, e.g. for CRSs that require rerouting of the harness, it can be neglected. If the headrest and harness height is not correctly adjusted, the child safety becomes decreased.

Alternative 1 - Self Adjusting Headrest

For Ref.A the headrest and harness height is automatically adjusted every time the harness is tightened. The harness straps runs through slots in the headrest, which slides up and down on rails inside the back of the seat. Two spring loaded belt spools pull the headrest up when the harness is loosened. This solution of automatically adjusting headrest is unique to Axkid, which could be an advantage from a marketing perspective. The solution does however come with some drawbacks. Automatic adjustment should ease fastening of a child in the CRS, but because the headrest height does not need to be adjusted frequently, it could have the opposite effect. If the harness is not sufficiently tightened, or if the harness loosens as the child shifts in the seat, the headrest can move up, which reduces the amount of sideways support for the head, impairing safety in a crash. To prevent the headrest moving up, it therefore needs to be able to be locked in place. If the headrest needs to be locked every time the child is fastened, the improvement in usability of a self adjusting headrest compared to a manually adjusted is eliminated.

The belt spools adds weight and cost, and take up space inside the seat. To accommodate space for the spools, the seat either needs to have substantial thickness above the headrest, or the belts need to be routed down to where there is sufficient space for the spools.

Alternative 2 - Manually Adjusted Headrest

A common solution for headrest adjustment is a headrest which is fixed by a locking mechanism, such that when it is released, the headrest can be moved manually.

For Ref.B, a strap at the top of the headrest is pulled to release the lock. In order to move the headrest down, the user needs to pull the strap with one hand, and use the other hand to push the headrest down. For Ref.C the headrest is unlocked by a lever at the bottom of the headrest. The operation is one handed, but if the child is already seated, the lever is hidden behind the child's head, preventing adjustment after the child has been placed in the seat.

A better solution is a lever positioned at the back of the top of the headrest, such that it can be depressed by gripping the top of the headrest (Figure 19), but not accidentally by the child's head. After unlocking the headrest it can then be moved up or down with one hand without repositioning the grip. When the headrest has been moved to the desired location, the grip is released and the headrest is locked in position again.

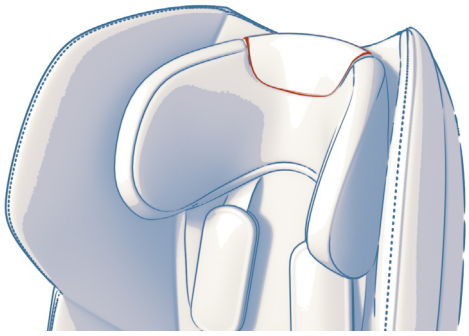

Figure 19. Headrest height adjusted by operating the lever placed in the top.

6.3.5. Harness and Buckle Positioning

During the focus groups and interviews it was identified that there existed a common problem that could occur when placing the child in the CRS. Many owners of CRSs described how the buckle and belt straps would have a default position that placed them behind the child when the child was put in the seat. This adds a step to the action sequence that needs to be performed in order to fasten the child and was described as an annoyance. In lieu of a new solution for harness positioning, the harness can be fully released and placed over the sides of the CRS, with the weight of the buckle tongues holding the harness in place.

Alternative 1 - Harness Hooks

A common way to move the harness straps out of the way is to allow the user to attach these to strap hooks at each side of the seat. This is a solution that is fairly common on today's market but they can often look like something thats been included into the design at a very late stage in the design process and can therefore have a negative impact on the aesthetics. This however is not an inherent property of the concept but rather of specific solutions and therefore there may be room for improvement.

Alternative 2 - Magnets

For this solution magnets are sewn into the pockets in the textile cover on each side of the seat. A metal plate (or if necessary, another magnet) is sewn into the textile padding on each shoulder strap so that the straps can be attached to the sides. Some indication such as an icon on the sides and the harness could provide guessability for this function.

Alternative 3 - Grooves

For this solution, grooves are located in the sides of the seat which the harness straps fit into. The harness is fixed in the slots by friction alone and can be pulled out once the child has been placed in the seat.

Buckle Positioning

To prevent the buckle from becoming stuck under the child, the natural position of the buckle needs to be lying forward onto the seat. To achieve this the slot in the textile cover that the lower harness strap and buckle protrudes from is extended in underneath the textile cover (Figure 20). The stiffness of the buckle padding pushes the buckle forward, but can still be bent backwards when tightening the harness.

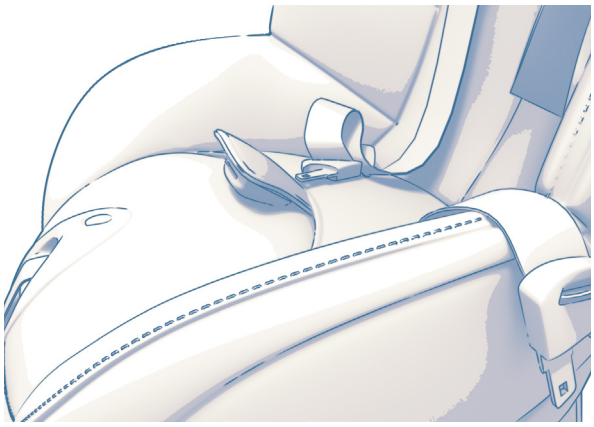

Figure 20. Buckle in its natural position: Leaning forward to prevent becoming stuck underneath the child.

6.3.6. ISOFIX Assembly Adjustment

During field testing, it was found that the ISOFIX anchor points are located at different depths inside the seat in different vehicles. This means the distance the ISOFIX connectors need to extend differ between cars, in order for the anti-rotation brace to apply appropriate pressure on the seat back. The length with which the ISOFIX connectors extend from the base should therefore be adjustable.

Alternative 1 - Manual Locking

For this solution the ISOFIX connectors are attached to a sled which slides along a track inside the base. A locking mechanism prevents movement of the sled, unless a button on the base is depressed. When installing the CRS in a car, the ISOFIX sled is first extended by holding down the button and pulling the sled outwards. The button is then released, fixing the sled in position. After the ISOFIX connectors have been attached to anchor points the connectors can then be unlocked again and retracted until the anti-rotation brace comes into contact with the back of the car seat.

Alternative 2 - Self Adjusting

This solution is used in Ref.B, for which a locking mechanism prevents the ISOFIX connectors from extending, while retracting them is not locked. This means after the ISOFIX connectors have been attached to the anchor points in the car seat, the base can be pushed towards the seat, retracting the connectors without operating a button or lever. When the connectors need to be released in order to remove the CRS from the car seat, a strap is pulled, allowing extension of the connectors and providing access to the buttons on the ISOFIX connectors.

A drawback of this solution is that when attaching the ISOFIX connectors to the anchor points, if the base is pushed towards the seat instead of the connectors, they may retract into the base instead of latching onto the anchor points.

If used for further development, it should be investigated if patents are held for this functionality to avoid infringement.

6.3.7. ISOFIX Connectors

To detach the ISOFIX connectors for Ref.A, a button is pushed on each connector. The direction of the action is towards the seat back, while the ISOFIX connector needs to be pulled away from the seat back to release the connector from the anchor point. During field testing this was found to be counter-intuitive, as the actions have opposite directions, as well as a difficult operation to perform with one hand.

For reference products B and C, the push direction of the release button is away from the seat back, proving such a solution is possible. However, as Axonkids already have developed an ISOFIX connector which can be implemented in the new concept, this usability issue could be ignored to reduce the cost of development. This solution should however be taken into consideration, should Axonkids decide to develop a new ISOFIX connector.

6.3.8. Harness Tensioning

As descibed in “3.3.1. Priority One Issues“ tensioning of the harness of the reference products can lead to installation errors and reduced safety of the child passenger.

Alternative 1 - Mechanical Advantage Harness Tensioning

The mechanical advantage harness system works the same way a block and tackle works , where a rope is routed through pulleys to gain a mechanical advantage. For the reference products the tensioning belt is connected directly to the shoulder straps of the harness and fed through the front of the chair. To gain a mechanical advantage, this solution the tensioning belt is connected to a static point inside the chair and is fed through a pulley connected to the shoulder straps and then out the front, as seen in Figure 21. As illustrated in Figure 21 the force needed to tighten the harness is half that of the reference products, but comes with the price of having to pull the tensioning belt twice the distance. This extra distance should not be a problem from a usability standpoint, but can result in more of the tensioning belt protruding from the chair. In order to not lose the advantage over a traditional tensioning system, the belt needs to run through the pulley and under the chair with minimal friction. To accomplish this the diameter of the roller in the pulley, the material of the belt and how the belt is routed could to be further examined.

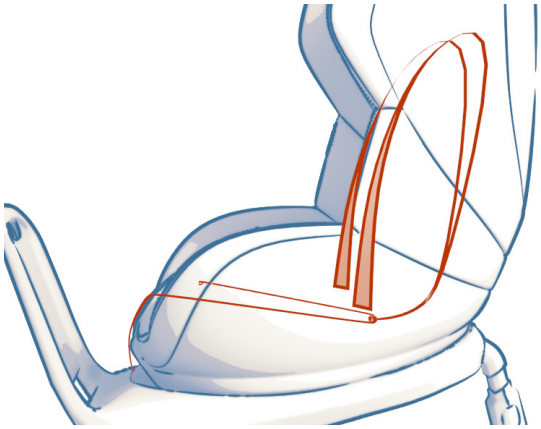

Figure 21. Mechanical advantage harness system.

Alternative 2 - Minimized friction

This solution focuses on minimizing the friction between the tensioning belt and the surfaces it comes into contact with. This is achieved by routing the belt over rollers instead of letting it slide over plastic and/or metal surfaces.

6.3.9. Excess Belt Management

On the reference products, when the harness is tightened a length of the tensioning belt protrudes from the front of the CRS. This can prove to be a usability problem, as the belt could become stuck or hidden from the user underneath the CRS. This problem is exacerbated by the mechanical advantage system described in "6.3.8. Harness Tensioning", as even more of the belt would protrude.

Tensioning Belt Spool

The tension belt spool is positioned next to the out feed of the tensioning belt, as seen in figure tensioning belt spool. As the harness is tightened, excess belt is automatically rolled onto a spring loaded cylinder. This effectively eliminates the possibility that the tensioning belt becomes stuck or hidden.

The area between the tensioning spool and the belt out feed is recessed. This recess allows the user to reach behind the belt to ease gripping. The spool has enough excess belt rolled up that when tightening the harness, the user can pull the same amount of belt from the spool as is pulled from the belt out feed. This allows the harness to be tightened in one operation, without need for the user to switch grips on the belt, as seen in Figure 22.

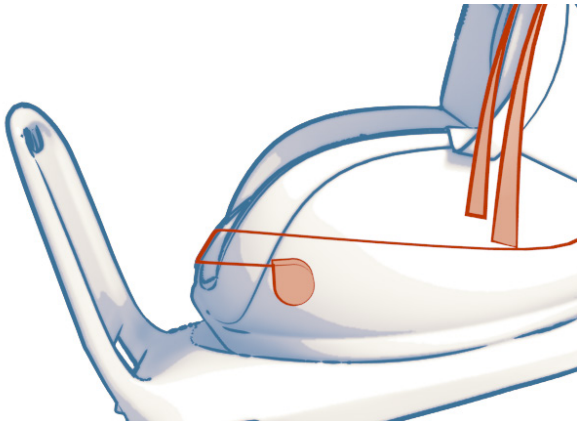

Figure 22. Spool for gathering excess tensioning belt.

6.3.10. Child Escape Prevention

According to Ida Hansson[1] ongoing research suggests children in CRSs tend to shift in their seat and move the seat belt out of position, resulting in a reduction of safety as the belt may not be in its intended position in a crash. However, the research has been conducted on children of seven years and older, and for three point car seat belts. It does not indicate the same would necessarily be true for children of four years or less using five point harnesses.
A solution commonly used for preventing a child from moving the harness out of position is a harness chest clip. Such a solution usually consists of two parts that are fixed on the shoulder straps of the harness in chest height and are then attached to each other to ensure the width between the two straps are even across the child's chest. A requirement in UNECE R129 (2014) states that it must be possible to unlock in one action, which means a separate chest clip cannot be implemented in a CRS and still meet the requirement. A chest clip must be sold separate, and was therefore not further explored in this project.

6.3.11. Belt Tension Indication

One of the more common errors users make when installing a child in a CRS is failing to tighten the harness enough. This can be detrimental to the safety of the child passenger.

1. Ida Hansson (Project assistant, Chalmers) Interviewed 14-02-12.

Klinich et al. (2014) suggests the high frequency of this type of error may be due to a lack of feedback, i.e. the user does not know if the harness is sufficiently tightened.

Auditory and Haptic Belt Tensioning Feedback

This solution consists of a mechanism which the tensioning belt is fed through. The belt runs over three rollers, of which the two outer ones have a static pivot point and the middle one slides up and down. The center roller is spring loaded so that it is naturally in its lowest position. The center roller is also fitted with a notched wheel on each end. As the harness is tightened, the tensioning belt forces the center roller up, letting the cogs engage a leaf spring. Friction between the belt and the roller causes it to spin, and for each cog the leaf spring passes it makes a clicking sound against the wheel as it springs back. The clicking sound notifies the user that the harness is sufficiently tightened. The spring forcing the roller down needs to have a suitable elastic force so that the mechanism only provides feedback if the harness is tightened to an appropriate degree. This mechanism could likely also provide haptic feedback as the force required to move the tensioning belt will be slightly larger as the cogs on the roller pushes on the leaf spring, and as the leaf spring passes over a cog the force is lower.

6.3.12. Dirt and Liquid Gathering Prevention

Tony Qvist[1] claims CRSs with rotating bases tend to gather dirt between the seat and the base, hindering adjustment of the inclination angle and seat rotation. During discussions with parents it became clear that liquids that are spilled or otherwise produced upon the CRS can gather inside the CRS, potentially causing foul smell as well as coating or corroding of moving parts resulting in hindered movement. It was also found that users might attempt to clean the CRS with a garden hose or high pressure washer (with the textile cover removed), which again could lead to corrosion.

1. Tony Qvist (CEO, Axonkids) interviewed 14-03-10.

Liquid Drainage

Surfaces that are likely to come into contact with liquids need to be free of depressions where liquids can gather. Where necessary, holes for mounting hardware should be capped. For concave surfaces where liquids will naturally gather, holes for drainage are placed. The liquids can then be routed through the CRS and out from the bottom by ducts such that no liquids come into contact with any internal parts or parts prone to corrosion, nor does it gather inside the CRS.

Dirt Drainage

To prevent dirt gathering between the seat and the base as well as inside the base, this solution features a threshold around the center of the base where the base meets the seat. A channel diverts the dirt into ducts going through the base and out the bottom, as seen in Figure 23.

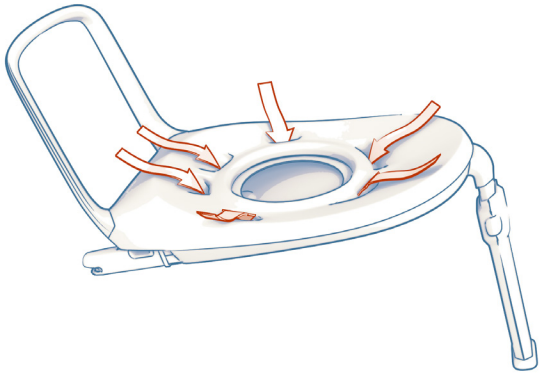

Figure 23. Ducts through the base to prevent gathering of dirt between the base and the seat.

6.3.13. Adjustment feedback

Klinich et al. (2014) suggests a lack of feedback when installing a CRS is one of the main reasons for installation errors by the user, and that feedback can reduce the frequency of misuse. The installation in this context includes adjustments such as seat rotation, adjusting headrest height and seat inclination.

As a rotating seat is a new feature for CRSs (only two models available as of May 2014) potential buyers may not immediately trust this feature, nor may they understand the benefits of it (as was supported by observations from the focus group). The CRS should provide auditory and/

or haptic feedback when the seat is rotated into one of the locking positions (rear-facing or forward-facing). To achieve this tactile bumps could be included in the mechanism that gives the user assurance that the mechanism is working as intended and that various operations have been executed correctly. An example could be to have a distinct tactile bump when the seat has been rotated by 90 degrees° (Forward facing, rearward facing, and facing the car door). This is not however exclusive to the seat rotation, as practically every operation that includes moving parts could potentially be optimized to provide different types of feedback.

6.3.14. Infant Passenger Accommodation

One requirement for the new product is that it accommodates a passenger that is between newborn and approximately 4 years old. For every size of the passenger the straps of the harness needs to be situated at the height of the passenger's shoulders, and the harness buckle needs to be close to the passenger. To accommodate for older passengers, CRSs are usually not suited for newborn babies, and are not recommended for passengers less than 6 month old.

Booster Cushion Insert

This solution consists of a padded cushion insert that is placed in the CRS, in which the infant is seated in. The padding makes the seat narrower, shallower and higher, moving the passenger closer to the headrest and the harness buckle as well as providing support from the sides. The cushion insert can be removed when the child is tall enough to reach the lowest setting of the headrest. The effect of this solution is that the range of adjustment of the headrest can be moved up, the harness buckle position moved forward and the seat made wider to accommodate older passengers.

6.4. Chapter Conclusion

Since the visual design is strictly controlled by the technical functionality of the product It was important to have a good grasp of which technical problems and possibilities existed before moving on to creating a visual design and expression. Some concepts were therefore scrapped before moving on to narrow down the possibilities in order to start producing visual designs. This included for example Child escape prevention which due to regulations would have to be sold separately anyway, as well as a seat angle indicator which could not work very well since the angle of the ground the car stands on could always have a misleading effect on the readings of the indicator.

7. Synthesis

The knowledge from the research phase provided a foundation upon which informed decisions could be made. This chapter describes the process of transferring this knowledge into three concept models. These are then evaluated against each other as well as some of the most prominent competitor products.

7.1. Methods and Execution

The methods used for the creative part of the project mixed traditional techniques such as sketching and mood boards with more modern digital tools. Some of these tools such as digital sculpting are primarily used in the VFX industry but can also be used very effectively for industrial design.

7.1.1. Mood Board

A mood board is most often a collage of images meant to function as a source of inspiration to the designer. Garner & McDonagh-Philp (2001) proposes that mood boards have a function for both problem finding and solving. They are traditionally used as a way of capturing a feeling or expression often with abstract images or images outside the field of design. At this stage in the project a final expression had not yet been decided on and therefore the moodboard was more of a collection of inspirational images mainly from furniture. The images were chosen because of their visual appeal and/or connection to the expressions in the semiotic network. These boards are however not intended as a description of the final expression but rather a collection of images to draw inspiration from when creating an expression in the designs. A typical scenario might be that the feeling of softness or comfort needs to be amplified in a concept. The designer can then look at designs from the board and try to deduce characteristics that capture those expressions.

7.1.2. Shape Design

Creative form generation has played an instrumental role in this project and the generated designs also have to fulfill different geometric criteria. Traditional sketching techniques were complemented with digital tools for generative shape design and evaluation.

Geometrical Constraints

The geometry of a CRS under i-Size regulations has to conform to some geometric constraints. The space the product can occupy is limited to what is referred to as the R2 and F2X envelopes (UNECE R129 2014). These envelopes were used as the base for concept generation which started by modeling the envelopes in a 3D environment, blocking in functional objects and exploring possibilities and restrictions of a rotating geometry. The geometry can be described with the following components, all of which are illustrated in Figure 24.

Seat and Base

The base of the CRS is stationary and can therefore be considered of low priority. The seat itself however is one of the most difficult components in terms of specifying correct dimensions due to the many constraints it has to meet. It needs to fulfill the demands of a growing child, geometrical constraints from regulations and support two axes of rotation.

R2 and F2X Envelopes

These are defined by the i-Size standard where the R2 envelope is used when the seat is rear-facing and the F2X envelope corresponds to a forward-facing position. The UNECE R129 (2014) does not specify that any configuration of the seat always has to fit inside the envelopes, only that they must be able to fit. This means for example that some parts of the seat can extend beyond the envelope when rotated in some way or if for example the headrest is in its top position it is allowed to break these constraints. When the seat is in its rear-facing position the constraints are a bit more important to fulfill since there can be a car seat in front of the CRS and any protruding geometry could collide and interfere with the functionality of the product.

Rotation Sphere

The rotation sphere will decide how the seat moves when the angle of recline is altered. It can also be further divided into a rotation origin and radius. These factors are crucial in order to keep the seat geometry inside the envelopes and avoid collision with other parts of the car.

Rotation Axes

The rotation sphere allows for manipulation in two axes (tilt and rotation) and the geometry of these decide how the seat moves within the envelope. The axis that allows for reclination of the seat has the same origin as the rotation sphere, and has to be perpendicular to both the vertical axis and the direction of travel. The axis that decides how the seat moves when it flips between rear- and forward-facing positions is however a variable that has to be decided. The angle of this axis relative to the vertical axis should preferably be small so that when placing the child while the seat is rotated 90 degrees, the seat will not not be significantly tilted. It is however also important to take into account how the seat geometry moves when switching directions, since an incorrect angle can easily create a situation where the geometry for seat reclination does not work in both forward and rearward facing positions.
Many of these factors are variables and there is no obvious way to formulate an optimal solution. The method for finding a good solution was therefore explorative. Simple representational geometries were created and a rigged digital model was used in order to evaluate how various configurations worked and the impact of specific variables (Figure 23). The concepts could then be designed to comply with the chosen solutions.

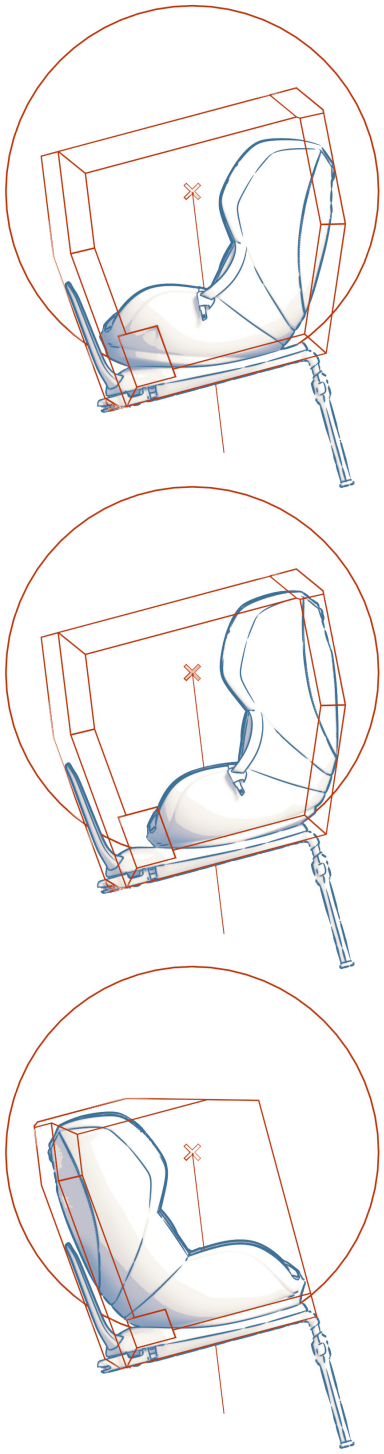

Figure 24. Size constraints, rotation sphere and rotation axis of the seat.

Digital Mannequin

The R2 and F2X envelopes are geometrical constraints that have been specified in absolute terms, but the CRS also has to fulfill the geometrical demands that is required by a growing child. To be able to meet these requirements satisfactory a digital model of a child mannequin was developed. The mannequin uses a bone rig with inverse kinematics, originally a method that calculates the transformation and joint movements needed to position a robotic arm in a desired position (Paul 1981). This allows for easy manipulation and positioning of the limbs of the mannequin to visualize different sitting positions at different ages, and to easily make changes to the design to optimize ergonomics.

Although there are some studies on anthropometric dimensions of children, none of these were considered to be well suited for this project due to flaws. The Dutch database Dined (DINED 2014) does not contain data on children younger than two years, and a large American database (NIST 2014) is based on data from 1975 - 77 and can therefore be considered to be outdated, and in addition it is not necessarily correct for the Scandinavian population. Instead the dimensions for the mannequins described in UNECE R129 (2014) was chosen as they are adequately representative for the different age groups. The digital mannequin was modeled and made into three different mannequins of different ages (Figure 25). These were then used actively in the design phase to shape the concepts around the mannequins.

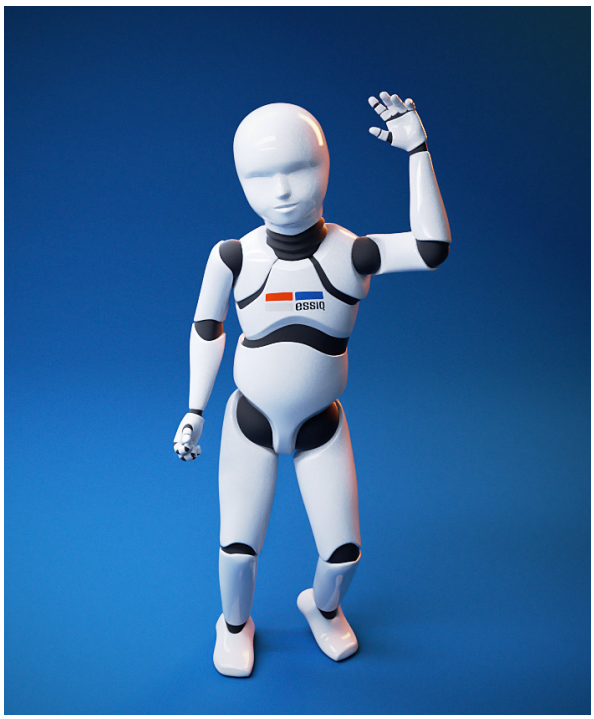

Figure 25. Mannequin modeled to the size of a 3 year old.

Digital Sculpting

Once most of the features were known and decided upon the concept generation continued in 3D. A digital sculpting environment was used to create a large number of concepts and variations (Figure 26). Digital clay puts very few restrictions on the created geometry and differs significantly from traditional parametric CAD solutions. By letting the user manipulate the geometry immediately through a digital pen input device, without having to make changes to parameters allows for a workflow that resembles traditional media such as sketching or clay. Another advantage is that the process creates a digital 3D representation that can be evaluated with digital mannequins and allows for simple analysis of different geometrical constraints. A sketch would also have to be translated to 3D surfaces, a process where some aspects of the original design may not come out as intended since the evaluation happens at a later stage. By utilizing the strengths of digital sculpting and other quick modeling techniques much of the evaluation can be done continuously in parallel to the design process.

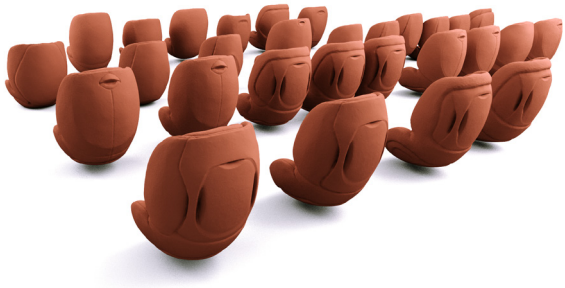

Figure 26. Examples of design variations created with digital sculpting.

7.2. Visual Expressions

The web survey together with the semiotic analysis of different CRSs provided an indication as to what a CRS should communicate to the customer in order to be competitive. The adjectives which seemed to have the strongest correlation to the total impression were Beautiful/Attractive, Exclusive, Fresh, Comfortable, Safe, Embracing and Manageable. However, most adjectives that were included in the web survey had a positive correlation in varying degrees to the total impression. These in combination with the desired expressions and values found in the study were used in order to create value based design cues. This type of cue consists of design elements such as shapes, materials, textures etc. in order to evoke references that are closely linked to the inteded expression (Karjalainen 2007). Although there are methods that aim to address the problem of effectively translating feelings into design features (e.g. Kansei engineering) (Schütte 2005) there was not enough time to complete such a project. The translation of expressions and feelings into design elements was instead done by analyzing the results of the study and making cross comparisons to the different products that were part of it. This was done by selecting products which had scored well for a certain expression and studying these as well as comparing them to products that did not score well. Such observations could then be used as references for discussion on what design elements should be used in order to achieve certain expressions. An intuitive and iterative approach was also taken, where designs that did not reflect the intended expressions sufficiently simply were discarded or modified. This method led to concepts which were fairly similar in appearance and while some attempts were made to make a wider exploration of form these were quickly discarded as they were deemed inferior.

7.3. Three Concepts

From the many sketches and concept models that were generated the best features were chosen through discussions within the team and then turned into three refined concepts. These concepts had many similarities in terms of design cues but were made with slightly different focus. The concepts were named C1, C2 and C3 and can bee seen in Figure 27. C1 is mostly focused on comfort and visual harmony with round large curves, and was also the first concept to be generated. C2 was an effort to create a lighter impression but otherwise much of the same characteristics as C1. The last concept, C3, aimed to enhance the feelings of robustness and safety.

Figure 27. From top to bottom: C1, C2 and C3.

7.4. Evaluation

For every technical solution with more than one alternative, as well as for the three visual concepts, an evaluation method was used to compare them against each other. For the visual concepts a web survey was conducted, and for the technical solutions, alternatives that were deemed unsuitable were ruled out. To aid in choosing solution alternatives that were not obviously superior, evaluation methods such as Pugh matrices, PUEA and ECW were used.

7.4.1. Web Survey II

A second web survey was designed in order to evaluate three different concepts. This survey was very similar to the first, but it had some important differences. Firstly, the number of products included in the study was reduced from nine to six. These six products consisted of the three concepts C1, C2 and C3, as well as the two products which ranked on top from the first study, as well as Ref.A. The number of expressions was also reduced to only include the ones which showed the highest correlation to the total impression, in total 7 adjectives plus the "total impression". The reason for these changes was that many of the responses from the first web survey were incomplete, probably due to the sheer amount of questions. For the second survey most of the questions weren't necessary as there was no longer a need to identify possible correlations. The survey got 41 responses in total.

The second survey also included a view of the back of each CRS which is likely to have an impact on the ratings of the products when comparing to the first survey. This was however deemed necessary in order to get a better

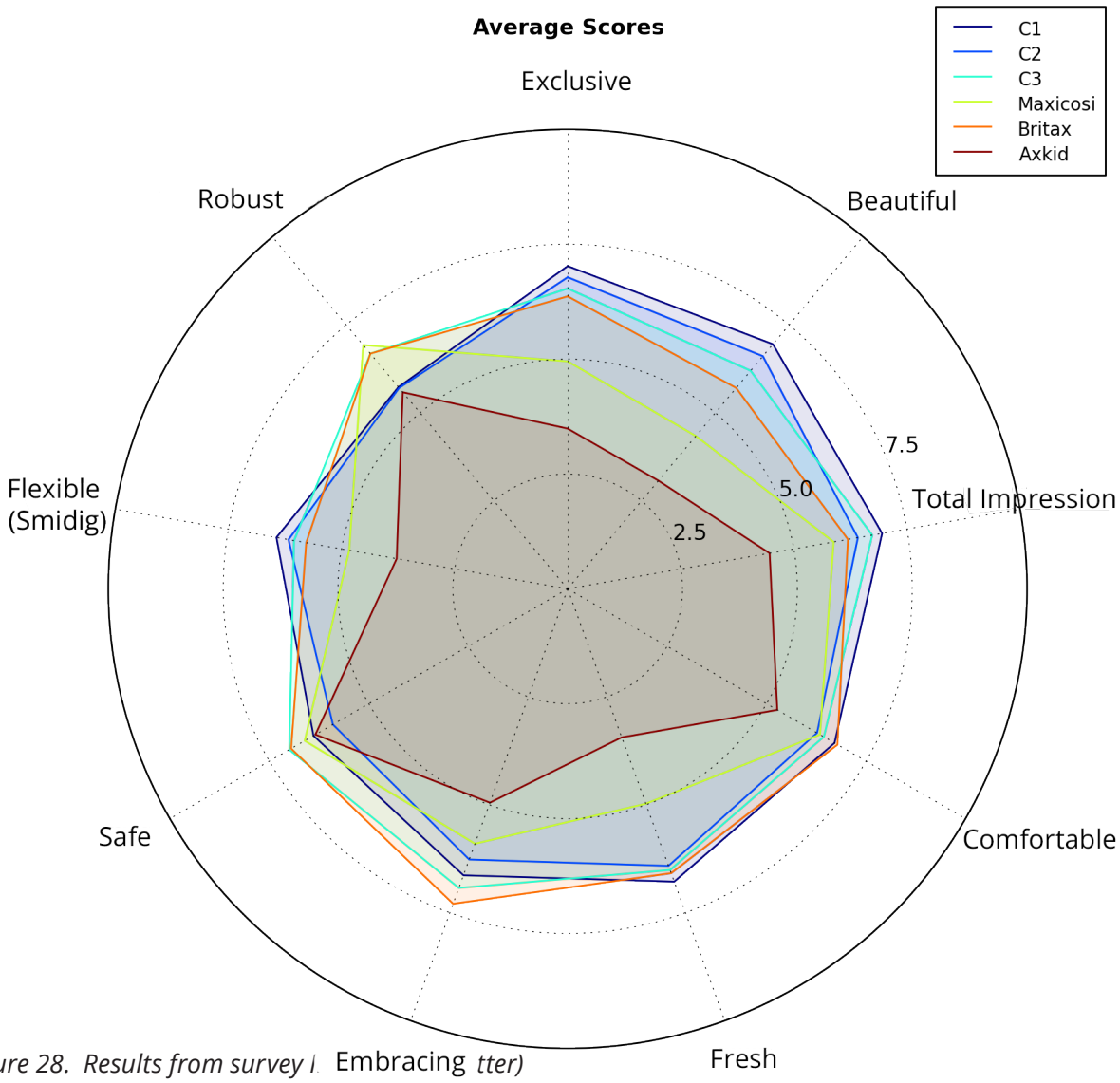

Figure 28. Results from survey I tter)

comparative measure of the total impression of the new concepts since a customer sees both sides when browsing a store.

As shown in Figure 28 all three of the new concepts scored better than both the “best” competitor products and much better than Ref.A in terms of the total impression. The variations in intended expressions also shows in the results, mainly between the C1 and C3 concepts.
Figure 29 shows how many times each of the alternatives were picked by someone as the top scoring product in terms of total impression. This could be interpreted as an indication to which product was the favorite by affective judgment for each person and thereby a possible indication as to which product they would purchase. This metric is important since a product that gets a high average still has the potential of not being purchased by anyone. The reason for this is that the customer base is likely not homogeneous in its aesthetic preferences. To illustrate this effect, consider Figure 30 which is similar to Figure 29 in that it also illustrates the number of times an alternative was picked as a favorite, but here only the ones that were undisputed, or in other words, was someones sole favorite, were counted. Interestingly the C2 concept does not seem to be favored by anyone despite the fact that it placed third in total impression and would be outperformed in sales even by the Axkid Kidzofix which had the lowest scores. This is a clear example on how trying to satisfy everyone can lead to a product that doesn’t fully satisfy anyone, and demonstrates the importance of knowing and focusing on your target group.

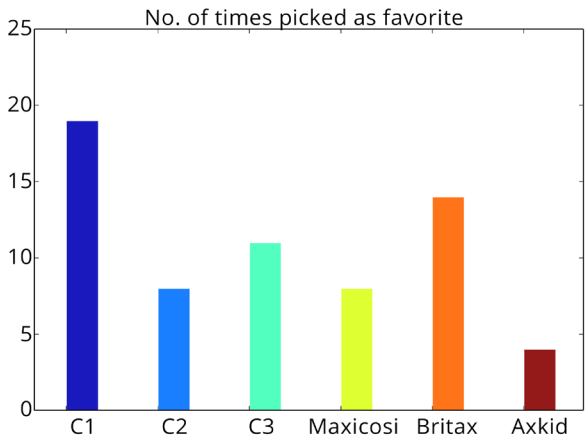

Figure 29. Number of times a CRS was picked as favorite.

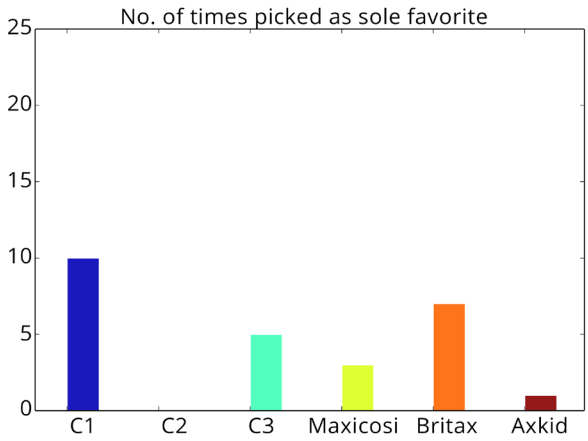

Figure 30. Number of times a CRS was picked as sole favorite.

Page & Herr (2002) discuss how “liking” often can be determined quickly by test subjects while perceived quality is a more reflective process and suggests that quality judgments often are more influenced by reviews in buyer guides and brand strength. The actual choice a consumer makes is based both on the affective judgment as well as the reflective judgment, the web survey however has primarily considered the affective side of a consumers evaluation of the products. The reason for this is that reflective quality aspects requires knowledge of the products performance which is partly unknown at a conceptual stage in the development process. This could also be a potential source of error in the web survey, since there is no way to know if the person answering the survey has any previous experience with the different CRSs.

7.4.2. Pugh matrices

A Pugh matrix is a tool for systematically evaluating one or several concepts compared to a reference. As the name suggests, it consists of a matrix of the different concept on one axis and on the other different properties, for example ease of use and cost. The concepts then get a score for each property: A positive score if the concept is better compared to the reference for said property, negative score if worse, and neutral if neither better nor worse. The total score is then calculated for each concept, after which the one with the highest score is superior. The results should however not be regarded as definite, as many factors outside the scope of a Pugh matrix can affect the viability of a concept (Silverstein et al. 2009).

Pugh matrices were used to evaluate solution alternatives, using existing solutions for one of the reference products to compare against.

7.5. ECW & PUEA

In accordance to the list of requirements a comparison was made between the results from the ECWs and PUEAs of the concepts and the reference product. Table 1 shows that the functionality of the new concepts have fewer usability problems when comparing to the reference and fulfills the requirement specification. The biggest issue we could identify in the new concepts is related to the ISOFIX connectors, since they require the user to perform a check that the connection is successful. If this check is not performed the seat is completely loose and gives little to no protection for the child. This is however a problem in all products we have seen and can be considered to be very unlikely of occurring since the user basically needs to forget to attach the CRS, a problem that is difficult to completely prevent.

7.6. Concept screening

The process with which a final concept was chosen was based on an analysis of the results from the evaluation, discussions with Axonkids concerning the feasibility and their thoughts in general, as well as reflections on branding issues.

The web survey showed that the C1 concept scored highest in both average total impression (Figure 28) and the number of times it was picked as a favorite (Figure 29), making it the “winner” of the web survey. This alone however is not a flawless way to determine the best choice. The C3 concept for example was a favorite of Axonkids and was also considered to more closely reflect the desired core values. This is also supported by the web survey where the C3 concept displayed high scores for the adjectives “safe”, “solid/robust” and “embracing”. These are expressions that are semantically close to the core values “Safety”, “Trust”, and “caring”. Those adjectives are also the ones where Ref.A had its highest scores, which gives an indication that the C3 concept has a profile where the old core values have been amplified and expanded upon.

Since Axonkids is such a small company where the employees and engineers are involved on a very personal level, it can also be speculated that their motivation could be affected negatively by working on a product that is not their preferred choice. Another way to put this is that the proposed company core values are an attempt to formulate the values of the individuals who created the company, and therefore their opinion is of high priority.

Number of errors	**1**	**2**	**3**	**4**
Revo Fasten/Remove Child	0	0	2	5
Kidzofix Fasten/Remove Child	0	6	8	7
Revo Replace Textile Cover	0	0	0	4
Kidzofix Replace Textile Cover	1	4	10	17
Revo Remove Textile Cover	0	0	0	2
Kidzofix Remove Textile Cover	0	5	4	3

Table 1. Number of errors for different operations according to ECW analysis.

Another observation made is that the C3 concept seemingly has a lower score than the Britax CRS in terms of how often it was picked as a favorite (Figure 29). This however is a somewhat misleading statistic since this score is affected by the presence of the C1 and C2 concepts. The three concepts are not competitors as only one of them will be made and therefore two of them have to be excluded from the survey in order to compare against actual competitors. In Figure 31 this has been done and the result is that the C3 jumps up to the top when the other two concepts are not available as alternatives.

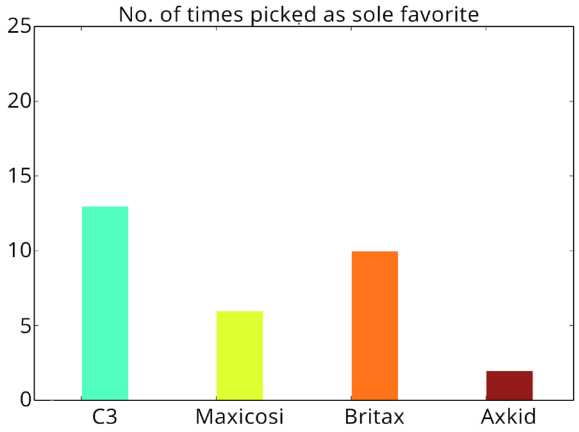

Figure 31. Number of times a CRS was picked as sole favorite. C1 and C2 removed from sample.

To summarize this, the web survey alone speaks for the C1 concept but brand strategy seems to rate the C3 concept higher. Both concepts have higher scores than all of the competitor products that were included in the study. The C2 concept was discarded since it did not have any significant strengths over the other alternatives. Although the C3 concept had a slightly lower score on total impression than the C1 in the survey it is worth mentioning that when only analyzing the results from parents they were close to equal, an increase that was predicted from the first survey based on how parents valued safety higher than non-parents. This is not a definitive conclusion however as it may also be due to, for example, the fact that most parents were older than the non-parents who participated in the study and this could significantly affect the outcome.

Figure 32. Final concept.

8. Final Concept

The final concept is primarily based on the C3 concept but also has some significant changes. These changes were primarily a result of discussions with Axonkids and decisions based on the results from the second survey. Some design elements from the C1 concepts were adapted to the C3 format. These mainly concerned the backrest design, since a textile covered surface lowers the manufacturing demands on the underlying surface which can aid in prize and weight optimizations in the final design. This chapter describes the features of the final concept.

8.1. Technical Solutions

Concept screening determined which technical solutions should be implemented in the final concept. The specific solutions chosen are described here.

8.1.1. CRS Fastening

In accordance with requirements, the final concept attaches to the car by ISOFIX connectors. The connectors are fixed to a sled which can be extended and retracted into the base (Figure 33). When the sled is retracted, it is fixed in position by a locking mechanism. To release the mechanism and extend the sled, a strap attached to the sled, positioned between the connectors, can be pulled. This alternative was picked over a button/buttons for unlocking because the extension of the connectors can be performed with a one handed operation. After the connectors have been attached to the anchor points the base can be pushed towards the car seat without interaction with the locking mechanism.

The solution for improved ISOFIX connectors was discarded as Axonkids has an existing solution, and the improvement in usability for the new solution was not deemed significant. Using the existing solution eliminates the cost of developing new dies for production of a new connector.

Figure 33. ISOFIX connectors.

8.1.2. Anti-rotation Devices

As a top tether was deemed unsuitable because of its lacking performance for rear-facing CRSs a support leg is located on the front of the base. The support leg rotates on an axis such that it can be folded under the base to ease transportation and storage. To further ease transportation locks in a folded position by a friction fit inside the rotating mechanism. In order for the support leg to be supported by the car floor, it is comprised of two aluminum tubes, one of them smaller to fit inside the other to allow extension of the support leg. To allow adjustment of the support leg length, a pinch grip interface was chosen (Figure 34). This solution was picked because it is visible from every direction and was deemed more

intuitive. It also takes up minimal space under the base when folded, providing a more stable stance on the ground.

An anti-rotation brace was chosen for additional anti-rotational support because it can be used in cars that are not fitted with rear-facing tether anchor points, and because it provides a carrying handle for transportation as well as protects the car seat. To decrease the weight of the CRS for transportation the brace is removable by unlocking it with a button underneath the base.

Figure 34. Support leg.

8.1.3. Textile Cover

The shape of the seat is designed in such a way that the textile cover is stretched over convex surfaces, and for concave surfaces sufficient material is supplied such that the padding attached to the back of the textile keeps the intended shape. The textile cover is attached by pulling it over the top of the seat and stretching it around the front of the seat into a groove in which the seam is hidden. The cover is then tightened by a zipper on the back of the seat. To allow removal and replacement of the cover, it is open in the middle where the harness can be pulled through without detaching the belts.

8.1.4. Headrest

Axonkids' solution for an automatically adjusting headrest was not chosen as the improvement in usability did not warrant the increased price, weight and mechanical complexity. Instead the pinch grip adjustment solution was chosen because it is a one handed operation and because it is visible and accessible, even after the child has been placed in the seat (Figure 35). The headrest is covered in the same type of textile cover as the seat which can be removed by pulling it over the sides of the headrest as it is not attached to any other part of the CRS. Attached to the headrest cover is a padded flap which covers up the hole in the textile cover to hide the internal structure of the seat.

Figure 35. Headrest with different color on top of the headrest to indicate the adjustment interface.

8.1.5. Seat Rotation and Angle Adjustment

Separate interfaces was chosen for seat rotation and angle adjustment, because it fared better in the evaluation compared to a combined interface (Figure 36). Position B, front of the seat was picked for the interface for seat rotation, to provide reach while the seat is rotated. Position A, the very top of the seat was picked for the interface for adjusting angle of recline. Position C was used for neither of the interfaces as the need for two buttons or levers results in excessive mechanical complexity.

Figure 36. Top: Interface for changing angle of recline. Bottom: Interface for rotating seat.

8.1.6. Harness and Buckle Positioning

For harness positioning solution, alternative three was chosen, for which the sides of the seat has grooves in which the harness can be fitted while placing the child in the seat (Figure 37). The other alternatives were discarded because they introduce unnecessary parts for a function which can be achieved through simpler means.

To position the harness buckle out of the way to prevent the child being placed on top of it, the hole in the textile cover for the buckle is designed to push the buckle forward.

Figure 37. Grooves in the sides of the seat for harness positioning.

8.1.7. Harness System

The mechanical advantage harness system in combination with the belt tension indication solution was implemented despite the introduction of mechanical complexity to the system, because of the considerable improvements in usability (haptic and auditory feedback) and ergonomics (reduced physical strain). Because this solutions requires a longer tensioning belt, the solution for excess belt management was also implemented. This is a combination of the solutions described in sections 6.3.8 and 6.3.9 (Figure 38).

Figure 38. Tensioning belt and belt spool.

8.1.8. Dirt and Liquid Drainage

The solutions for dirt and liquid drainage have here been combined into one solution. Dirt or liquid that comes into contact with the seat or the base and that is not contained by the textile cover is drained through holes in the seat and base.

8.1.9. Infant Passenger Accommodation

To accommodate infant passengers the solution embodied by a removable booster cushion was designed to fit in the seat to provide additional support to an infant passenger, to be either sold with the CRS or separately as an accessory.

8.1.10. Discarded solutions

A solution for seat angle indication was not implemented, simply because it could give a false reading, causing the user to make inappropriate adjustments to the angle of the seat.

Solutions for child escape preventions were discarded because i-Size regulations require the harness to be released with one single operation.

8.2. Visual Identity & Brand

This section describes in greater detail how meaning has been implemented in the final concept through design features. It also describes the design language and should serve as guidelines for future products from the same brand. Many of the design cues should be possible to transfer to other product categories such as infant carriers etc.

8.2.1. Value-based Design Cues

The surveys with the semantic differential were done in Swedish, and the adjectives has here been translated to English which may not be a perfect representation of their true semantic meaning in Swedish culture.

It is important to keep in mind that the relationship between expressions needs balance. In the correlation matrix it can be observed that size seem to have almost no correlation to the total impression, however this is of course not entirely true. An extremely bulky CRS would not be well accepted with customers but within reasonable limits there are other factors than size that are far more important to the overall expression. Since many of the expressions depend on each other in sometimes very complex ways, changes made in order to improve one factor may at some point start to affect another more important factor and therefore have a negative impact on the total impression.

Many of the reflections on what features correspond to certain expressions are based on the experience and opinions of the authors and should therefore not necessarily be considered as objective facts.

Beautiful

Unsurprisingly, beauty had a strong correlation to the total impression. This relationship has been studied before (Tractinsky et. al 2000), but its causality is not necessarily one-way. There are a number of other expressions which have a positive and fairly strong correlation to “beauty” which could be an indication that beauty is not just a separate quality but we may feel that a product which we like because of other qualities may also to some extent become more beautiful. It could also be the other way around, that a product which does not seem to fulfill our needs and expectations also affects our judgment of beauty in a negative way. Clear correlations does however exist between “beautiful”, “exclusive”, and “fresh”.

Exclusive

Exclusiveness as a word basically means not to “include”. In design the expression has some nuances that separates it somewhat from its original meaning. It has become closely related to the price of a product and exclusive products are often status symbols. In product design this is often implemented through choice of materials and build quality. Metal, wood and glass are generally more exclusive than plastics. Exclusive products can often be minimalistic in their expressions. Excessive use of icons stickers and other elements that clutter the

visual space does not belong in an exclusive product. Examples of exclusive design brands are Bang & Olufsen and Apple.

The expression is however somewhat ambiguous as another "kind" of exclusiveness is the extravagant type that for example can be observed in some, but not all, Rolex watches where minimalism has been replaced with diamonds and gold. This type of exclusiveness is more closely related to the actual meaning of the word, but it is very far from the AxKid brand values and pricing. "Exclusive" also seems to have an apparent correlation to "fresh" which the authors also suspects is an indication that "clean" minimalism is what the expression is actually referring to in this instance.

Some design cues that relates to exclusiveness in the final concept:

• Denim style textile cover (Figure 39). The threads are much finer and softer than in regular denim but the small color variations creates a textile with a higher quality feel to it.

• Well fitting textile cover. A slight elasticity in the textile as well as more effort in the creation of a well fitting cover gives a feeling of high quality. It also creates a "cleaner" more minimalistic expression which goes well in line with exclusiveness.

• Reduced amount of unnecessary instructions. Instead of having printed instructions on various places on the product visual cues can aid the user to find these functions by themselves. The final concept uses a color coding to indicate areas where interaction is possible. The belts, levers and headrest lock all share a specific color in order to aid users and let them figure out the mechanics in an exploratory fashion. Extra instructions can be included in a manual and a quick manual for users who are more goal oriented (Hassenzahl 2003). These factors helps to convey the minimalistic and clean expressions that relates to an exclusive design.

• Some effort was put to create color combinations that would be perceived as "exclusive". These are described in detail in a dedicated section.

All of these cues are intended to either create signs that relates to exclusiveness or avoid signs that may have a detrimental effect to the perceived quality of the product and thereby also the exclusiveness.

Figure 39. Denim style textile cover.

Comfortable

The factor which had the strongest correlation to "comfortable" was surprisingly "safe". The semantic network had predicted expressions such as "embracing" "soft" and "relaxed", and no significant correlation was predicted with "safe", "robust", and "stable". The reasons for this is not entirely clear but speculations can be made. Both safety and comfort are qualities that mainly concerns the well being of the child and therefore they might be affected by each other.

The correlations to "stable" and "robust" (more correctly to the Swedish word "gedigen") may simply be byproducts of the correlation to "safe" but may also hint that the same design cues that expresses robustness and safety may also express comfort. For example if you imagine an armchair that seems robust, stable and safe, chances are that the mental image you get is of an armchair that also seems very comfortable. This correlation could in other words be amplified by a semantic duality in commonly used design cues.

Other design cues that helps to convey a comfortable expression:

• Embracing design. Described in more detail later in this chapter.

• Convex shapes. This hints at the padding used in the chair and therefore makes it seem soft and comfortable.

• Fabric in textile cover. By using a softer textile that produces less sound when touched a the feeling of softness should be improved further

Comfort was also one of the expressions which were valued higher by parents which can be explained with the assumption that parents reflects more on taking care of their children than someone who does not have children of their own.

Fresh

Fresh as an expression is somewhat ambiguous. Some people used the word to describe factors concerning maintenance and cleanliness while on its own it rather seems to be more related to a visually clean look, which also explains the correlation to "exclusive" and "beautiful". Design cues that relates to Freshness are the big sweeping surfaces and well fitting textile with few creases which should indicate a product that is both clean and easy to keep clean and fresh.

Safe

The expression of safety closely matched the predictions from the semiotic network with the exception of the correlation to "comfortable". A feeling of safety is generally conveyed through a robust and stable design that also protects the child as a shield by embracing it from the sides.

Although there may exist signs that may have a direct relation to safety, it is more likely a product of semiosis. Design elements that are directly related to safety, such as seat belts, are most often an integral part of the product itself, and even if the product and all approved CRSs have to be safe, so in reality it is very difficult to tell which CRS is the safest merely by looking at it. The expression of safety is instead a function of expressions such as "robust", "stable", "protecting", and "embracing". A robust and embracing design will therefore lead to a CRS that feels safe. How to achieve these are described in more detail later in the chapter.

Embracing

Embracing is an expression that was placed at the lowest level in the semantic network, in other words there is no reason to believe that other expression contribute significantly to amplifying the expression of "embracing". The expression should however contribute to other expressions. The data in the correlation matrix is also mostly consistent with the semantic network with the exception that there seems to exist some kind of correlation between "soft" and "embracing". When examining the CRSs that were included in the survey it was concluded that this could be explained based on how a body sinks into a soft padding, which could enhance the feeling that the seat "embraces" the child. It is however likely the expression is mostly communicated by the actual shape of the seat and not as a result from causal relationships to other expressions. The main factor that expresses this in the final concept is therefore the big surfaces that sweeps around the sides of the child and offers both protection in case of a side impact and "embraces" the child in a quite literal sense.

Robust

Robustness is like "embracing" at the lowest level in the semantic network and should be one the first signs in a semiosis chain. A robust product is one that does not easily break or bend. Some of the design cues that are intended to convey this:

• Angular design. Compared to the C1 and C2 concepts the final concept uses a combination of sweeping curves and a bit sharper corners and line intersections. The intention is that this design language should relate more to engineering rather than artistry and therefore get a more robust expression. This also shows in the survey results as the C3 had significantly higher scores in both robustness and safety.
• A spherical connection between the base and the seat. There are possibilities for other geometries but the sphere is the only geometry that can be rotated around two axes and still maintain a constant distance to any point on its surface. Other geometries would create a gap between the base and the seat which then will be perceived as less robust and stable.

• The product looks solid. There does not seem to be any holes or crevices in the design and therefore should look durable and robust.

8.2.2. Artificial Design Cues

Artificial design cues do not have a purpose of conveying a message, however they can be instrumental in building brand recognition. Recognition does require more than one product, but before a family can be created some basic rules has to be formulated to develop consistency (Karjalainen 2014). The final concept includes a couple of design features that can be used across a product family:

• A two-tone color scheme in the textile. Consistent use of brand colors is one way to improve recognition. This is a problem for a product that offers the customer a choice of color. What can be done however is to have some guidelines on how colors are chosen and why, or to consistently use of a set of brand color schemes. This is described in more detail in the next section.
• Visible seam with accent color. A simple way to add an accent color to a textile product is by using a seam as decoration. Simple yet effective (Figure 40).
• Back curves. All three concepts had long curves that were ended at the top of the back where the seat sweeps around the child. For an even more distinct artificial design cue the back "oval" of C1 and C2 was also adopted in the final modified version of the C3 concept (Figure 41).

Figure 40. Visible seams on textile cover.

Figure 41. Oval back design cue.

8.2.3. Color combinations

Axonkids stated that they will produce five different color variations of the textile cover. These variations will have to cover as many different types of customers as possible, while still being in line with the brand identity. A detailed study of colors has not been performed and since color preference can be very subjective the variations in color alternatives should be diverse. A two tone color theme was chosen for the design, where surfaces which faces the child has one color while the outer shell has another. The purpose is to enforce the idea of a soft inside with a protective outer shell. The thread has a color that stands out from the others to accentuate it as a design feature. An important guideline for picking colors has been to not use fully saturated colors, as these have a tendency to look cheap and artificial. Colors which are somewhat desaturated however can look more natural and, instead of using neutral grays, color combination can be enhanced by using slightly cool or warm grays. No specific NCS color codes or similar have been chosen as the perceived color of the product is in fact a combination of two thread colors in the textile and the quality of the textile itself can also have an impact on the appearance of the color. The final color codes will therefore have to be chosen from fabric samples. Instead renderings are provided which can serve as a source of inspiration for these future decisions (Figure 42).

Option A, Black:

A black alternative is a common color variation and presumably popular due to its discreet and exclusive expression. It can also blend well with many car interiors. The black is given some variation with a dark grey inside color with a pattern.

Option B, Brown & Blue:

This is another dark color variation, but it is more unique and may appeal to those who want a personal touch to their product. The style is inspired from denim-style fashion, where blue jeans coupled with a brown belt is a classic combination.

Option C, Red:

This alternative does not aim to fit into the car interior but instead tries to stand out. While all of the variations presented strives to be unisex, this is the alternative which was most often described as “feminine”.

Figure 42. (Spread) Color combination options.

Option D, Red & Green:

A bright color combination that combines two complementary colors. The red is slightly shifted towards orange and the green is highly desaturated, almost to the point where it looks like a warm gray.

Option E, Red & Black:

In their current product catalog (Axkid, 2014) Axkid only presents products with color variations in black, gray, and red. Since these are important colors to Axkid and can be found in their current logo and website a black and red alternative was developed. Some important changes in this version is that the black is more of a dark gray, and the red is less saturated.

Bonus Option, Leather:

Leather adds significantly to the price of a CRS, but despite this it is not unusual to provide such alternatives as many cars have leather interiors. Leather has the drawback that it can deform over time when a child uses the seat, and therefore this alternative uses a soft comfortable textile for the inner surfaces and leather on the outside in order to get the best of both worlds.

9. Discussion

This chapter discusses the following aspects of the project: The final result, process, methods and execution as well as sustainability. Furthermore it presents important aspects of further development and recommendations.

9.1. Final Result

The finished concept improves upon weaknesses of preceding Axkid products. The new concept is superior in terms of both affective and usability qualities. It surpasses its predecessor (ref.A) but also all of the products in the reference group with regards to the metrics which has been used in this project. Much works still needs to be done however and weight optimizations, fit of textile cover, and economy are examples of factors which may have an impact on a final product. This concept should nevertheless serve as a good starting point, and as a goal to work towards.

The concept is not the only part of the result. Equally important is the documentation and reasoning that led to the concept, as this is meant to be used as a foundation for long-term brand building. The usability issues are not as general in character since some issues and solutions are very specific to this type of CRS and cannot be translated to for example an infant car seat, or a booster cushion.

9.2. Process

The success of this project depended on efficient use of design iterations. By using an integrated design environment where decisions and geometries could be evaluated and have the evaluation as a part of the creative process was instrumental to this success. The relatively complex shapes of a CRS increases the time to create concepts and a traditional approach to the design process, using a recursive and iterative method would have required more time and/or human resources. The standard design process where a design is first completed to a high degree, then evaluated to identify problems and then make a new design based on the errors, makes each iteration very resource intensive. Continuous evaluation removes the need for some of these iterations and can therefore reduce the time required to reach similar results.

9.3. Methods

The method used to identify desired product expressions was developed as a part of this project. It has it's foundation in Peirce's theory of semiotics and experts such as Hassenzahl also describe how expressions can have co-variations between each other. This project can be seen as a proof of concept that this type of methodology with a statistical approach to finding and rating relationships between expressions can produce usable results. However, the methodology can be improved to achieve more reliable results.

The first step of the process is to collect the words which will be used to create the semantic network. There is a balance between practicality and accuracy here, since if more expressions are included the greater is the potential to find different semantic connections, but this also makes each survey submission take significantly longer time to fill in. This makes it important to collect the "correct" words and a more detailed study would be needed on how to achieve this in an efficient manner. We have only tried to identify what expressions are of most importance, but we can also envision a scenario in which the researcher inserts specific words to this set in order to study their significance and possible relations.

There are other ways than those used in this project of measuring dependence between expressions. While the Pearson correlation coefficient combined with manual inspection was used in this project and created usable results, there may be other, more accurate ways of quantifying dependence. Tests could for example be made to check for quadratic dependence or other types of dependence models. Osgood (1957) also describes a method of measuring the "distance" in the semantic space which also can be investigated further.

Further efforts can also be made on investigating good methods of plotting of the semantic network for example via cluster analysis.
It is however important to keep in mind that correlation does not equal causation. Just because a connection between two expressions seems to exists does not give any indication to the cause. However with the semantic network as a tool a designer can make more informed decisions and try to analyze apparent correlations in more detail.

The method could also be used by a company to identify their customer profile. By comparing different products against each other the customers who prefer the company brand can be identified and then further analyzed in order to understand which expressions are most important to them, and then use this information to further tailor the design to fulfill their requirements.

9.4. Sustainability Aspects

As the structural design of the new concept is not in the scope of this project, no comprising materials have been determined. As a result of this no evaluation of the environmental impact of the production of the CRS has been carried out. An aspect of sustainability which could be affected by this project is one of a sociological nature. Improvements in accessibility of the CRS functions could benefit users with disabilities. The rotating seat provides better reach for users bound to wheelchairs, or users with otherwise hindered reach. Users with limited strength or coordination could benefit from the reduced force needed to tighten the harness provided by the mechanical advantage harness system and improved direction of the fastening force provided by the rotating seat. Other solutions for improved usability such as easier transportation and easier installation of the CRS could also benefit users with various disabilities.

9.5. Further Development and Recommendations

The full road map for taking this concept to market is a task for AxonKids to complete. Some recommendations can be made however in regards to tasks which needs to be carried out that still has a connection to this project. The first step would be the construction of a simple and cheap prototype in order to verify as much as possible before manufacturing dies. Such a prototype could be made out of for example Styrofoam or similar, and can be used to solve several potential issues. Since our concept has been developed in a completely digital environment there still exists a risk that important changes has to be made. The digital mannequins for example were used in order to ensure a sitting position with good ergonomics for children in many age groups, but real tests with children should be carried out in order to identify potential issues before the final geometry is decided upon. Another potential pitfall is how well the textile cover will follow the intended shape. The concept has been designed in order to take the behavior of textile into account by trying to design with surfaces which are close to being developable,

which means that they can be flattened out to a plane, or that they have a low degree of double curvature. This is important since you cannot for example wrap a piece of cloth around a sphere without creating folds and creases. If there is some elasticity in the cloth it will compensate to some degree for double curvature of underlying surfaces but in order to be sure how the textile cover will behave and whether any changes should be made, a prototype would have to be created in order to test this.

When performing the structural and mechanical design of the new CRS, the need for feedback should be considered. For every adjustment that can be made, any type of feedback could indicate to the user that the correct adjustment has been made. This could both reduce the displeasure of not knowing if the correct adjustment has been made, and reduce the amount of errors.

In the development of new CRS models Axonkids should strive for a common visual expression in order to define Axkid's visual brand identity. This could be achieved by incorporating some or several of the design cues used in the new concept, as they should associate to the chosen core values. Examples of these design cues are the two tone color scheme, visible seams and the denim look textile cover.

Some of the new functions of the new concept could have associated usability issues that were not foreseen in this project. These types of issues could possibly be detected by conducting user testing with a functional prototype.

Optional labels could be made removable, such that they can be read the first time the user interacts with the CRS, providing improved learnability, after which they can be removed. This could reduce the visual clutter otherwise associated with abundant labels, while still providing improved learnability.

For functions which require/could benefit from more instructions than can fit on a label, a link or a QR-code pointing to an instructional video or further reading can be printed on a label.

Because some of the functions and features of the new concepts can be found in existing CRS models, patents for these solutions may exist. To avoid infringement, an investigation of existing patents should be conducted in the countries in which the new product is expected to be sold.

10. Conclusion

The final result of the project is concept for a new CRS which features solutions for the usability issues found in the reference products. Solutions were also developed for aspects of the CRS which are commonly associated with use errors which could lead to reduced safety.

Through interviews and market analysis, a list of expressions commonly used to describe CRSs were identified. Through interviews and a survey, semiotic relationships between these expressions were found. The results from the survey shows that there exists correlations between different expressions, from which it was deduced which expressions the new concept should communicate to the user and their relative importance. Design cues were defined and used to achieve the desired expressions of the new concept. Their positive effect on the general expression of the concepts could then be confirmed by an additional survey.

The design cues and general design language of the new concept can be reused in the development of future CRS models, and this can have a positive impact on future brand building for Axkid.

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Figures

Figure 13 [Correlation examples] [Electronic image] Available at: http://en.wikipedia.org/wiki/File:Correlation_examples2.svg [Accessed 2014-05-21]

Figure 9. Brown, Justin (2012) [Electronic image] Available at: https://www.flickr.com/photos/justininsd/8104017791/in/photostream/ [Accessed 2014-05-17]

Appendix II: Persona 1. Reshef, Or (2007) [Electronic image] Available at: http://www.flickr.com/photos/12191223@N00/2220237941/sizes/o/ [Accessed 2014-05-17]

Appendix II: Persona 2. [Father and son] [Electronic image] Available at: http://en.wikipedia.org/wiki/File:Father_and_son_27.jpg [Accessed 2014-05-17]

12. Appendices

Appendix I. Reference Products
Appendix II. Persona
Appendix III. HTA (Competitor/Kidzofix)
Appendix IV. ECW (Competitor/Kidzofix)
Appendix V. PUEA (Competitor/Kidzofix)
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Appendix I: Persona

Persona 1: Therese 27
Therese lives in an apartment in Bromma with her boyfriend and their baby son. She has since a year back worked as a geologist at Stockholm University but is right now on parental leave. She feels the work was not quite what she expected, and although it is starting to grow on her, getting some time off was a welcomed change.

Therese is very concerned with the safety and comfort of her son, often reading many reviews and exploring options before buying products for him. When shopping for food, she prefers eco-friendly and locally produced items, both because she believes it is more healthy and because she cares for the environment.

They have been using an infant car seat that they have borrowed from a friend, but is now looking to upgrade to a bigger seat. When researching what car seat to buy, she is mostly concerned with safety and comfort, but also wants a seat that is practical and can be used for a long time.

Therese and her boyfriend share a Mini Cooper, and is looking for a child car seat that fits in their car. She also wants the new car seat to use ISOFIX fastening, as she has read it is both safer and more practical.

Persona 2: Fredrik 36
Fredrik lives in a house 10 minutes outside Lund with his wife and 3 year old daughter. He works for a medium sized marketing firm in central Lund. Fredrik enjoys the responsibility and creativity of his work, as well as his colleagues.

Fredrik likes to stay updated with technology and enjoys buying the latest gadgets. He especially enjoys Apple products, as he thinks they are so easy to use, but still look fantastic. When buying new things, Fredrik often chooses products from brands that he has owned before and trust. The first child car seat Fredrik bought was a Axkid Kidzofix, as it was recommended to him by a colleague.

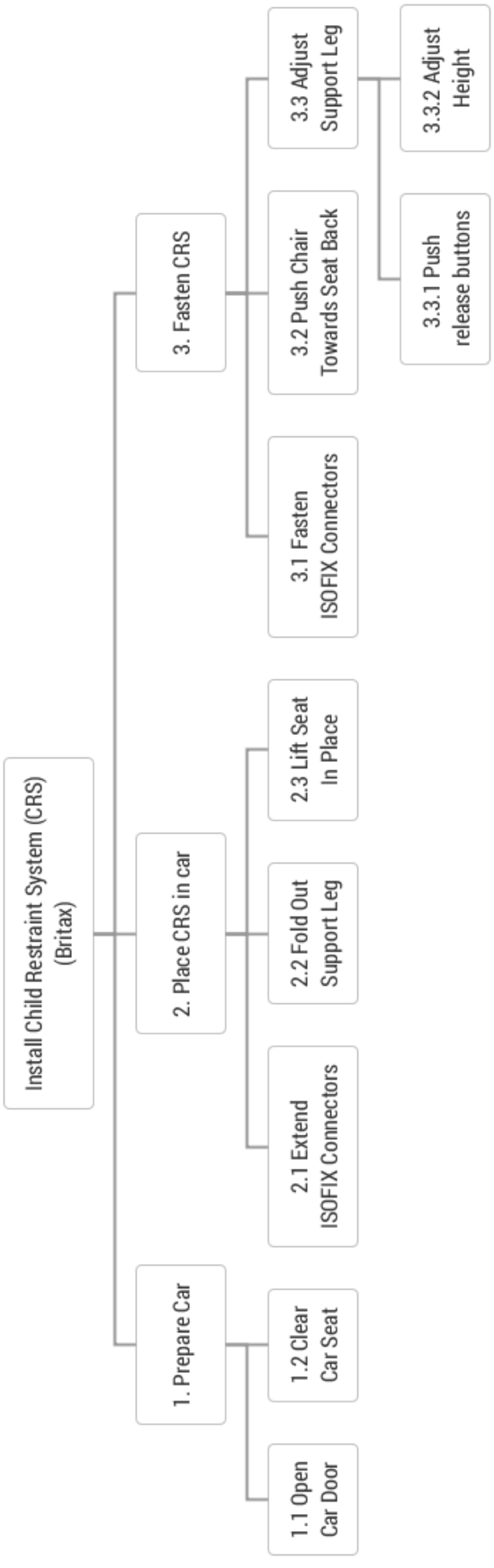
Fredrik is usually the one to drop off their daughter at daycare, and does so in his Volvo XC60. His wife drives a Fiat 500, and when she needs to take the daughter to daycare, they switch cars, as Fredrik thinks moving the seat is too much of a chore.

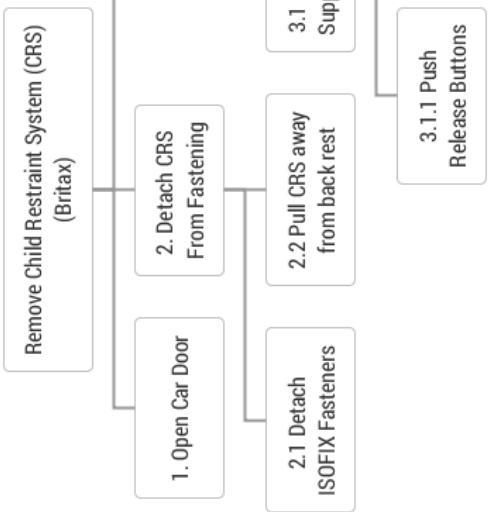
Now that Fredrik and his wife are expecting another baby, he would like to buy another seat, possibly from Axkid. Although he was not totally satisfied with the last one, he trusts the newest model will have fixed all the issues he had with the first one.

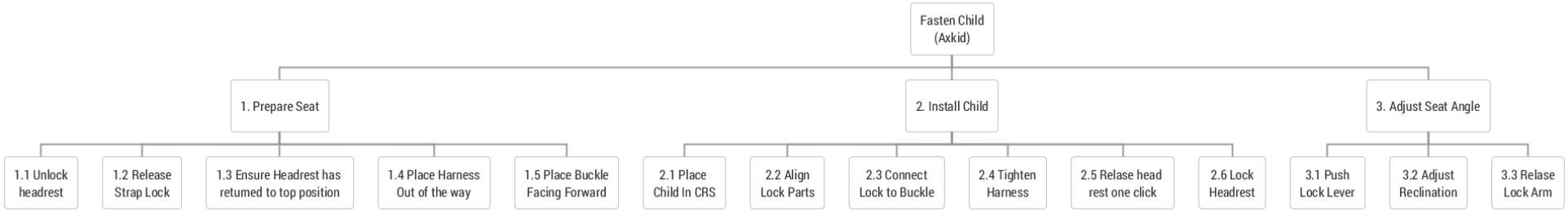
Appendix II: Reference Products

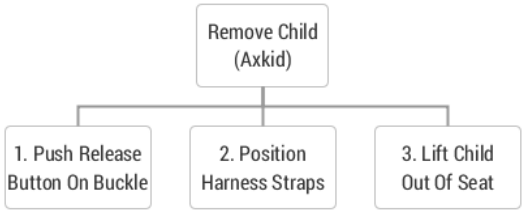
	Reference Product A	Reference Product B	Reference Product C
			
Model name	Axkid Kidzofix	Britax Dualfix	Cybex Sirona
Passenger approx age	9 month to 4 years	0 to 4 years	0 to 4 years
Passenger weight	9-25 kg	0-18 kg	0-18 kg
Fastening	Seat belts/ISOFIX	ISOFIX	ISOFIX
Anti-rotation devices	Support leg & rear-facing tether	Support leg & brace	Support leg & brace
Rotatable	By seat reinstallation	Yes	Yes
Headrest adjustment	Automatic	Manual	Manual
Adapted for i-size	No	Yes	Yes

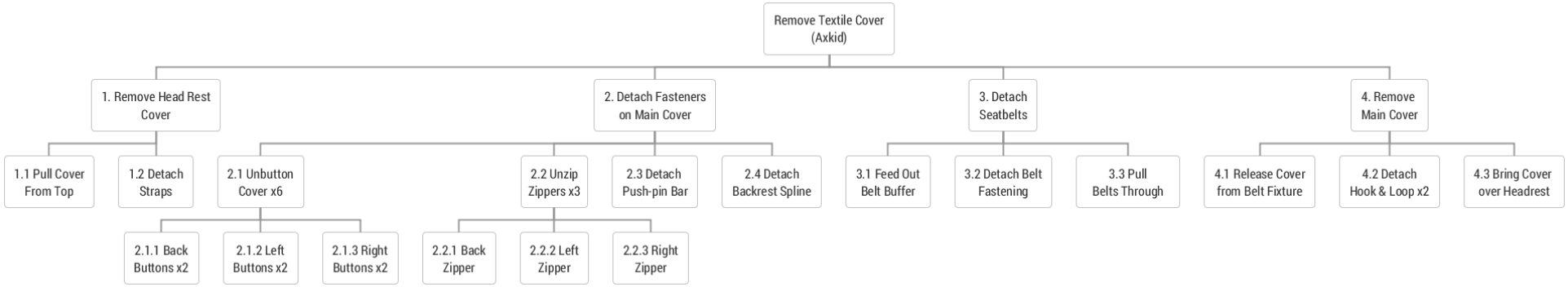
Appendix III: HTA (Competitor/Kidzofix)

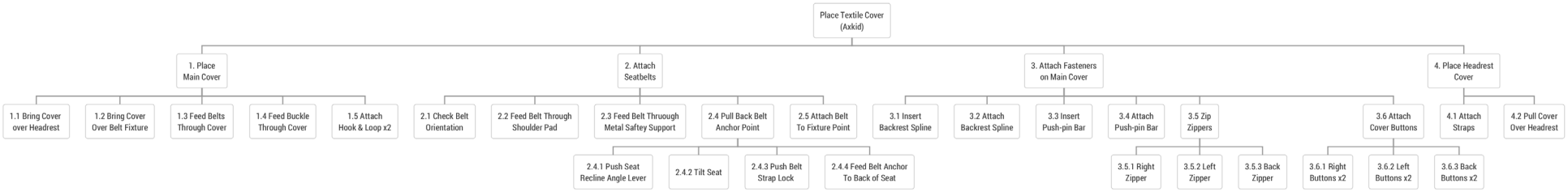





Fasten Child (Axkid)
1. Prepare Seat
2. Install Child
3. Adjust Seat Angle
1.1 Unlock headrest
1.2 Release Strap Lock
1.3 Ensure Headrest has returned to top position
1.4 Place Harness Out of the way
1.5 Place Buckle Facing Forward
2.1 Place Child In CRS
2.2 Align Lock Parts
2.3 Connect Lock to Buckle
2.4 Tighten Harness
2.5 Relase head rest one click
2.6 Lock Headrest
3.1 Push Lock Lever
3.2 Adjust Reclination
3.3 Relase Lock Arm


Remove Child (Axkid)
1. Push Release Button On Buckle
2. Position Harness Straps
3. Lift Child Out Of Seat


Remove Textile Cover (Axkid)
1. Remove Head Rest Cover
2. Detach Fasteners on Main Cover
3. Detach Seatbelts
4. Remove Main Cover
1.1 Pull Cover From Top
1.2 Detach Straps
2.1 Unbutton Cover x6
2.2 Unzip Zippers x3
2.3 Detach Push-pin Bar
2.4 Detach Backrest Spline
3.1 Feed Out Belt Buffer
3.2 Detach Belt Fastening
3.3 Pull Belts Through
4.1 Release Cover from Belt Fixture
4.2 Detach Hook & Loop x2
4.3 Bring Cover over Headrest
2.1.1 Back Buttons x2
2.1.2 Left Buttons x2
2.1.3 Right Buttons x2
2.2.1 Back Zipper
2.2.2 Left Zipper
2.2.3 Right Zipper


Place Textile Cover (Axkid)
1. Place Main Cover
2. Attach Seatbelts
3. Attach Fasteners on Main Cover
4. Place Headrest Cover
1.1 Bring Cover over Headrest
1.2 Bring Cover Over Belt Fixture
1.3 Feed Belts Through Cover
1.4 Feed Buckle Through Cover
1.5 Attach Hook & Loop x2
2.1 Check Belt Orientation
2.2 Feed Belt Through Shoulder Pad
2.3 Feed Belt Thruough Metal Saftey Support
2.4 Pull Back Belt Anchor Point
2.5 Attach Belt To Fixture Point
3.1 Insert Backrest Spline
3.2 Attach Backrest Spline
3.3 Insert Push-pin Bar
3.4 Attach Push-pin Bar
3.5 Zip Zippers
3.6 Attach Cover Buttons
4.1 Attach Straps
4.2 Pull Cover Over Headrest
2.4.1 Push Seat Recline Angle Lever
2.4.2 Tilt Seat
2.4.3 Push Belt Strap Lock
2.4.4 Feed Belt Anchor To Back of Seat
3.5.1 Right Zipper
3.5.2 Left Zipper
3.5.3 Back Zipper
3.6.1 Right Buttons x2
3.6.2 Left Buttons x2
3.6.3 Back Buttons x2

Appendix IV: ECW (Competitor/Kidzofix)

-	**Fasten Child**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.	**Prepare Seat**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might forget function.	Sequence error	4	S
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.1	**Unlock Headrest**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action.	User does not expect action.	2	U
(2)	Do not know. User might not see feature.	No Usability Problem	2	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.2	**Release Strap Lock**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	2	U
(2)	Yes.	No Usability Problem	5	-
(3)	Do not know. User might not associate strap lock with head rest height.	User does not associate actio	2	U
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.3	**Ensure Headrest Has Returned To Top Position**	**Usability Problem**	**PS**	**PT**
(1)	No. User does not expect action	User does not expect action	2	U
(2)	No. User cannot see mechanism	HIdden feature	2	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.4	**Place Harness Out Of The Way**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might forget action.	Action omitted	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.5	**Place Buckle Facing Forward**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might forget action	Action omitted	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-

(5)	Yes.	No Usability Problem	5	-
2.	**Install Child**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.1	**Place Child In CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.2	**Align Lock Parts**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might try connecting parts before aligning.	Sequence error	3	S
(2)	Yes, probably. Feature not obvious	HIdden feature	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.3	**Connect Lock To Buckle**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.4	**Tighten harness**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes, probably. May be hard to reach	Hard to reach	4	P
(5)	Yes.	No Usability Problem	5	-
2.5	**Release Headrest One Click**	**Usability Problem**	**PS**	**PT**
(1)	No. User does not expect action	User does not expect action	3	U
(2)	No. No clue to feature	Hidden feature	3	H
(3)	No. Instructions impossible to understand	Text impossible to understand	3	T
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.6	**Lock Headrest**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User mioght not expect funcitonality	User does not expect function	3	U
(2)	Do not know. Feature not obvious	Hidden feature	3	H
(3)	Yes.	No Usability Problem	5	-

(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.	**Adjust Seat Angle**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might not expect functionality.	User does not expect function	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.1	**Push Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might not expect action.	User does not expect action	4	U
(2)	Do not know. User might not see lever	Hidden feature	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes, probably. Can be hard to reach when rear facing	Hard to reach	4	P
(5)	Yes.	No Usability Problem	5	-
3.2	**Adjust Inclination**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3	**Release Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	**Install CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes. The user expects to be able to install the CRS.	No Usability Problem	5	-
(2)	Yes. Connectors are visible.	No Usability Problem	5	-
(3)	Yes. The purpose of the connectors is clear.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes, probably. Potential lack of feedback of correct installation.	Lack of feedback	4	F
1	**Prepare car**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.1	**Open car door**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might pick up the seat before realising the door is closed.	Potential sequence error	4	S
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.2	**Clear seat**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might pick up the seat before realising the seat is not cleared	Potential sequence error	4	S
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2	**Place CRS in car**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.1	**Extend ISOFIX Connectors**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. The user might not expect action. Potential sequence error	User does not expect action.	3	U, S
(2)	Do not know. User might not see how to perform action.	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.2	**Fold Out Support Leg**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. The user might not expect action. Potential sequence error	User does not expect action.	3	U, S
(2)	Do not know. The feature might be hidden.	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.3	**Lift Seat In Place**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes, probably. Bulky seat can be difficult to fit into car	Awkward lifting	4	P
(5)	Yes.	No Usability Problem	5	-
3	**Fasten CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

3.1	**Fasten ISOFIX Connectors**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Do not know. User might not see feature	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.2	**Push Chair Towards Seat Back**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Do not know. User might not see feature	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3	**Adjust Support Leg**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3.	**Push Release Buttons**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might not expect action	User does not expect action	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3.	**Adjust Height**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	Remove Child	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1	Push Release Button on Buckle	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2	Position Harness Straps	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3	Lift Child Out Of Seat	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	Remove Textile Cover	Usability Problem	PS	PT
(1)	Yes Probably. Most, if not all CRS have this functionality so the user is likely to expect that this function exists	User is unaware of this functionality	4	U
(2)	Yes. Buttons, zippers and fit indicate that this functionality exists	No Usability Problem	5	-
(3)	Yes. The purpose is obvious.	No Usability Problem	5	-
(4)	Yes. It is impossible to not notice that the cover is coming off	No Usability Problem	5	-
(5)	Yes. It is obvious that the cover has been successfully removed	No Usability Problem	5	-
1.	Remove Head Rest Cover	Usability Problem	PS	PT
(1)	Yes Probably. If the main cover is removable than the headrest cover can also be expected to be removable.	User is unaware of this functionality	4	U
(2)	Yes. The elastic strap shows that it is removable	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes. It is impossible to not notice that the cover is coming off	No Usability Problem	5	-
(5)	Yes. It is obvious that the cover has been successfully removed	No Usability Problem	5	-
1.1	Pull Cover From Top		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.2	Detach Straps		PS	PT
(1)	Yes, The user will notice that the cover is still attached to something	No Usability Problem	5	-
(2)	Yes, Probably. The user will probably find out how the straps are attached but they are somewhat difficult to access and see	The function is hidden	3	H
(3)	Yes Probably. If the user identifies the hooks it should be natural to assume that the straps can be unhooked	The hooks can be difficult to identify as hooks	4	U
(4)	Do not know. The user may not figure out the proper technique, have to big hands/fingers, or have some kind of reduced functionality to be able to complete the operation	The hooks are very difficult to access	2	P
(5)	Yes	No Usability Problem	5	-
2.	Detach fasteners on main cover		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.1	Unbutton Cover		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.2	Unzip Zippers		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.3	Detach Push Pin Bar		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	No. There are no visible clues presented and the user has to guess on how to detach the bar.	There are no visible clues	1	H
(3)	Yes	No Usability Problem	5	-
(4)	No, Uncertain. The bar requires so much power to remove that the user may believe they are breaking the product	Too much power is needed	1	P, H
(5)	Yes.	No Usability Problem	5	-
2.4	Detach Backrest Spline		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	No, The Spline is hidden	The Spline is hidden	3	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.	Detach Seatbelts		PS	PT
(1)	No, Uncertain. The user cannot be expected to know that a part that is not connected to the textile cover has to be detached in order to remove it	User does not expect functionality	2	U
(2)	No. There are no visible clues	Functionality is hidden	1	H
(3)	No. There are no visible clues	Functionality is hidden	2	H
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.1	Feed Out Belt Buffert		PS	PT
(1)	Probably Not. It is uncertain if the user will realize that more belt is needed in order to perform the operations that follows	User may not have fully comprehended the product	3	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-

(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.2	**Detach Belt Fastening**		**PS**	**PT**
(1)	Do not know. Given that the user has realized that they have to feed out the belt they may also have realized that the belt has to be released.	User may not have fully comprehended the product	2	U
(2)	No. There are no visible clues	No visible clues	2	H
(3)	Yes	No Usability Problem	5	-
(4)	Probably Yes. The belt can be slightly tricky to release	The belt can be a bit tricky to release	4	-
(5)	Yes	No Usability Problem	5	-
3.3	**Pull Belts Through**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.	**Remove Main Cover**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.	**Release Cover From Belt Fixture**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.	**Detach Hook and Loop**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes, Probably. It can be a little difficult to reach the upper parts of the Hook and loop straps	difficult to reach	4	P
(5)	Yes	No Usability Problem	5	-
3.	**Bring Cover Over Headrest**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-

-	Replace Textile Cover	Usability Problem	PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.	Place Main Cover	Usability Problem	PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.1	Bring Cover Over Headrest		PS	PT
(1)	Do not know. User might start with operation 1.2, which will force them to redo the sequence	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.2	Bring Cover Over Belt Fixture		PS	PT
(1)	Do not know. User may not have performed operation 1.1, which will force them to redo the sequence	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.3	Feed Buckle Through Cover		PS	PT
(1)	Do not know. User may not realize this operation should be performed at this stage.	Unclear sequence order	3	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.4	Feed Belts Through Cover		PS	PT
(1)	Do not know. User may not realize this operation should be performed at this stage.	Unclear sequence order	3	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.5	Attach Hook & Loops		PS	PT
(1)	Do not know. The user may have forgotten that the Hook and loops exist	Purpose of the straps may be unclear	4	U
(2)	Do not know. If the hook and loops happen to stick to each other by accident the user may notice them	Hidden features	4	H
(3)	Yes	No Usability Problem	5	-
(4)	Yes, probably. The user may have problems reaching the top part of the hook and loop straps.	Some areas are difficult to reach	4	P
(5)	Yes	No Usability Problem	5	-
2.	Attach seatbelts		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes, probably. The belt anchor point may not be recognized as part of the belt system and can be hard to spot	Unclear and hidden feature	3	H, U
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.1	Check Belt Orientation		PS	PT
(1)	Yes, Probably. Most likely the user will realize they have to check the belt orientation	User may forget this step	3	U
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.2	Feed Belt Through Shoulder Pad		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes, probably. The user may have difficulties to get the belt to feed through properly	Difficult operation	4	P
(5)	Yes	No Usability Problem	5	-
2.3	Feed Belt Through Metal Safety Support		PS	PT
(1)	Do not know. There is a good possibility that the user may skip this step	User does not expect action	1	U
(2)	No, Uncertain. The only clue is that the hole is roughly the right size for the belt	User have to understand the construction	2	U
(3)	Do not know. The user has to realize that the metal bar is there as a safety construction	The User has to understand the goal	2	U
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.4	Pull Back Belt Anchor Point		PS	PT
(1)	No, Uncertain. If the anchor point is not visible the user will probably not realize this function	User may be unaware of function	3	U
(2)	No, Uncertain. The user has to reverse engineer the construction to figure out where the Anchor is located	Requires user to analyze product	2	U, H
(3)	No, Uncertain. The clues lies in the construction of the CRS	No direct clues	2	H
(4)	Yes	No Usability Problem	5	-

(5)	Yes	No Usability Problem	5	-
2.4.1	**Push Seat Recline Angle Lever**		**PS**	**PT**
(1)	No, Uncertain. The user has to comprehend the problem before figuring out the correct sequence and action	Requires user to plan and analyze	5	S, U
(2)	Yes, Probably. If the user has figured out where the Anchor is the lever should also be visible	Lever is not clearly connected to seat angle	4	H
(3)	Do not know. The user may be unaware of how to recline the seat angle	Unclear purpose of action	4	U
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.4.2	**Tilt Seat**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.4.3	**Push Belt Strap Lock**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.4.4	**Feed Belt Anchor to Back Of Seat**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes, Probably. It can be somewhat difficult to reach into the crammed space between the seat and the base	No Usability Problem	4	P
(5)	Yes	No Usability Problem	5	-
3.	**Attach Fasteners On Main Cover**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.1	**Insert Backrest Spine**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes, probably. The user may forget that this part exists and therefore cannot perform this action	User may forget separate needed part	3	U
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Do not know. the user may insert the bar from the wrong way.	Risk for error in assembly	4	F
3.2	**Attach Backrest Spine**		**PS**	**PT**
(1)	Do not know. User might not expect the need to fasten spline	User does not expect action	3	U
(2)	Do not know. No clues are given.	Hidden features	3	H
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes, probably. Slight lack of feedback when attaching spline.	Lack of feedback	4	F
3.3	**Insert Push-pin Bar**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes, probably. The user may forget that this part exists and therefore cannot perform this action	User may forget separate needed part	3	U
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Do not know. the user may insert the bar from the wrong way.	Risk for error in assembly	4	F
3.4	**Attach Push-pin Bar**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes, Probably. The bar has to be pushed with some force in order to get attached	Requires force	4	P
(5)	Do not know. if 3.2 has been performed incorrectly this step may also be performed incorrectly	Lack of feedback	4	F
3.5	**Zip Zippers**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
3.6	**Attach Cover Buttons**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
4.	**Place Headrest Cover**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-

(5)	Yes	No Usability Problem	5	-
4.1	**Attach Headrest Cover Straps**		**PS**	**PT**
(1)	Do not know. User might now that the straps need to be attached.	User does not expect action.	4	U
(2)	Do not know. Feature is hard to see.	Hidden features	3	H
(3)	Yes	No Usability Problem	5	-
(4)	Do not know. Fastening straps is very tricky.	Difficult operation	4	P
(5)	Do not know. Fastened straps are hard to see. Goal can be partly completed as two straps need to be attached to each hook	Lack of feedback	4	F
4.2	**Pull Cover Over Headrest**		**PS**	**PT**
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-

Appendix V: PUEA (Competitor/Kidzofix)

Fasten Child	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Prepare Seat	User Misses 1.1
	User Misses 1.2
	User Misses 1.3
	User Misses 1.4
	User Misses 1.5
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
1.3 Ensure Headrest has returned to top position	The user may perform an incorrect assessment
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Attach Seatbelts	User Misses 2.4
	User Misses 2.5
	User Misses 2.6
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
2.4 Tighten Harness	User May Tighten the harness too loosly or too tightly
2.5 Relase head rest one click	User May Release the head rest too far
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Adjust Seat Angle	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	

c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Fasten Child									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
1a	User Misses 1.1	A8: Action omitted	L/K	Headrest will not adjust it's height automatically	3: Child Comfort/Safety is reduced	4: User most likely notices if the headrest is at the wrong height	Redo 1.1, 1.2, 1.3 & 2.4	None	None
1b	User Misses 1.2	A8: Action omitted	L	Not enough belt will be available	5: the headrest will not return to it's top position	5: Detected in 1.3	None	None	None
1c	User Misses 1.3	A8: Action omitted	L	The Headrest will not return to its top position	3: Child Comfort/Safety is reduced	3: User most likely notices if the headrest is at the wrong height. May be difficult to realize the cause	Unlock headrest, release belt strap, and pull the headrest upwards.	None	None
1d	User Misses 1.4	A8: Action omitted	L	The harness will be in the midle of the seat	5: The belt may be difficult to reach if the child is placed on top of it	5: Can be fixed when user notices secondary consequence	Reach underneath child to grab strap	None	None
1e	User Misses 1.5	A8: Action omitted	L	The buckle will be placed towards the back of the seat.	5: The Buckle may be difficult to reach if the child is placed on top of it	5: Can be fixed when user notices secondary consequence	Reach underneath child to grab buckle	None	None
1.3	The user may perform an incorrect assessment	C4: Wrong check on right object	S	The Headrest will not return to its top position	3: Child Comfort/Safety is reduced	3: User most likely notices if the headrest is at the wrong height. May be difficult to realize the cause	Unlock headrest, release belt strap, and pull the headrest upwards.	None	None
2a	User Misses 2.4	A8: Action omitted	L	Headrrest will not be at the correct height and the belt will not be sufficiently tightened	3: Child Comfort/Safety is reduced	3: User most likely notices if the headrest is at the wrong height.	redo 2.4	None	None
2b	User Misses 2.5	A8: Action omitted	L	Headrest will not be correctly ajusted	4: Child Comfort is reduced	2: Almost nothing that aids detection	release straplock	None	None
2c	User Misses 2.6	A8: Action omitted	L	Headrest will not be licked in place	None	None	N/A	None	None
2.4	User May Tighten the harness too loosly or too tightly	A4: Action too little/too much	S	Harness will be too loose/tight	4: Reduced Safety/comfort	3: User will likely know what is sufficient	adjust tightening	None	None
2.5	User May Release the head rest too far	A4: Action too little/too much	S	Headrest will not be correctly ajusted	4: Child Comfort/safety is reduced	3: User will likely know what is sufficient	Relase headrest fully and then tighten	None	None

Install CRS	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Prepare Car	
b. What happens if the user makes an error in the sequence of operations?	
1. Prepare Car	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Place CRS in car	User Misses 2.1
	User Misses 2.2
b. What happens if the user makes an error in the sequence of operations?	
2. Place CRS in car	user performs 2.3 before 2.1
2. Place CRS in car	user performs 2.3 before 2.2
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Fasten CRS	User misses 3.1
	User misses 3.2
	User misses 3.3
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	

d. What can the user do incorrectly during this operation?	
3.1 Fasten ISOFIX Connectors	User Fails to connect the ISOFIX connectors properly
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Install CRS									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
2a	User Misses 2.1	A8: Action omitted	L	The ISOFIX connectors will not be extended	It will be more difficult/impossible to attach the ISOFIX connectors	Can be fixed with some effort when user notices secondary consequence	Pull the seat forward in order to reach the ISOFIX connectors and extend them	None	None
2b	User Misses 2.2	A8: Action omitted	L	The support leg will not be in its correct position	the seat cannot be placed correctly	The user will notice that the CRS tips when placed on the car seat	lift the seat out and fold out the support leg	None	None
2c	user performs 2.3 before 2.1	P5	R	The ISOFIX connectors will not be extended	It will be more difficult/impossible to attach the ISOFIX connectors	Can be fixed with some effort when user notices secondary consequence	Pull the seat forward in order to reach the ISOFIX connectors and extend them	None	None
2d	user performs 2.3 before 2.2	P5	R	The support leg will not be in its correct position	the seat cannot be placed correctly	The user will notice that the CRS tips when placed on the car seat	lift the seat out and fold out the support leg	None	None
3a	User misses 3.1	A8: Action omitted	L	The ISOFIX connectors will not be connected to the car	1: The CRS will not be fastened to the car	2. User may notice that the seat does not feel rigidly attached but it requires the user to perform a check	recovery is trivial	None	None
3b	User misses 3.2	A8: Action omitted	L	Seat will not have support from the seat backrest	3: The CRS will not be as rigidly attached in case of an accident	2: The user will see that there is a gap between the CRS and the car seat	Push the seat back	None	None
3c	User misses 3.3	A8: Action omitted	L	The Support leg will not be at its correct height	2: The CRS will not be properly secured for forward rotation	2: The User may notice that the support leg does not touch the car floor	Perform 3.3	None	None
3.1	User Fails to connect the ISOFIX connectors properly	A9: Action incomplete	S	The ISOFIX connectors will not be connected to the car	1: The CRS will not be fastened to the car	3. User may notice the indicator on the connector has not changed color	recovery is trivial	None	None

Remove CRS	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
Not Possible	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not Possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Detach CRS From Fastening	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Remove	User Misses 3.1
	User Misses 3.3
b. What happens if the user makes an error in the sequence of operations?	
3. Remove	User performs 3.2 before 3.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
3.1 Retract Support Leg	User does not fully retract the support leg

e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Remove CRS									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
3a	User Misses 3.1	A8: Action omitted	L	Support leg is not retracted	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3b	User Misses 3.3	A8: Action omitted	L	ISOFIX fixture is not retracted	CRS takes more space in storage	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3c	User performs 3.2 before 3.1	P5	R	Support leg is retracted after removing CRS from car	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3.1	User does not fully retract the support leg	A4: Action too little	S	Support leg is not fully retracted	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None

Place textile cover	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Place main cover	User Misses 1.2
	User Misses 1.3
	User Misses 1.4
	User Misses 1.5
b. What happens if the user makes an error in the sequence of operations?	
1. Place main cover	User performs 1.2 before 1.1
	User performs 1.4 before 1.1 and 1.2
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
1.3 Feed Belts Through Cover	The user feeds the belts through the wrong holes
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Attach Seatbelts	User Misses 2.1
	User Misses 2.2
	User Misses 2.3
b. What happens if the user makes an error in the sequence of operations?	
2. Attach Seatbelts	user performs 2.2 before 2.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
2.1 Check Belt Orientation	User Misjudges belt orientation
2.3 Feed Belt Through Metal Safety Support	User incorrectly routs the belt
2.4 Attach Belt To Fixture Point	User does not attach the belts correctly/twisted to the fixture
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2.4 Pull Back Belt Anchor Point	User Misses 2.4.1 and 2.4.2
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	

c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Attach Fasteners On Main Cover	User Misses 3.1
	User Misses 3.2
	User Misses 3.3
	User Misses 3.4
	User Misses 3.5
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
3.2 Attach Backrest Spline	User may not fully attach the spline
3.4 Attach Push Pin Bar	User insterts push-pin bar the wrong way
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
4. Attach Headrest Cover	User Misses 4.1
b. What happens if the user makes an error in the sequence of operations?	
4. Attach Headrest Cover	User Performs 4.2 before 4.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
4.1 Attach straps	User fails to attach all straps
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

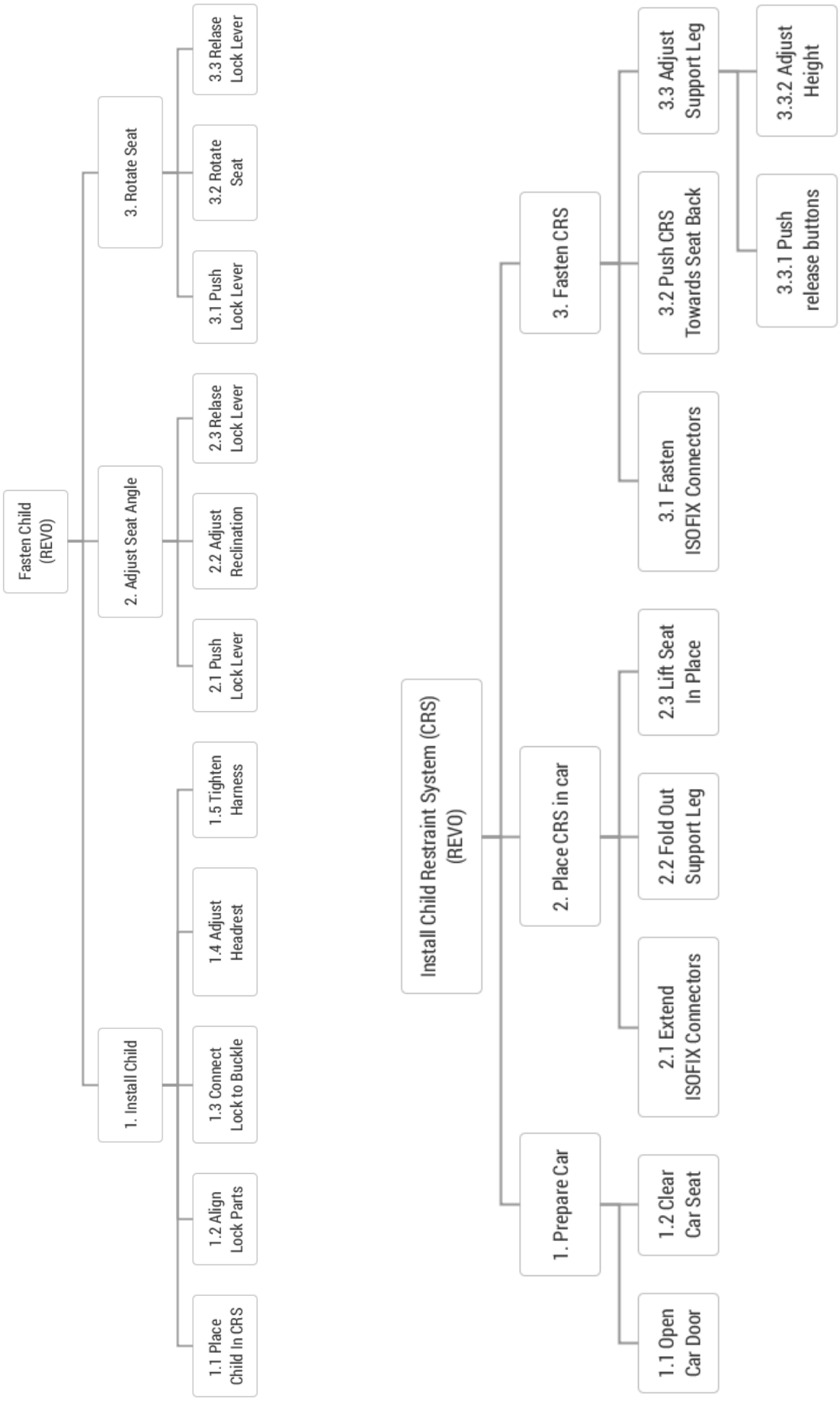
Replace Textile Cover									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
1a	User Misses 1.2	A8: Action omitted	L	The Cover will not be correctly placed around the Belt Fixture	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Redo 1.2	None	None
1b	User Misses 1.3	A8: Action omitted	L	The Belts will remain underneath the cover	2: The Belts cannot be attached	4: Can be fixed with some effort when user notices secondary consequence	Undo the cover until belts can be reached	None	None
1c	User Misses 1.4	A8: Action omitted	L	The Buckle will Remain Underneath the cover	2: The Belt cannot be fastend	5: Can be fixed when user notices secondary consequence	Reach in through the hole to try and find the Buckle	None	None
1d	User Misses 1.5	A8: Action omitted	L	The Cover Will not be fastened with hook and loops	5: The Intended Aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Pull the cover in place	None	None
1e	User performs 1.2 before 1.1	P5: Wrong order	R	1.1 cannot be perfomed	3: The cover cannot be placed	4: Can be fixed with some effort when user notices secondary consequence	Undo 1.2	None	None
1f	User performs 1.4 before 1.1 and 1.2	P5: Wrong order	R	1.1 cannot be perfomed	3: The cover cannot be placed	4: Can be fixed with some effort when user notices secondary consequence	Undo 1.2	None	None
1.3	User feeds the belts through the wrong holes	A10: Wrong action on right object	S	Belts will not be correctly placed	2: Child can not be correctly fastend	3: Can be fixed with significant effort when user notices secondary consequence	Undo Belt Attachment and cover	None	None
2a	User Misses 2.1	A8: Action omitted	L	Belts will not be correctly oriented	4: Child comfort will be effected	3: Can be fixed with significant effort when user notices secondary consequence	Undo Belt Attachment	None	None
2b	User Misses 2.2	A8: Action omitted	L	Shoulder pads will not be correctly placed	4: Child comfort will be effected	3: Can be fixed with significant effort when user notices secondary consequence	Undo Belt Attachment	None	None
2c	User Misses 2.3	A8: Action omitted	L/K	Belts will not be correctly routed	1: Child safety is severly effected	1: No detection before secondary consequence	Undo Belt Attachment	None	None
2d	User performs 2.2 before 2.1	P5: Wrong order	L	Belts will not be correctly oriented	4: Child comfort will be effected	4: Can be fixed with some effort when user notices secondary consequence	Undo 2.2	None	None
2.1	User Misjudges belt orientation	C4: Wrong check on right object	S	Belts will not be correctly oriented	4: Child comfort will be effected	3: Can be fixed with significant effort when user notices secondary consequence	Undo Belt Attachment	None	None
2.3	User incorrectly routs the belt	A10: Wrong action on right object	S/K	Belts will not be correctly routed	1: Child safety is severly effected	1: No detection before secondary consequence	Undo Belt Attachment	None	None
2.4a	User does not attach the belts correctly/twisted to the fixture	A10: Wrong action on right object	S	Belts will not be correctly attached	1: Child safety is severly effected	1: No detection before secondary consequence	Undo Belt Attachment	None	None
2.4b	User Misses 2.4.1 and 2.4.2	A8: Action omitted	K	Seat will not be reclined	4: It will be more difficult to reach the belt strap lock	3: If the user does not know about the action detection is improbable	Immediate Recovery	None	None
3a	User Misses 3.1	A8: Action omitted	L/K	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3b	User Misses 3.2	A8: Action omitted	L	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3c	User Misses 3.3	A8: Action omitted	L	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3d	User Misses 3.4	A8: Action omitted	L	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3e	User Misses 3.5	A8: Action omitted	L	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3.2	User may not fully attach the spline	A9: Action incomplete	S	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
3.4	User inserts push-pin bar the wrong way	A7: Wrong action on right object	S	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	3: Can be difficult to understand what is wrong	Immediate Recovery	None	None
4a	User Misses 4.1	A8: Action omitted	L/K	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None
4b	User Performs 4.2 before 4.1	P5: Wrong order	R	It will be more difficult to perform 4.1	N/A	No secondary consequence	Immediate Recovery	None	None
4.1	User fails to attach all straps	A9: Action incomplete	V	The Cover will not be correctly attached	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Immediate Recovery	None	None

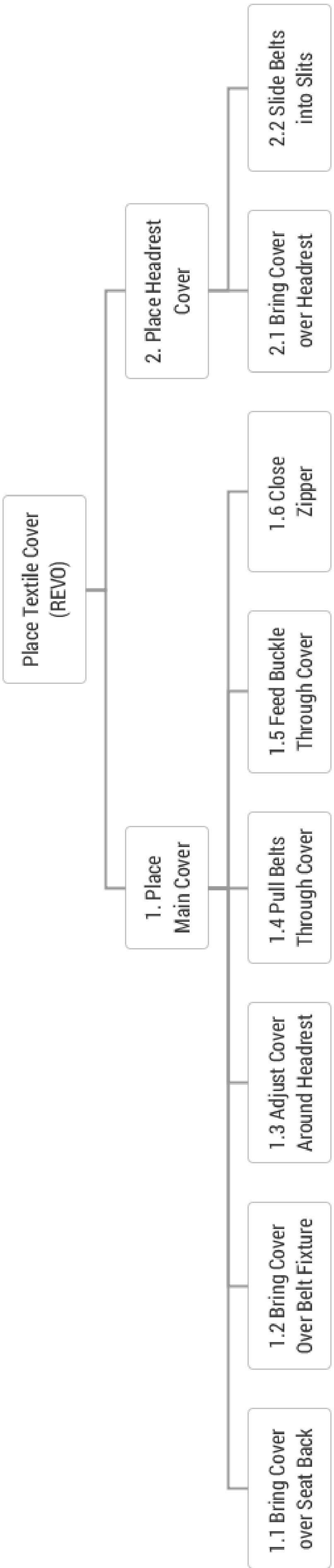
Remove textile cover	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
Not Possible	
b. What happens if the user makes an error in the sequence of operations?	
1. Remove Head Rest Cover	User performs 1.2 before 1.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
1.2 Detach straps	User hurts finger on metal parts
e. What happens if the user performs this operation at the wrong time?	
Not possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
2.3 Detach Push-Pin Bar	User may not dare to use the required force and not complete this step
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
2.3 Detach Push-Pin Bar	User breaks the push pin bar
e. What happens if the user performs this operation at the wrong time?	
Not possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Detach Seatbelts	User Misses 3.1
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
not possible	

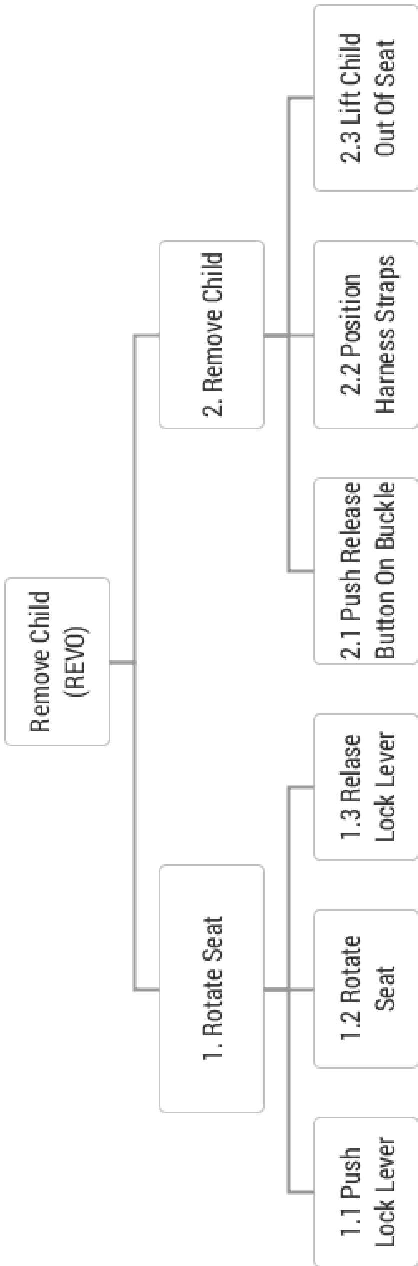
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

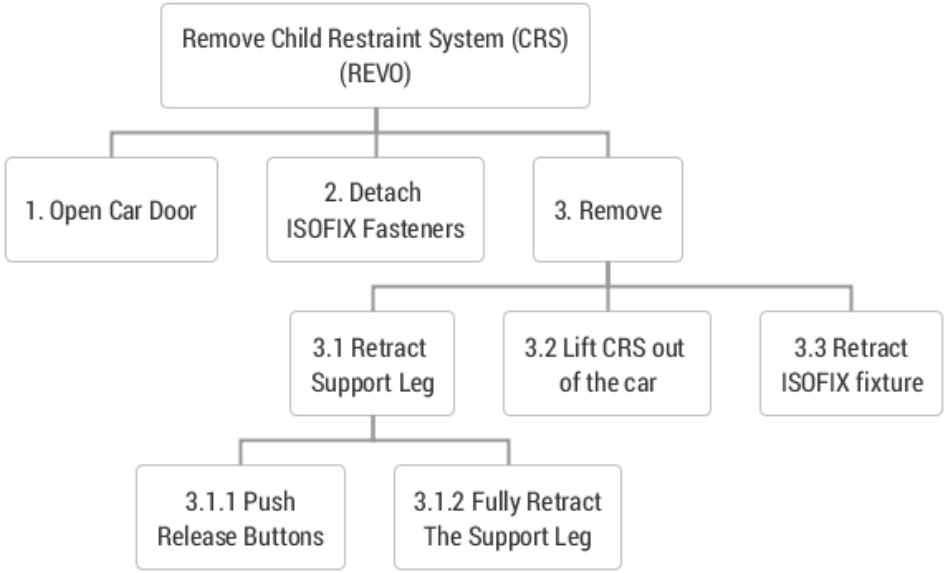
Remove Textile Cover									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
1	User performs 1.2 before 1.1	P5: Wrong order	R	It will be more difficult to perform 1.1	N/A	No Secondary consequence	N/A	None	None
1.2	User hurts finger on metal parts	A7: Wrong action on right object	S	User Hurts Finger	N/A	No Secondary consequence	N/A	None	None
2.3a	User may not dare to use the required force and not complete this step	A8: Action incomplete	K	User Will not remove the Push pin bar	3: Textile Cover cannot be completely Removed	3: The User may or may not try to use more force	Recovery Possible at any time	None	None
2.3b	User breaks the push pin bar	A4: Action too much	S	The push pin bar will break	3: The textile Cover cannot be correctly fastened	4: User should notice the bar is about to break before they break it	Order New bar from axkid	None	None
3	User Misses 3.1	A8: Action omitted	S	Not enough belt will be available for subsequent actions	3: 3.2 cannot be performed	5: Can be fixed when user notices secondary consequence	perform 3.1	None	None
4a	User Misses 4.2	A8: Action omitted	L						
4b	User performs 4.3 before 4.1 and 4.2	P5: Wrong order	R						

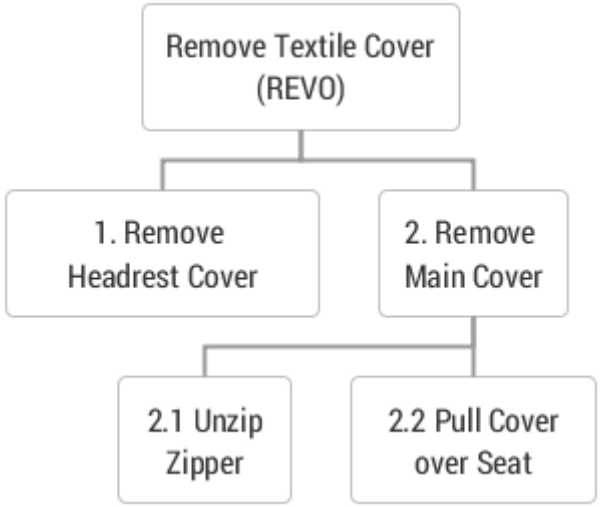
Appendix IV: HTA (REVO)




Place Textile Cover (REVO)
1. Place Main Cover
2. Place Headrest Cover
1.1 Bring Cover over Seat Back
1.2 Bring Cover Over Belt Fixture
1.3 Adjust Cover Around Headrest
1.4 Pull Belts Through Cover
1.5 Feed Buckle Through Cover
1.6 Close Zipper
2.1 Bring Cover over Headrest
2.2 Slide Belts into Slits


Remove Child (REVO)
1. Rotate Seat
2. Remove Child
1.1 Push Lock Lever
1.2 Rotate Seat
1.3 Relase Lock Lever
2.1 Push Release Button On Buckle
2.2 Position Harness Straps
2.3 Lift Child Out Of Seat


Remove Child Restraint System (CRS) (REVO)
1. Open Car Door
2. Detach ISOFIX Fasteners
3. Remove
3.1 Retract Support Leg
3.2 Lift CRS out of the car
3.3 Retract ISOFIX fixture
3.1.1 Push Release Buttons
3.1.2 Fully Retract The Support Leg


Remove Textile Cover (REVO)
1. Remove Headrest Cover
2. Remove Main Cover
2.1 Unzip Zipper
2.2 Pull Cover over Seat

Appendix V: ECW (REVO)

-	**Fasten Child**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.	**Install Child**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.1	**Place Child In CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.2	**Align Lock Parts**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might try connecting parts before aligning.	Sequence error	3	S
(2)	Yes, probably. Feature not obvious	HIdden feature	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.3	**Connect Lock To Buckle**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.4	**Tighten harness**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.5	**Adjust Headrest**	**Usability Problem**	**PS**	**PT**

(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.	**Adjust Seat Angle**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might not expect functionality.	User does not expect function	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.1	**Push Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might not expect action.	User does not expect action	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.2	**Adjust Inclination**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.3	**Release Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.	**Rotate Seat**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might not expect functionality.	User does not expect function	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.1	**Push Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might not expect action.	User does not expect action	4	U

(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.2	**Rotate Seat**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3	**Release Lock Lever**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	**Install CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes. The user expects to be able to install the CRS.	No Usability Problem	5	-
(2)	Yes. Connectors are visible.	No Usability Problem	5	-
(3)	Yes. The purpose of the connectors is clear.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes, probably. Potential lack of feedback of correct installation.	Lack of feedback	4	F
1	**Prepare car**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.1	**Open car door**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might pick up the seat before realising the door is closed.	Potential sequence error	4	S
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.2	**Clear seat**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. The user might pick up the seat before realising the seat is not cleared	Potential sequence error	4	S
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2	**Place CRS in car**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.1	**Extend ISOFIX Connectors**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. The user might not expect action. Potential sequence error	User does not expect action.	3	U, S
(2)	Do not know. User might not see how to perform action.	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.2	**Fold Out Support Leg**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. The user might not expect action. Potential sequence error	User does not expect action.	3	U, S
(2)	Do not know. The feature might be hidden.	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2.3	**Lift Seat In Place**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes, probably. Bulky seat can be difficult to fit into car	Awkward lifting	4	P
(5)	Yes.	No Usability Problem	5	-
3	**Fasten CRS**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.1	**Fasten ISOFIX Connectors**	**Usability Problem**	**PS**	**PT**

(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Do not know. User might not see feature	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.2	**Push Chair Towards Seat Back**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Do not know. User might not see feature	Hidden action	3	H
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3	**Adjust Support Leg**	**Usability Problem**	**PS**	**PT**
(1)	Do not know. User might not expect action	User does not expect action	3	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3.	**Push Release Buttons**	**Usability Problem**	**PS**	**PT**
(1)	Yes, probably. User might not expect action	User does not expect action	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3.3.	**Adjust Height**	**Usability Problem**	**PS**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	Remove Child	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.	Rotate Seat	Usability Problem	P	PT
(1)	Yes, probably. User may not expect this functionality	User unaware of function	4	U
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.1	Push Lock Lever	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.2	Rotate Seat	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
-	Remove Child	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1.3	Release Lock Lever	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
1	Push Release Button on Buckle	Usability Problem	P	PT
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-

(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
2	**Position Harness Straps**	**Usability Problem**	**P**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-
3	**Lift Child Out Of Seat**	**Usability Problem**	**P**	**PT**
(1)	Yes.	No Usability Problem	5	-
(2)	Yes.	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes.	No Usability Problem	5	-
(5)	Yes.	No Usability Problem	5	-

-	Remove Textile Cover	Usability Problem	PS	PT
(1)	Yes Probably. Most, if not all CRS have this functionality so the user is likely to expect that this function exists	User is unaware of this functionality	4	U
(2)	Yes. A large zipper indicate that this functionality exists	No Usability Problem	5	-
(3)	Yes. The purpose is obvious.	No Usability Problem	5	-
(4)	Yes. It is impossible to not notice that the cover is coming off	No Usability Problem	5	-
(5)	Yes. It is obvious that the cover has been successfully removed	No Usability Problem	5	-
1.	Remove Head Rest Cover	Usability Problem	PS	PT
(1)	Yes Probably. If the main cover is removable than the headrest cover can also be expected to be removable.	User is unaware of this functionality	4	U
(2)	Yes. The elastic strap on the backside indicates that it is removable	No Usability Problem	5	-
(3)	Yes.	No Usability Problem	5	-
(4)	Yes. It is impossible to not notice that the cover is coming off	No Usability Problem	5	-
(5)	Yes. It is obvious that the cover has been successfully removed	No Usability Problem	5	-
2.	Remove Main Cover		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.1	Unzip Zipper		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.2	Pull Cover over Seat		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-

-	Replace Textile Cover	Usability Problem	PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.	Place Main Cover	Usability Problem	PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.1	Bring Cover Over Seat Back		PS	PT
(1)	Do not know. User might start with operation 1.2, which will force them to redo the sequence	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.2	Bring Cover Over Belt Fixture		PS	PT
(1)	Do not know. User may not have performed operation 1.1, which will force them to redo the sequence	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.3	Adjust Cover Around Headrest		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.4	Pull Belts Through Cover		PS	PT
(1)	Do not know. User may not realize this operation should be performed at this stage.	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.5	Feed Buckle Through Cover		PS	PT
(1)	Do not know. User may not realize this operation should be performed at this stage.	Unclear sequence order	4	S
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
1.6	Close Zipper		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.	Place Headrest Cover		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.1	Bring Cover over Headrest		PS	PT
(1)	Yes	No Usability Problem	5	-
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-
2.2	Slide Belts into Slits		PS	PT
(1)	Yes, Probably. User may not realize this has to be performed	User unaware of operation	5	U
(2)	Yes	No Usability Problem	5	-
(3)	Yes	No Usability Problem	5	-
(4)	Yes	No Usability Problem	5	-
(5)	Yes	No Usability Problem	5	-

Appendix VI: PUEA (REVO)

Fasten Child	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Install Child	User Misses 1.4
	User Misses 1.5
b. What happens if the user makes an error in the sequence of operations?	
1. install child	user performs 1.5 before 1.4
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
1.4 Tighten Harness	User May Tighten the harness too loosly or too tightly
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Adjust Seat Angle	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Rotate Seat	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	

d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Fasten Child									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
1a	User Misses 1.4	A8: Action omitted	L/K	Headrest height may be incorrect	3: Child Comfort/Safety is reduced	4: User most likely notices if the headrest is at the wrong height	Redo 1.4	None	None
1b	User Misses 1.5	A8: Action omitted	L	Harness will be too loose	3: Reduced Safety/comfort	4: User most likely notices that the harness is not tightend	Redo 1.5	None	Indicator for harness tightening
1c	User performs 1.5 before 1.4	A8: Action omitted	R	The harness will bee too loose	3: Reduced Safety/comfort	4: User most likely notices that the harness is not tightend	Redo 1.5	None	Indicator for harness tightening
1.4	User May Tighten the harness too loosly or too tightly	A4: Action too little/too much	S	Harness will be too loose/tight	4: Reduced Safety/comfort	3: User will likely know what is sufficient	adjust tightening	None	Indicator for harness tightening

Remove Child	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Rotate Seat	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Remove child	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible	

Install CRS	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Prepare Car	
b. What happens if the user makes an error in the sequence of operations?	
1. Prepare Car	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Place CRS in car	User Misses 2.1
	User Misses 2.2
b. What happens if the user makes an error in the sequence of operations?	
2. Place CRS in car	user performs 2.3 before 2.1
2. Place CRS in car	user performs 2.3 before 2.2
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Fasten CRS	User misses 3.1
	User misses 3.2
	User misses 3.3
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	

d. What can the user do incorrectly during this operation?	
3.1 Fasten ISOFIX Connectors	User Fails to connect the ISOFIX connectors properly
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Install CRS									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
2a	User Misses 2.1	A8: Action omitted	L	The ISOFIX connectors will not be extended	It will be more difficult/impossible to attach the ISOFIX connectors	Can be fixed with some effort when user notices secondary consequence	Pull the seat forward in order to reach the ISOFIX connectors and extend them	None	None
2b	User Misses 2.2	A8: Action omitted	L	The support leg will not be in its correct position	the seat cannot be placed correctly	The user will notice that the CRS tips when placed on the car seat	lift the seat out and fold out the support leg	None	None
2c	user performs 2.3 before 2.1	P5	R	The ISOFIX connectors will not be extended	It will be more difficult/impossible to attach the ISOFIX connectors	Can be fixed with some effort when user notices secondary consequence	Pull the seat forward in order to reach the ISOFIX connectors and extend them	None	None
2d	user performs 2.3 before 2.2	P5	R	The support leg will not be in its correct position	the seat cannot be placed correctly	The user will notice that the CRS tips when placed on the car seat	lift the seat out and fold out the support leg	None	None
3a	User misses 3.1	A8: Action omitted	L	The ISOFIX connectors will not be connected to the car	1: The CRS will not be fastened to the car	2. User may notice that the seat does not feel rigidly attached but it requires the user to perform a check	recovery is trivial	None	None
3b	User misses 3.2	A8: Action omitted	L	Seat will not have support from the seat backrest	3: The CRS will not be as rigidly attached in case of an accident	2: The user will see that there is a gap between the CRS and the car seat	Push the seat back	None	None
3c	User misses 3.3	A8: Action omitted	L	The Support leg will not be at its correct height	2: The CRS will not be properly secured for forward rotation	2: The User may notice that the support leg does not touch the car floor	Perform 3.3	None	None
3.1	User Fails to connect the ISOFIX connectors properly	A9: Action incomplete	S	The ISOFIX connectors will not be connected to the car	1: The CRS will not be fastened to the car	3. User may notice the indicator on the connector has not changed color	recovery is trivial	None	None

Remove CRS	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
Not Possible	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not Possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Detach CRS From Fastening	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
not possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
3. Remove	User Misses 3.1
	User Misses 3.3
b. What happens if the user makes an error in the sequence of operations?	
3. Remove	User performs 3.2 before 3.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
3.1 Retract Support Leg	User does not fully retract the support leg

e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Remove CRS									
#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
3a	User Misses 3.1	A8: Action omitted	L	Support leg is not retracted	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3b	User Misses 3.3	A8: Action omitted	L	ISOFIX fixture is not retracted	CRS takes more space in storage	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3c	User performs 3.2 before 3.1	P5	R	Support leg is retracted after removing CRS from car	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None
3.1	User does not fully retract the support leg	A4: Action too little	S	Support leg is not fully retracted	CRS is harder to remove from car	5: Can be fixed when user notices secondary consequence	5. Immediate Recovery	None	None

Place textile cover	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
1. Place main cover	User Misses 1.2
	User Misses 1.4
	User Misses 1.5
	User Misses 1.6
b. What happens if the user makes an error in the sequence of operations?	
1. Place main cover	User performs 1.2 before 1.1
	User performs 1.5 before 1.1
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not possible.	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	
a. What happens if the user performs an incomplete operation or omits an operation?	
2. Place Headrest Cover	User Misses 2.2
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible to perform an operation at the wrong time	

Replace Textile Cover

#	Error	Type	Cause	Primary	Secondary	Detection	Recovery	Protection	Prevention
1a	User Misses 1.2	A8: Action omitted	L	The Cover will not be correctly placed around the Belt Fixture	5: The intended aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Redo 1.2	None	None
1b	User Misses 1.4	A8: Action omitted	L	The Belts will remain underneath the cover	2: The Belts cannot be used	5: Can be fixed when user notices secondary consequence	Redo 1.4	None	None
1c	User Misses 1.5	A8: Action omitted	L	The Buckle will Remain Underneath the cover	2: The Belt cannot be fastend	5: Can be fixed when user notices secondary consequence	Reach in through the hole to try and find the Buckle	None	None
1d	User Misses 1.6	A8: Action omitted	L	The Cover Will not be fastened with the zipper	5: The Intended Aesthetics will not be achieved	5: Can be fixed when user notices secondary consequence	Close the Zipper	None	None
1e	User performs 1.2 before 1.1	P5: Wrong order	R	1.1 cannot be perfomed	3: The cover cannot be placed	4: Can be fixed with some effort when user notices secondary consequence	Undo 1.2	None	None
1f	User performs 1.5 before 1.1 and 1.2	P5: Wrong order	R	1.1 cannot be perfomed	3: The cover cannot be placed	4: Can be fixed with some effort when user notices secondary consequence	Undo 1.2	None	None
2a	User Misses 2.2	A8: Action omitted	L	Belts will nor be correctly placed	4: Child comfort will be effected	5: Can be fixed when user notices secondary consequence	Redo 2.2	None	None

Remove textile cover	
Function/Operation	Use error
a. What happens if the user performs an incomplete operation or omits an operation?	
Not Possible	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible	
a. What happens if the user performs an incomplete operation or omits an operation?	
Not possible	
b. What happens if the user makes an error in the sequence of operations?	
Not Possible	
c. What happens if the user performs this function at the wrong time?	
Not possible to perform the function at the wrong time	
d. What can the user do incorrectly during this operation?	
Not Possible	
e. What happens if the user performs this operation at the wrong time?	
Not possible	

Appendix VI: Survey I

	0	1	2	3	4	5	6	7	8	9	10
Säker	○	○	○	○	○	○	○	○	○	○	○
Lätthanterlig	○	○	○	○	○	○	○	○	○	○	○
Praktisk	○	○	○	○	○	○	○	○	○	○	○
Fräsh	○	○	○	○	○	○	○	○	○	○	○
Smidig	○	○	○	○	○	○	○	○	○	○	○
Passar i bilinteriör	○	○	○	○	○	○	○	○	○	○	○
Bekväm	○	○	○	○	○	○	○	○	○	○	○
Ditt totala intryck	○	○	○	○	○	○	○	○	○	○	○
Lätt	○	○	○	○	○	○	○	○	○	○	○
Skyddande	○	○	○	○	○	○	○	○	○	○	○
Omfamnande	○	○	○	○	○	○	○	○	○	○	○
Snygg/Vacker	○	○	○	○	○	○	○	○	○	○	○
Mjuk	○	○	○	○	○	○	○	○	○	○	○
Exklusiv	○	○	○	○	○	○	○	○	○	○	○
Stor	○	○	○	○	○	○	○	○	○	○	○
Len	○	○	○	○	○	○	○	○	○	○	○
Avslappnad	○	○	○	○	○	○	○	○	○	○	○
Bullig	○	○	○	○	○	○	○	○	○	○	○
Lätt att hålla ren	○	○	○	○	○	○	○	○	○	○	○
Kraftig/Gedigen	○	○	○	○	○	○	○	○	○	○	○
Stabil	○	○	○	○	○	○	○	○	○	○	○

Bestäm på en skala från 0 till 10 hur väl orden stämmer med stolens uttryck.

Pictured is one of the questions from the survey. Participants were shown a picture of a CRS and was asked to determine to what extent the different expressions fit with the picture shown, on a scale from 0 to 10. This question was asked 9 times, with a different CRS pictured for each question, in a random order.

Appendix VII: Requirements

Req#	Requirement	Comment	Wish/ demand	Fit criterion
1	**Axkid expressed requirements**			
1.1	Allow seating for child aged 0-4 years (approx)		D	Evaluation of CAD-model of concept with manikin
1.3	Implementation of an additional anti-rotation device for rotation backwards		W	
1.4	Head rest adjustment should use existing solution of self-adjusting height		W	
1.5	Head rest height should be lockable	Locking head rest height reduces risk of incorrect securing of child. Applicable if self-adjusting solution is implemented.	W	
1.6	Seat should be able to be rotated to allow switching from rear facing to forward facing seating	Seat should be rotated independently of base	W	
1.7	Allow reclining of seat		W	
2	**i-Size Requirements**	The following is a condensed version of the i-size requirements. For full list of requirements see ECE R129r2		
2.1	Combined weight of child and CRS must not exceed 33kg		D	Estimation / educated guess
2.2	Allow installation of CRS in car by ISOFIX fasteners		D	
2.3	Include an anti-rotation device	ECE R129r2 6.1.2.1	D	
2.4	CRS shall fit inside the R2 Cube when rearward facing	Specified in ECE R16r7 Annex 17 Appendix 2	D	CAD-model evaluation
2.5	CRS shall fit inside the F2X Cube when forward facing	Specified in ECE R16r7 Annex 17 Appendix 2	D	CAD-model evaluation
2.6	Airbag warning label	ECE R129r2 4.4	D	
2.7	0-15 front facing warning label	ECE R129r2 4.5	D	
2.8	Additional markings	ECE R129r2 4.6 - 4.8	D	
2.9	Allow for child stature of min 83cm in rearward facing position	ECE R129r2 6.1.3	D	Evaluation of CAD-model of concept with manikin
2.10	The internal geometry of the seat shall allow for antropometric data from ECE R129r2 annex 17		D	Evaluation of CAD-model of concept with manikin
2.11	If a support leg is used as anti rotation device it shall fit within the "support leg dimension assessment volume" as defined in ECE R129r2 annex 19	ECE R129r2 6.3.5.1	D	
2.12	The support leg shall be adjustable in increments of a maximum of 20 mm		D	
2.13	Minimum width of harness straps is 25mm		D	
2.14	Allow sufficient leg room for rear facing seating for child up to 15 months of age		D	Evaluation of CAD-model of concept with manikin
3	**Usability requirements**			
3.1	All textile and soft foam should be removable and replaceable		D	
3.2	Estimated time of removing and replacing textile cover of CRS should be less than current Kidzofix model		D	Testing of current model, Estimation of concept
3.3	Allow cleaning textile cover in washing machine		D	
3.4	The amount of possible errors when placing the child in the CRS should be fewer than for current Kidzofix model		D	PUEA
3.5	Reduce the likelyhood of a child partially escaping their safety harness in comparison to the current Kidzofix model		W	
3.6	Ergonomics when tightening the seatbelt should be better than the current Kidzofix model		W	Estimation
3.7	It should be possible to release the harness with one hand only.		W	

3.8	The isofix fasteners should be more intuitive to release in comparison to the current Kidzofix model		W	
3.9	The CRS should include intuitive gripping areas suitable for carrying the product		W	
3.10	Installation of CRS should have as many or fewer usability problems compared to competitor model	Problem seriousness needs to be taken into account	D	ECW
3.11	Installation of CRS should have no serious usability problems		W	ECW
3.12	Adjustment of anti-rotation device should not require more actions than current Kidzofix model	Time of operations need to be taken into account	D	HTA
3.13	Adjustment of head rest should not require more actions than current Kidzofix model	Time of operations need to be taken into account	D	HTA
3.14	Head rest adjustment interface should be at least as accessible as current Kidzofix model		D	
3.15	It should be possible to tell visually if the child has been correctly secured to the CRS.		W	
3.16	Adjusting the angle of recline should not require more actions than the current Kidzofix model	Time of operations need to be taken into account	D	HTA
3.17	It should be possible to adjust the angle of reclination with one hand		W	
3.18	The Usage of the CRS shall be free of critical errors effecting safety, even if they are unlikely	Some possible user errors are impossible to remove but they can often be considered to be "extremly unlikely"	D	PUEA
3.19	CRS should give feedback when seat is rotated into a locked position		W	
3.20	Seat rotation should be a one hand operation		W	
3.21	No parts of the CRS interface shoud be hidden underneath the product.		D	
3.22	The force vector required to unlock the ISOFIX connectors should have the same direction which is required to remove the seat. i.e towards the front of the car		W	
3.23	It should be possile to extend the ISOFIX arms with one hand		W	
3.24	It should be possible to extend the ISOFIX arms after the CRS has been placed on the car seat		W	
3.25	All Instructional labels should be illustrated.	Supporting text should only be added if neccessary	D	
3.26	The support leg should have no more than one point of adjustment		D	

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