Child Comfort in Rear Seats of Cars
A seating comfort study of how to improve and evaluate older children’s perceived comfort when riding on a belt-positioning booster

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Abstract

During the last couple of years several studies have been conducted to investigate how children move and position during car rides. This in order to map when, and for how long children sit in positions that are not safe as well as to identify the reason for these movements. One of the conclusions is that children do not always sit comfortable in today’s belt-positioning boosters and thereby they chose positions that are unwanted for safety reasons.

The aim for the master thesis has thereby been to improve seating comfort for children while traveling safely in the rear seat of a car. The target group has been children in ages 5-11 years old with body height 110-145 cm, a Swedish population 50 percentile has been used for the extreme dimensions.

The master thesis process is divided in three phases; Discovery, Development and Testing and Evaluation. In the Discovery phase information in the areas child safety, child methodology and comfort was gathered through literature study, interviews with experts, benchmarking and a focus group with parents. As a final step customer needs were formulated. In the Development phase a workshop with children was initially performed to complement the customer needs with inputs from the users. The customer needs were afterwards reformulated into a specification of requirements and five comfort hypotheses. Finally a prototype was developed, designed from the requirements with the purpose to validate the comfort hypotheses, using an anthropometric design method (Ovalder, et al., 2010). In the final phase, Testing and Evaluation, the prototype and reference belt-positioning boosters were evaluated by children in two user studies; one static study and one on road study, to evaluate comfort features and try out different seating comfort evaluation methods.

The result is divided into child seating comfort characteristics and child seating comfort methodology guidelines. To assist future development of belt-positioning boosters, seven comfort features are defined to help children ride comfortable in a safe position in the car. Furthermore, 13 child methodology guidelines are formulated to help further seating comfort evaluation with children.

Conclusively to make children sit comfortable and safe positioned in the car they should be seated in a belt-positioning booster with headrest, backrest, seat cushion and foot support, the supporting parts need to be perceived as soft around head, back and under the buttock and all parts need to be dimensioned for all children in the target group. The size of the belt-positioning booster and the combination of foam thickness, foam hardness and shape are the main factors for affecting the perceived seating comfort. Furthermore, children shall be included as both design partners and testers during the development of belt-positioning boosters. During the prototype development static comfort evaluation with children should be done repeatedly to verify measurements, shape and foam hardness. To evaluate comfort both static evaluation and on road evaluation should be performed since comfort varies over time. Data should be collected subjectively from children through quantitative methods, such as rating scales, and qualitative methods, such as general questions regarding comfort/discomfort experience. Video observations can identify children’s position during car rides. Different positions can be timed and together with subjective data reasons for repositioning can be identified.
Preface

This master thesis was conducted at Volvo Car Corporation at the department ergonomics. Therefore we first of all want to thank all people at the department for all help and for all support they have provided as well as for giving us the opportunity to write our master thesis in such an inspiring field. We would like to express our gratitude to our supervisors at Volvo Car Corporation, Tommy Apell and Pernilla Nurbo for their support, commitment and for contributing with inputs and second opinions. We also would like to express an extra thank to Krister Hedlund at ergonomic for his irreplaceable help. Other people at Volvo Car Corporation that we also want to thank is Lotta Jakobsson and Isabelle Stockman for inspiring us and sharing their knowledge about real life safety for children. We also would like to thank the people been involved in the development of our prototype as well as we want to express our gratitude to all the parents and children that has been participating in the performed user studies, workshop and focus group.

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Lastly we want to thank our families and all our friends for listening to us going on and on about this master thesis.

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Sofia Boberg
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## Definitions and abbreviations

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<td>CRS</td>
<td>Child Restraint System, general word for a device that position a child to better fit the geometry of the vehicle seat belt</td>
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<tr>
<td>Belt-positioning booster</td>
<td>General word for a kind of child restraint system that specifically elevates the child to fit the belt geometry.</td>
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<td>Booster cushion</td>
<td>A belt-positioning booster with no backrest. It looks like a quadrangular cushion and is an add-on solution, which means it is removable and can be placed in all car seats.</td>
</tr>
<tr>
<td>High-back booster</td>
<td>A belt-positioning booster with a backrest, looks like a seat and is an add-on solution, which means it is removable and can be placed in all car seats.</td>
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<td>IBC</td>
<td>Integrated Booster Cushion. A belt-positioning booster that is mounted in the vehicle seat cushion that can be down-folded when not used</td>
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<td>Crash test dummy</td>
<td>Anthropomorphic test devices that are used in crash tests as replacements for humans</td>
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<td>OOP</td>
<td>Out-Of-Position, which refers to when children are seated in another position than the child restraint system is designed and tested for.</td>
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<td>Real life safety</td>
<td>Refers to what actually happens on the roads when humans are involved, in contrary to simulations or crash tests with crash test dummies.</td>
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<td>Submarining</td>
<td>An unsafe position when the pelvis slips under the lap part of the seat belt in a crash, and the load is applied to the soft abdomen instead of the hard pelvis.</td>
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<td>M2M</td>
<td>Meat to Metal, refers to the distance between the buttock and the hard components under the foam in a car seat cushion</td>
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<td>TP</td>
<td>Test Person</td>
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<td>VCC</td>
<td>Volvo Car Corporation</td>
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1 INTRODUCTION

To assure children's safety on the roads a comfortable belt-positioning booster is an essential factor. The first belt-positioning boosters was announced in the late 1970s with the purpose to improve the child safety (Norin, et al., 1979). The invention made it possible for children to place the three-point seatbelt correctly and thereby travel more safely until a child was tall enough to sit directly on the car seat (DeSantis Klinich, et al., 1994). Belt-positioning boosters can either be integrated in the seat or removable, and are designed for children that are tall enough to travel in a forward sitting position. Today there are three main belt-positioning boosters: Booster cushion (see Figure 1), high-back booster (see Figure 2) and Integrated Booster Cushion (IBC) (See Figure 3)

Since the first belt-positioning booster was released research and tests with crash test dummies have resulted in development of several kinds of boosters to keep children safe. Crash test dummies are anthropomorphic test devices that are used in crash tests as replacements for humans. It is also possible to perform studies that explore what happens on the roads when humans are involved, this is called real life safety.

![Figure 1- Booster cushion](image1.png)

![Figure 3- Integrated Booster Cushion (IBC)](image3.png)

![Figure 2 – High-back booster](image2.png)
During the last years several studies in the field of real life safety for children in vehicles have been conducted (Stockman 2016, DeSantis Klinich, et al. 1994, Andersson, et al. 2010, Osvalder, et al. 2013, Jakobsson et al. 2011, Charlton, et al., 2010). These studies indicate that children occasionally prefer to sit in different positions than the standardized position identified by crash test dummies. When children no longer are seated in the standardized positions it results in important implications for children’s protection (Charlton, et al., 2010, Osvalder, et al., 2013). This since unstandardized positions can lead to reduction or elimination the restrain system’s safety benefits.

Since the comfort level of the belt positioning booster has big impact on children’s sitting postures the seat comfort thereby also affect the real life safety (Andersson, et al., 2010, Jakobsson, et al., 2011). Comfort is therefore an important aspect when designing child safety products for vehicles. This area is today a rather unexplored and no specific method for evaluating child comfort in vehicles is at this time published.

This master thesis has been carried out at Volvo Car Corporation (VCC), on the department of User Experience and Craftsmanship, to get a deeper understanding on how to evaluate and improve comfort, and thereby real life safety, for children.

1.1 VOLVO CAR CORPORATION

One of Volvo Car Corporation’s (VCC) core values is safety and it has been one of the most important aspects for the company since it was founded (Volvo Car Corporation, 2017). Solutions focusing on child safety in the vehicle have been implanted in different ways in VCC throughout the years. One of today’s solutions is the integrated booster cushion (IBC), which is a booster integrated in the rear seat. In order to improve the real life safety for children VCC wants to investigate how children sit comfortable in the rear seat to keep them in position.

VCC is a global brand with headquarter in Gothenburg, Sweden and production in Sweden, China, Malaysia and Belgium. Currently (year 2017) VCC has almost 30 000 full-time employees. They produce a range of cars including wagons, sport wagons, sedans, cross country cars and SUVs. Volvo Group was formed to make vehicles 1927 in Sweden. From Year 1999 VCC is no longer a part of Volvo Group and is, since 2010, owned by Zhejiang Geely Holding of China. (Volvo Car Corporation, 2017).

VCC's vision is to be the most progressive and desired premeium car brand. Their mission is that their global success will be driven by making life less complicated for people, while strengthening commitment to safety, quality and the environment. (Volvo Car Corporation, 2017)

1.2 AIM

The aim of the master thesis is to improve seating comfort for children while traveling safely in the rear seat of a car.
1.3 RESEARCH QUESTIONS

The research questions that will be answered in this study are:

RQ1: How can a belt-positioning booster support a child to sit comfortable and safe positioned in the rear seat of a car?

RQ2: Which methods and methodology is suitable when collecting data with children as the target group?

RQ3: Which methods and methodology is suitable when evaluating seating comfort with children as the target group?

1.4 GOAL

The goal is to define important seating comfort characteristics and improve seating comfort for children traveling safely in the rear seat of a car. This is to be accomplished by:

- Develop a concept idea of a belt-positioning booster that illustrates important seating comfort characteristics when children riding comfortable in a safe position in the rear seat of a car.
- Develop comfort methodology guidelines that can assist future evaluation of seating comfort for children in cars.

1.5 TARGET GROUP

For this master thesis the target group is children in the age 5-11 in a 50 percentile. The body height span for this group is 110-145 cm and they thereby represent the average span of children that are allowed to travel in a forward position in Sweden but are too short to sit in a safe position directly on the car seat.

1.6 ETHICAL CONSIDERATIONS

The aim of Etikprövningsnämnden (2015) is to throughout research protect individuals and the respect for human dignity. If research in Sweden can imply a risk for the participant subjects a trial shall be carried out by Etikprövningsnämnden (Research Ethics Committee).

According to Etikprövningsnämnden (2015), if the work performed is not a scientific work to acquire new knowledge or a development work carried out on a scientific basis, it is not bound to the law of ethical review of research involving humans. Student work performed in within the scope of university education, at basic or advanced level is according to Etikprövningsnämnden not research and needs therefore not to be considered by Etikprövningsnämnden (Etikprövningsnämnden, 2015).
The master thesis is within the scope of university education at an advanced level and doesn't need to be considered by Etikprövningsnämnden. The study will neither imply risks for the participant subjects and is not a scientific work to acquire new knowledge or a development work carried out on a scientific basis.

1.6.1 Ethical requirements when involving children in research

According to Johansson & Karlsson (2013) there are ethical guidelines developed by Vetenskapsrådet to protect the subject’s interest during research. This guidelines are developed for research made on children but the ethical guidelines should be followed even when research and development is conducted with children. There are four basic and general requirements: The information requirement, the consent requirement, the confidentiality requirement and the utility requirement (Vetenskapsrådet, 2002).

The information requirement: According to Vetenskapsrådet (2002) the participants shall be informed about the aim of the study, their task and the terms that applies for their participation. This as well as that their participation is voluntary.

The consent requirement: According to Vetenskapsrådet (2002) the participants have to give their consent to their participation. If the participant is younger than 15 years old their parents/guardians needs to give their consent. The participants shall be able to decide for how long and during which terms they participate. The participator shall not be exposed for any pressure regarding their decision to participate or end the study.

The confidentiality requirement: According to Vetenskapsrådet (2002) the privacy of the participant and the confidentiality of their personal information should be respected and the information should be stored so that no unauthorized can get hold of them. The presented material shall be formed so that no individual can be identified by outsiders.

The utility requirement: According to Vetenskapsrådet (2002) information collected in the study, about the participators can only be used for research purposes. It cannot be used for commercial use, non-scientific purposes or for actions that affects the participant.

1.7 PROCEDURE

The procedure for this master thesis is to explore comfort for children by developing a comfort prototype from customer needs, with anthropometric design as a starting point. The comfort prototype is then evaluated in two user studies, one static and one on the road study. The user studies are performed to evaluate the comfort and discomfort level for the prototype and examine how well the setup works to evaluate comfort and discomfort with children.
1.8 DELIMITATIONS

The delimitations for the master thesis are:

- The child restraint system is limited to belt-positioning boosters
- No solutions where the child is placed rearward are included
- No technical solutions or functions for belt-positioning boosters will be developed nor explored
- The prototype is designed for the left sided rear seat of a Volvo car, model S90 and V90
- Only the rules and regulations in Sweden are taken into consideration.
- All phases and activities are carried out in Sweden with Swedes as test persons
2 THEORETICAL FRAMEWORK

*In this chapter the theoretical framework for the master thesis is explained.*

2.1 COMFORT AND DISCOMFORT

According to De Looze, et al., (2003) comfort refers to a broad subject and has no exact definition. Even though it is a well-used term and comfort aspects for products is increasingly demanded in highly developed societies.

Hägg, et al., (2011) argue that discomfort is not a straight opposite to comfort since both concepts are complex and includes different variables. Zhang, et al., (1996) are on the same track and from two performed studies it was noticed that comfort seemed to be associated with wellbeing. Discomfort on the other hand with biomechanics and fatigue factors like pain, tiredness and ache. Similar De Looze, et al., (2003) identified in a study, where research about sitting comfort and discomfort where summarized, that statistically comfort is associated with feelings like relaxation and wellbeing. Discomfort was instead related to feelings like pain, numbness, ache and stiffness. However they also states that there are several studies treating comfort and discomfort as one variable and then when measuring comfort a scale goes from high discomfort to high comfort. In a study by Vink and Hallbeck (2012) ten papers were analyzed on the subject of comfort and discomfort in relation to product design, they defined comfort and discomfort as:

"Comfort is seen as pleasant state of relaxed feeling of a human being in reaction to its environment" and "discomfort is seen as an unpleasant state of the human body in reaction to its physical environment" (Vink & Hallbeck, 2012)

In a study by Helander & Zhang (1997) performed to evaluate chair comfort and discomfort, it was noticed that discomfort have a central effect on discomfort since persons pointing out high discomfort also tended to point out low comfort. According to Helander (2003) high values of comfort can only be attained if the values of discomfort are low (see Figure 4). Similar De Looze, et al., (2003) identified that if discomfort factors are present for a person it seems like comfort factors become secondary in the perception of comfort and discomfort.

![Figure 4- Comfort/discomfort model based on Helander](image)

Figure 4: Comfort/discomfort model based on Helander
To sum up, the concepts comfort and discomfort is not each other’s opposites since they includes different variables. Comfort is related to feelings of wellbeing and relaxation and discomfort to feelings like pain, ache, stiffness etc. According to the writers emergence of discomfort affect the comfort experience and high comfort can only be attained if the experience of discomfort is low.

To explain the concepts comfort and discomfort and included affecting variables, a comprehensive model demonstrating a nonlinear relationship between sitting comfort and sitting discomfort was introduced by De Looze, et al. (2003), see Figure 5. The model demonstrates that physical impact has a more direct effect on discomfort. Which is consistent with Hägg, et al., (2011) that argues that discomfort is a perception of improper physical load. They continue that emergence of discomfort shall be investigated in order to be able to change the conditions. De Looze, et al. (2003) model, see Figure 5, specifies three main influencers for comfort and discomfort assessments: the human, the seat (or the product), and the setting.

The left side in the model (Figure 5) is the discomfort side that concerns feelings of pain, numbness, ache and stiffness. The right side of the model, the comfort side, concerns feeling of wellbeing and relaxation. Regarding human aspects De Looze, et al., (2003) suggest that comfort is influenced of human’s individual expectations and emotions. This as well as perception of discomfort for humans is influenced by physical processes such as muscle activity and physical capacity like weight and endurance. Regarding Seat aspects (the products aspects) perception of comfort and discomfort is influenced by the seats physical features such as dimensions, foam hardness etc. Also aesthetic design of the seat can affect the felling of comfort which likewise was identified in the study by Helander & Zhang (1997). Regarding the setting, perception of comfort and discomfort is influenced by physical environment such as temperature. A task is also affecting the perceived comfort such as driving or filling out a form. Comfort is also influenced by psycho-social factors which refers to example social support.
2.1.1 Measure and evaluate seating comfort

Comfort and discomfort is hard to define and therefore it is challenging to provide a method for measuring comfort and discomfort (Judic, et al., 1993), (Osvalder, et al., 2010). Tools for measuring comfort and discomfort are based on objective conclusions such as using electronic equipment, while others are subjective and built on people’s perception (Openshaw, 2011).

Sitting comfort or discomfort is often evaluated with subjective rating scales which then can be used as references to an objective measure of the chair, the occupant or the task, such as observed sitting postures (Fenety, et al., 2000). According to Osvalder, et al., (2010) the use of subjective methods when evaluating comfort and discomfort is hard to quantify and it is hard to draw conclusions for a whole population. This because parameters like age, earlier injuries, experience etc. matters for a person perception of comfort and discomfort. Trough linking subjective data with objective observations of changes in behavior, such as changing posture, changing center of gravity and movements, a better way for understanding a situation is accessed which increases the reliability.

The subjective measures are important to include since individual preferences often affects the perceived comfort and discomfort (Judic, et al., 1993) (Osvalder, et al., 2010). According to Openshaw (2011) subjective measures are influenced by a person’s current state of mind, biases, experiences etc. However, the subjective methods allow a researcher to interact with the test person to understand what the test persons actually perceive and without subjective data the human aspect can be lost. Comfort and discomfort are complex concepts and can be hard to express in normal terms like more or less comfort. According to Vink & Hallbeck (2012) perceived discomfort is commonly a measured parameter. From studies focusing on car seats, truck seats and office chairs conclusions can be drawn that subjective estimations of perceived discomfort are the most effective and dependable measure to use (Osvalder, et al., 2013).

Hägg, et al., (2011) argues that that it is important to be aware of that the perception of comfort and discomfort differs over time. In accordance with this Osvalder, et al., (2013) argues that, from performed studies with adults evaluating sitting discomfort in cars, it was identified that perceived discomfort increases after 1-1,5 hours.

2.2 CHILDREN’S GROWTH

This chapter concerns the development of children’s bodies and how children’s age development matters when researching with children.

2.2.1 Children’s body development

When designing for children it is important to understand that children are not miniature adults. Budri, et al., (1969) states that on the contrary a child’s body dimensions, proportions and biomechanical properties are distinctly different from an adult’s. From birth to old age, the dimensions and parts of the human body grow and develop sporadically and non-uniformly, but are following predictable trends. A newbors head is approximtely 25% of the total body size, as well as their neck is weak and therefore children in the age 3-4, are safest when riding in a backward position. (Tarrière, 1995). Older children have a stronger neck as well as their head is proportinally less and therefore they can travell positioned forward-facing (Jakobsson, et al., 2005). Though
there is still differences compared to adults, which is important to be aware of in order to provide children the same amount of protection as adults when traveling forward-facing in a vehicle (Jakobsson, et al., 2011b).

**Figure 6 – Pelvis (A), iliac crest (B) and iliac spines (C)**

When the lap part of belt is well positioned on adults, the iliac spines of the pelvis (See Figure 6) work as anchor point to keep the belt positioned on the firm skeleton parts instead of the soft vulnerable abdomen (Burdi, et al., 1969). However, it is first at 10 years of age that the pelvis develops into a shape that is similar to adults and during younger years the child's iliac crest has a concave shape without a prominent spine, (Huelke, 1998) see Figure 7. Furthermore, when the child sit down the pelvis tilts to the rear which leaves only a little space in the pelvic-thigh angle to place the lap belt (Burdi, et al., 1969). This increases the risk that the belt overpasses the child’s pelvis and penetrates the abdomen in a collision (Tarriére, 1995). This phenomenon is called submarining.

**Figure 7 – Development of the pelvis; from the child’s concave shape (A), to the development of the pelvis wing during puberty (B) and the full-grown pelvis in adult age (C). (Tarriére, 1995)**

Burdi, et al. (1969) highlight this phenomenon and the childrens lack of firm structural anchor point as a significant problem. Jakobsson, et al. (2007) are on the same track and states that the growth of the iliac spines must be considered when designing a CRS. They continually argue that belt-positioning boosters elevates the child, making it possible to place the lap belt over the thighs rather than over the pelvis, which increase the chance to avoid the interaction between the belt and the abdomen. To keep the belt in position could be done by adding belt-positions devices, as guiding horns on the belt-positioning booster or by letting the belt-positioning booster put the child in a more upright position with more thigh support (Jakobsson, et al., 2007).
2.2.2 Children’s psychological development

According to Karlsson (2013) Children’s age matters when performing research with children. Older children possess linguistic abilities as well as emotional and motoric abilities that smaller children miss which shall be considered. On the other hand older children can perceive methods and questions as childish, which also need to be taken into account when developing suitable methods. Hansen Orwehag (2013) states that when developing methods for research with younger children it is important to consider that younger children's attention is of short duration.

When it comes to workshops and co-design Karlsson (2013) writes that there are researchers including (Angeliki & George, 2008) that consider studies with children around eight to ten years and upwards to be easier to perform since they have developed an understanding for abstract ideas. In a study by (Vajaakallio, et al, 2009) performed to explore co-design methods with children aged 7-9 years old it was identified that children in the age span were capable of developing ideas but had trouble with group dynamics and reflect everyday experience into design ideas.

Osvalder, et al. (2013) State that the age range of the included children in on road studies doesn't commonly affect objective data collection. However age is an important aspect when collecting subjective information to attain reliable data. They are on the same track as Christensen & Prout (2002) when they states that the design of the used methods like interviews and questionnaires needs to meet the children’s abilities. Further they state that experience from earlier studies performed in Sweden regarding protection in cars shows that children below seven years old sometimes have troubles to state their actual opinions and express themselves verbally. Therefore follow up questions in interviews can be helpful to verify children’s answers. Other things that can be helpful are scales with facial expression and coloring perceived experiences on figures. Studies like (Scaife & Rogers, 2001) shows that children as young as 4-6 years old can be included in different design activities during development, though the design methodology used required a lot of effort and was time consuming.

2.3 REASONS FOR CAR RESTRAINT SYSTEMS FOR CHILDREN

In passenger vehicles children are the primary occupants of the rear seat and 70 percent of rear seat occupants are less than 14 years old (CHOP, 2013). Belt-positioning boosters are proven to help preventing injuries for children if a crash occurs (CHOP, 2013).

A study with children aged 4-7 years shown that the likelihood of injury was 59% lower for a child restrained in a belt-positioning booster compared to the seat belt alone (Durbin, et al., 2003). Furthermore, the study showed that seat belt related injuries to the abdomen and spine were almost eliminated for children seated on belt-positioning boosters. Similar results was seen in a study with children aged 4-8, where the risk for injury was reduced with 45% for children restrained on a belt-positioning booster (Arbogast, et al., 2009).

Even though child restraint systems are shown to reduce injuries (CHOP, 2013), misuse, like not route the seat belt correctly, and a too early change-over to use of only seat-belt increases the risk for the children to get injured anyway (Transportstyrelsen, 2017).

When children grow older US statistics (CHOP, 2013) shows that injury risks for the age group 9-12 years are higher than for the age group 4-8 years. One explanation for this is
that children in the age span 9-12 years may not be offered the same protection from the vehicle's rear seat and associated safety features as children in the lower age span are from the belt-positioning boosters. A study with Swedish children in age 7-8 shows that they perceive child restraint system as important for safety and comfort reasons, but that they also perceive them as childish (Bohman, et al., 2007).

In this chapter it will be described why children ride more safely on a belt-positioning booster, when children are seated in a safe position and what the reasons and risk can be for getting out of position.

2.3.1 Types of belt-positioning boosters

Children older than three years and until they are at least 135 cm shall use certified child restraint systems in a vehicle (Transportstyrelsen, 2017). Today the three main belt-positioning boosters are: Booster cushion, high-back booster and Integrated Booster Cushion (IBC). All three solutions are used together with the adult seat belt, elevate the child, and thereby allow the belt to be positioned over the thighs (Jakobsson, et al., 2007).

The booster cushion is often provided with guiding loops to route the lap-belt over the thighs and keep the booster and the seat belt in place during a crash (Jakobsson, et al., 2007) see Figure 8.

The high-back booster has, as a backrest which initially intended to lead the seat belt in an optimal track over the child’s shoulder and chest (Jakobsson, et al., 2011b). Nowadays large side supports along the torso (called bolsters) and the head have been added to the high-back boosters. The child restraint manufactures two main reasons for this are to improve side impact protection and to provide a more comfortable position for the children (Jakobsson, et al., 2011b).

In some cars an integrated booster cushion (IBC) is provided and it has the intention to simplify usage and minimize misuse. The cushion is integrated in a regular seat and by keeping the children in a more upright position the seat belt is placed over the thighs without the need of guiding loops (Jakobsson, et al., 2007). A further development is a 2-stage version, which allows a wider range of children a possibility to use a IBC (Jakobsson, et al., 2011b), see Figure 9.
2.3.2 Safe position for children on belt positioning boosters

Belt-positioning boosters’ purpose are to improve the child’s seatbelt geometry. This is most commonly done by changing the belt routing. Decent belt geometry is characterized by placing the belt in anatomical regions where the restraint forces can be directed onto the skeleton and not onto soft tissues, (Reed, et al., 2013) see Figure 10. According to a study performed by Charlton, et.al (2010) children’s use of CRS was considered accurate if their limbs were correctly restrained by seatbelt and lap portion of seat belt placed low over pelvis, not going up over abdomen and also that the seatbelt buckle was correctly attached.

A lap belt positioned to high on the child’s abdomen can occur submarining which means that the pelvis slides down and under the lap belt, then the body is restrained by the abdominal instead of the strong pelvic bone (See Figure 11). The shoulder belt should preferably be placed on the shoulder, as close to the neck as possible without affecting the comfort negatively. If the child experience discomfort, misuse of the belt can occur, like putting the belt under the arm. If the belt is placed far out on the shoulder the belt can slide of the shoulder, which can lead to excessive head excursion since the torso will not be restrained properly. (Reed, et al., 2013)

2.3.3 Children out of position

Child restraint systems (CRS) for vehicles are developed to provide child occupants with specialized protection if a crash occurs (Charlton, et al., 2010). With a belt positioning booster the belt fit improves significantly (DeSantis Klinich, et al., 1994) and it is shown that children perceive child restraint system as important for safety and comfort reasons (Bohman, et al., 2007).

In a study by Charlton, et al. (2010) that focused on children traveling with CRS in the age 1-8 years old, investigated children’s behavior in cars. In the study video recordings from 92 trips with 12 families were collected and analyzed. On average, children were out-of-position (OOP) approximately 70 % of the traveling time. Children OOP was in the study
referred to as being out of the protective zone given by the CRS structure or as being away from the preferred location within the CRS or vehicle restraint system.

Charlton, et al. (2010) found out that the most common OOP was leaning forward out of the restraint (28.7 % of the journey). Arms or feet outside the restraints (16.7 % respectively 15.9 %) was approximately as common as lateral shift to the right or left (15.6 % respectively 14 %). According to the study behaviors such as sleeping and playing were common and associated with children being OOP.

**Forward movement**

One reason for children to lean forward are perceived discomfort by the backrest of a high-back booster (Osvalder, et al., 2013). In a driving study performed by Andersson, et al. (2010) including six children, 3-6 years old the childrens positions were compared between two high-back boosters, one with big side support and one with smaller. Discovered was that for both high back boosters the children lent forward, with the main part of the head in front of the front edge of the head side supports, for more than 50% of the ride. They also identified that for the high-back booster with smaller sidesupport the children were sitting with their entire back against the backrest 45% of the ride compared to 75% for the one with larger side supports. They thereby concluded that the design of the high-back booster’s side support had impact on the time children spent OOP and that big side support affected the children's view both inside the car and out of the windows. For an example were a child travelling on an IBC and leaning forward, see Figure 12.

A study by Jakobsson, et al. (2011) was carried through with older children, aged 8-12, that compared childrens positions on a booster cushion and the original car seat using the seat belt only. This study shows that the children spent most of the ride in a posistion with their upper back and shoulders in contact with the seat back, independent of using a booster or not. In a study with six children aged 7-9 comparing an IBC with a high-back booster, showed that children seated on a high-back booster spent less time sitting with the upper back and shoulders in contact with the backrest compared to the IBC (Osvalder, et al., 2013). These three studies show tendencies of the design of the high-back booster being a reason for a forward leaning position.

According to Andersson, et al., (2010), children's activities in a car also contributed to leaning the head forward. For activites such as reading, playing with something, looking at something in the lap, and eating all lead to a distinctly forward tilted head position.

**Lateral movement**

In a study by Jakobsson, et al. (2011) they conclude that children using a belt-positioning booster are less likely to move laterally, than when seated directly on the seat. Andersson, et al. (2010) performed a study where the children were positioned almost constantly between the side supports in the two different high-back boosters during the ride. In a study by Arborgast, et al. (2016) 37children's, aged 1-8 years, head positions were compared when riding on a high-back booster with integrated belt harness (a seatbelt mounted in the high-back booster), a booster cushion or directly on the seat. The study showed that children riding on the original seat had a bigger tendency to lateral (sideways) head movement and magnitude of skewness and thereby bigger risk to get out
of position (OOP). These Three studies show that the child’s freedom to move tend to affect the lateral movement. Osvalder, et al. (2013) also states that children move more freely on the IBC and that the belt thereby was off the child’s mid shoulder due to lateral movements for a longer period of time. For an example were a child travelling on an IBC and is moving laterally, see Figure 13.

An interesting observation from the study by Arbogast, et al. (2016) was difference in lateral head movement due to where in the rear seat the children were placed. The children seated in center rear seat showed the smallest range of head positions compared to the left-right seated children. According to Arbogast, et al. (2016) these moving patterns may depend on that there are limited space in the middle of the rear seat when travelling with other occupants as well as they have no one to interact with when travelling alone in the rear seat. The left-right positioned children may move inboard either because to see out of the front window or to watch the DVD player that was placed in the center of the car ceiling during the study ride.

Even though big side bolsters on high back boosters seems to increase a forward-leaning position for children (Andersson, et al., 2010) the bolsters have an importance for children’s lateral position while sleeping. During a nighttime study including 30 children, in ages 7-14, carried through by Forman, et al. (2011), side bolsters turned out to be central to keep children in position while sleeping. Children sleeping with side bolsters resulted in less lateral motion of the head and thereby more consistently appropriate fit of the shoulder belt. A wider range of lateral head movements were noticed for the children travelling on a belt-positioning booster without side supports which lead to a higher frequency of poor shoulder belt fit.

**Feet and arms outside the restraint system**

Huang & Reed (2006) performed a study in 2006 where it was stated that if a child’s thighs are shorter than the length of the seat cushion it causes a situation where the calves rest on the front edge of the cushion. To avoid putting pressure on their legs children tends to slouch, which result in a poor belt fit and risk for submarining (DeSantis Klinich, et al., 1994). According to Huang & Reed (2006) an integrated booster cushion (IBC) can prevent slouching since the seat then is devided in two lengths. This is partly confirmed by findings from a study by Jakobsson, et al. (2011) which shows that slouching occured in a bigger extent when the child were seated directly on the seat compared to seated on a booster cushion. Even if a child slouch a belt-positioning booster can helt the belt to stay in a correct position.

A study by Osvalder, et al. (2013) shows that children seated on an IBC tends to let their feet rest on the adult cushion base bellow the IBC, see Figure 14. Or they rest one foot on the floor panel bellow the door and one foot on the centre panel.

The study by Osvalder, et al. (2013) also states that the children mostly positioned their arms along or angled forward the sides of the torso, independent of if they played with
something or just had their hands in their laps. Extreme upper arm positions of short duration occurred and was a result of children interacting with the driver, pointing at something etc.

**Activities and extreme positions**

In three of the studies conducted (Andersson, et al., 2010; Jakobsson, et al., 2011; Osvalder, et al., 2013) the authors refers to extreme positions as no contact with backrest with either shoulder or back and/or lateral movement outside the side supports. Extreme positions occurred rarely but when they did they occurred as a result of activities, like talking to the driver, or of perceived discomfort. (Andersson, et al., 2010; Osvalder, et al., 2013).

In a study by Osvalder, et al. (2013) the children were busy with a number of activities for the majority of travelling time and thereby frequently changed positions. A leaning forward position was identified for children interacting with a device and children not performing any activities were more likely to be in position and thereby travel more safely.

**Out of position due to discomfort**

According to Osvalder, et al. (2013) discomfort, and choice of activities, influences the selection of children's sitting posture and seat belt position. In the study conducted by Osvalder, et al. (2013), it was showed that most children perceived inconvenience around the front and the back of the neck, in the area where the seat belt was placed, the children moved the seat belt away from the neck independently of type of belt-positioning booster. If the belt causing discomfort during a ride it can result in the child push the straps off or open the buckles, a serious consequence for safety reasons (Road Safety Authority, 2016).

Both Osvalder, et al. (2013) and Jakobsson, et al. (2011) evaluatated comfort by objective and subjective methods during their studies. These studies also show that tendencies of familiarity play a part in which of the seats the children prefer. The children in most cases prefer to use the kind of restraint system they are used to.

The majority of the children participating in the study by Osvalder, et al. (2013) preferred the IBC over the high-back booster due to the possibility to move freely, the soft seat cushion and absence of torso support. A few children felt discomfort at their bottoms from the IBC and one child perceived discomfort due to the short seat. In the study the high-back booster led to more discomfort due to it was perceived hard and created a locked-in feeling. Several of the children pointed out the entire back and neck, the front shoulder and the arms as areas of discomfort because of the hard backrest and the narrow side support. In the study by Osvalder, et al. (2013) the children also pointed out that the high-back booster moved in situations, like when the car turned, which they perceived as unpleasant.

The children reacted more to discomfort when seated on the high back booster which according to Osvalder, et al. (2013) and Jakobsson, et al. (2011) it may be because of that the children were not locked in an upright position by the side supports on the high-back booster. Discomfort is also noted in the objective study by Andersson, et al. (2010). In the study foam thickness and angle of the backrest are noted and suggested as reasons for discomfort and thereby a difference in positions between the two compared seats.
2.1 PERFORMED REAL LIFE SAFETY STUDIES

In the area of real life safety for children some studies have been conducted to explore how used restraints increase child safety in vehicles, how risks occur and how to make improvements in the area (Stockman 2016, DeSantis Klinich, et al. 1994, Andersson, et al. 2010, Osvalder, et al. 2013, Jakobsson et al. 2011). In these studies user tests with children have been carried through with the purpose to evaluate seat belt positions, sitting postures and/or activities. The information from the user studies has mainly been collected from objective data through observations, using video cameras. Subjective data has also been collected in some of the studies.

Osvalder, et al., (2013) researched the field of child comfort, for boosters designed for the rear seat, in a study where sitting postures and comfort experience were analyzed. In the study six children participated and subjective data was collected through questionnaires and interviews. In addition to this objective data was collected by the use of observations. Osvalder, et al. (2013) argue that it was an advantage to use both objective and subjective measures in the study to be able to evaluate why the children felt discomfort. There have not been a lot of studies executed regarding child comfort in the rear seat, but the research made has shown that there is a linkage between comfort and safety when studying the childrens sitting postures (Osvalder et al., 2013, Jakobsson et al. 2011).

2.2 SWEDISH CAR SAFETY REGULATIONS

According to Transportstyrelsen (2017) and Trafikverket (2012) children, shorter than 135 centimeters, must according to the Swedish law, use a booster cushion, high-back booster or other belt-positioning booster instead of or in combination with seat belt, while riding in cars in Sweden. Scientists and physicians recommend that children use a booster cushion or high back booster until they are 10-12 years old.

To ensure that the belt-positioning booster is legal and safe it should be EU certified and E-labeled according to EG-directive or ECE-regulation 44-03 or a later version. From year 2014 the labeling UN R 129, also called i-Size turned up and it will in the future replace ECE-regulation 44. (Transportstyrelsen, 2017).

2.3 INVOLVING CHILDREN IN A PRODUCT DEVELOPMENT PROCESS

When involving children in a research process there is, according to (Christensen & James, 2000), no given method to use, on the contrary there is nothing special nor unique with children that would exclude any of the methods that include adults as a research subjects or objects. Even though, they state that children are not adults and therefore the practices of the methods should be adapted to children’s own concerns and routines. Christensen & Prout (2002) are on a similar track stating that research methods should always be adapted to the study and the participants. When researching with children it is important to have in mind that people have different references especially when collecting subjective data (Osvalder, et al., 2013).
According to Johansson & Karlsson (2013) there is a structural difference between the researcher and the child from the very beginning. This since the researcher needs to get approval from adults to get in contact with the child as well as that the he child's experiences of adults often include the adults' authoritarian position, such as a teacher's perception of right and wrong. Druin (2002) as well as Christensen & James (2000) states that the structure of our community, were children are dependent on adults, may lead to a situation where the child has a more difficult position to go against the adult. According to Johansson & Karlsson, (2013) adult has an idea of knowing what the child thinks and wants. This relationship can make it more difficult for children to voice their opinion Druin (2002). However the children have the power to refuse to cooperate or make things up and therefore it is important to create a space where an as equal conversation as possible can be held (Johansson & Karlsson, 2013). Since research aim to find out things that are not yet known, the researcher have to develop a mutual trust, between oneself and the child (Johansson & Karlsson, 2013). In the end the most important thing while researching on children is the researcher's attitude, not the methods (O’Kane, 2000).

According to Doveborg & Pramling Samuelsson (2001) children’s experiences and thoughts often surprises adults since adults commonly design things for children out of their own experience and thoughts. If adults really want to know what children think, the children needs to be put in situations where they have to think and then the adults can interact or observe them. Children as well as adults takes things in everyday life for granted, though what is taken for granted seems to differ between adults and children.

According to Doveborg & Pramling Samuelsson (2001) misinterpretations also occur when adults presume that children know and/or understand fundamental knowledge, which is not always the case. When researching with children it is important to explain what should be done and why it should be done, to avoid misunderstanding and confusion. Sometimes children interpret things that they are told literary which also should be considered. Children often want to please teachers or researchers and they often identify the aim of a study in order to be able to meet their expectations and please them.

2.3.1 Children’s different roles in a development process

Based upon literature and analysis by Druin (2002), regarding research with children as participants in design processes, she has identified four main roles for children in the technology design process, user, tester informant and design partner see Figure 15.

![Figure 15- The role that children may have in workshop, inspired by (Druin, 2002)]
According to Druin (2002) in the user role children contributes to a development and research process through usage of the technology. Designers can through example observations get information which can be used in future development to meet the children’s needs.

In the tester role children are observed or asked about their experience of using the technology. The information can then be used in future iteration of the pre developed technology.

In the informant role, children can contribute in different and various phases in the design process. Example children can be asked or observed when using similar technology as the one to be developed or they can be asked for their opinions on low-tech prototypes, sketches and later on the finished developed technology.

The role as a design partner is similar to the role as an informant, but in this role it is suggested that children will be part of the design process throughout the experience. Children can then contribute with their expertise and point of view equal to the adult designers.
3 METHOD THEORY

In this chapter methods and methodology used for the master thesis is explained.

3.1 COMFORT AND DISCOMFORT EVALUATION METHODS

This chapter concerns different subjective and objective methods that is used when evaluating and measure comfort and discomfort. Long term comfort assessment is also included.

3.1.1 Objective methods for comfort and discomfort assessments

According to Osvalder, et al., (2010) an objective method is pressure distribution where the sitting pressure distribution for a human can be measured with special carpets that can be placed on e.g. a car seat. According to a study by De Looze (2003) pressure distribution is the objective measure, which seems to give the clearest linkage with subjective ratings for especially car seats and they state that a statistical relationship between pressure distribution and local discomfort has been noticed. According to Osvalder, et al., (2010) it is hard to find a clear linkage between pressure distribution measurements and sitting discomfort. This because there is no ideal comfortable sitting posture as well as the time of exposure is crucial. Perceived discomfort influence the selection of sitting posture (Osvalder, et al., 2013) and therefore observation, direct or by video recording, is a suitable objective method to identify, map and quantify movement patterns and body postures (Osvalder, et al., 2010).

3.1.2 Subjective methods for comfort and discomfort assessments

Osvalder, et al., (2010) argues that a good procedure to identify people's perceived alterations of discomfort is by subjective estimations, which can be done through the use of interviews, focus groups and forms including scales measuring test persons perceived discomfort, pain, tiredness etc.

One method by Corlett & Bishop (1976) visualizes a human body and the test persons are instructed to rate the amount of pain they perceive in different areas of the body on 1 to 10 scale. This is a one linear scale so if no pain is marked it is assumed that no discomfort
is perceived and therefore it is also assumed that the individual is comfortable. Helander & Zhang (1997) separated questions about comfort and discomfort in order to allow the test person to answer to questions more accurately. Questions about comfort concerned relaxation, wellbeing and aesthetics where questions like: I feel relaxed, Chair is spacious, Chair looks nice, Chair feels soft etc. (Helander, 2003). Questions concerning discomfort where questions about biomechanical factors, pain and soreness like: I have sore muscles, I feel pain, I feel tired etc. (Helander, 2003). According to Ziolek (2014) Subjective methods like ratings of perceived comfort and discomfort can be connected to body measures in order to identify variations in opinions related to body measures.

3.1.3 Long term comfort and discomfort assessments

In a study by Ziolek (2014) performed to evaluate long term seat comfort and discomfort in vehicles a comfort and a discomfort questionnaire were developed. Since perception of comfort and discomfort differs over time (Hägg, et al., 2011) the comfort questionnaire was filled in by the test persons in the beginning and in the end of the ride in order to identify how the test persons comfort experience had change during the ride. The discomfort questionnaire focused on when, where and to which amount, numerically, the test persons experienced discomfort and this where assessed several times during a ride. According to Ziolek (2014) it is also important to be aware of that the initial fatigue can bias the results. Therefore vehicle seat rated in the end of a test day of an on road study could be given lower comfort scores. The subjective data can then be compared with objective data like observations and body measures.

3.2 INTERVIEWS WITH CHILDREN

Interviews are mostly used when individual children’s views and experiences are needed (Gallahager, 2009). It is according to Doveborg & Pramling Samuelsson (2001) important to speak to the children in a way they understand as well as follow up their answers. This to create a good contact in order to make the child willing and comfortable to collaborate. The one to one situation can make children uncomfortable but it enables the interviewer to focus on the individual child and attain a flexible approach (Gallahager, 2009).

(Gallahager, 2009) States that the questions should preferably be tested on at least one child before the actual interviews to identify if the questions are understandable for the children as well as how they interpret the questions and if they had time enough to answer. It is important to dare to be silent when interviewing children since they sometimes need some time to think. When interviewing children the questions should first be broad to give the children the opportunity to choose direction and then after a while more specific questions can be added.

According to (Gallahager, 2009) when performing a group interview it will be identified that children influence and affect each other as well as how the composition of children look like, is some children talkative, is any shy etc.
3.3 QUESTIONNAIRES WITH CHILDREN

According to (Sorbring, 2013) one advantage with having the researcher present during the performance of a questionnaire is that the researcher can be sure that the child has understood his or hers rights and that it is voluntary to participate. The participant's answers may though become less sincere because of the present of an adult and therefore it is important to create an equal relation between the researcher and the child.

When developing a questionnaire (Sorbring, 2013) writes that it is a good idea to start with easier questions and tasks in order to make the children motivated to continue. To be considered is that the order of the questions can influence the children's answers. To cover as much as possible when developing a questionnaire regarding a subject, several sub themes can be created and to make children take a stand scales can be used in relation to questions or claims. This is also used in order to be able to perform statistical calculations. A usual scale is Likert-skalan which goes from 1 to 5. When the values are summarized an indication of the children's opinion, experience or perception is given. Other examples of suitable respond alternatives can be: Strongly agree, agree, neutral, disagree or strongly disagree. It is also possible to use a four point scale in order to make the child take a stand. If a "middle" alternative is used this should not be an option for "don't know". If the researcher want to have an option for don't know this should be placed outside the scale. If using illustrations the researcher needs to inform the child in order to ensure that the child understand the illustrations. Illustrations can also help to make the children's answers less personal (Gallahager, 2009). According to (Sorbring, 2013) Facial expressions can be used and then a very happy facial expression indicated high and positive values as well as a sad indicated low values. It is important to be aware of that facial expressions demonstrated a feeling and therefore this facial expressions should be used when a feeling should be measured. Pictures with facial expressions is used in studies with children in different ages.

When developing a questionnaire it is according to (Sorbring, 2013) important to give clear information and avoid several questions in one main question. Negations and leading questions should also be avoided as well as complicated words. Gallahager (2009) is on the same track and states that careful design is crucial. The questionnaires should be as short as possible and the language should be simply and clearly and the questionnaire shall be tested before the execution.

3.4 PROPOSED GROUP WORK TOOLKIT WHEN RESEARCHING WITH CHILDREN

In the book researching with children and Young adults (Hill, et al., 2009) a toolkit and a step-by-step approach to works with groups of children is provided. This toolkit is divided into four sections:

- **Preparing for you research or consultation group**
  
  According to Hill, et al., (2009) the majority of studies including children are based on aims set by adults. When doing research with children it is important to understand that exploring their views on a certain subject is the adult researcher's agenda and may not be theirs. It is also important to consider that the participating children refrain their spare time to participate in the study. Therefore it is
important to make it fun, provide a variety of options, offer other choices for children not wanting to participate in an activity, stay with the time plan and be flexible dependent on what the children seems to enjoy.

In the preparation phase it is important to set up clear aims and objectives as well as to choose what to be discussed and how to recruit children. It is also important to consider how you will negotiate consent and communicate accurate information in an understandable way to the children. Other aspects are also amount of participants, if the participants have any specific needs, where the meeting will be held etc. It is also of interest if there will be any other persons included in the study. For example can it be supportive to have two facilitators, and to include participants that are already known to the children in order to make them feel comfortable. Although, adults that are known to the children can change the dynamics and try to speak for the children, which is important to be aware of. To be considered is also how the data will be collected for example, audio recording, notes and art work etcetera.

- **Getting started with your group**

At first Hill, et al., (2009) states that the place where the session will be carried out should be created so that children feel welcome. When they arrive a good ice breaker is some informal talk and it is important to talk to the children and not the parents or teachers.

When introducing yourself at the session do it clearly so that the children will understand and ask them if they have any questions. Emphasize that they don't have to take part or answers to question or whatsoever during the session. If audio-recording will be used tell the children why and for what it will be used and ask them for their permission.

A warm up game is a good way to obtain a more relaxed environment. An example of a game can be that all participants tell their name as well as something they like and something they dislike. Making name badges is also a good start as well as a group agreement can be used to create a non-treating environment for the participants.

- **Answering your research questions: activities**

According to Hill, et al., (2009) different activities can be used to explore the defined research questions. Brainstorming with association is a well-used tool to explore children's views and ideas. Creating characters can help children since it can feel safer to talk about another person than themselves. Also statements can be used, which the children can agree or disagree with. For this colored cards can be used to visualize the children's opinion. Gallahager (2009) writes that a focus group also can be used with children and that children often feel more comfortable when there is more children than adult. Although the group dynamics can cause problems since some children tends to be more dominant which may make it difficult for more shy children to speak up.

- **Positive endings**

When the session comes to its end Hill, et al., (2009) states that it is important to convey appreciation for the children's participation. It can also be valuable to ask the children for feedback regarding the group session in order to improve future sessions. Also ensure that there are some time after the sessions were the participants can talk to you, ask questions or if they are anxious about something they said.
4 SEATING COMFORT AT VOLVO CAR CORPORATION

In this chapter Seating comfort at Volvo Car Corporation is presented. The Seating Comfort team’s work with seating comfort will be explained and the information was attained through interviews with Tommy Apell, titled as attribute leader seating comfort.

4.1 VOLVO CAR CORPORATION’S SEATING COMFORT DEVELOPMENT PROCESS

Seat comfort is an important part in Volvo Car Corporation’s (VCC) process of launching a new car seat. Generally most of the seat comfort development at VCC is based on comfort studies with humans. The results from the studies is always well analyzed and thereby the knowledge and experience of how comfort in VCC’s seats is perceived can be used through the whole development process. Although, before launching, the seat goes through three big phases; strategy, concept and industrialization, where the seat comfort attribute is developed through all phases.

In the strategy phase the seat comfort team is given a specification for the new car’s different attributes. The team’s task is then to redefine all relevant characteristics regarding the seat as comfort requirements. This is partially done from benchmarking.

The next step in the strategy phase is to define the seat further and into more specific requirements. In this stage a close collaboration is held together with the design team and the seat system team. The seat comfort team works with comfort curves, to design a comfortable shape for the seat, the foam thickness, hardness and weight distribution. It is important to have the right distance between the buttock and the hard components under the foam in the seat cushion, this distance is called meat to metal (M2M). In this phase the seat is looped several times between the comfort team, seat system team and design team to give the seat the right character. The output from the phase is the first seat suggestion.

For the concept phase virtual clinics and comfort clinics are executed in iterations to develop the seat. In the virtual clinics a virtual model is studied which shows how a manikin affects the seat. In the model the team is analyzing the weight distribution, M2M and where the manikin is placed in the seat according to a reference point. The weight distribution is mainly evaluated from experience. From the virtual clinics the comfort team provide the design team with inputs regarding what they can and can’t accomplish with the design.
Comfort clinics are executed later in the *concept phase* and are used to evaluate the physical seat, either with a smaller expert group or with a larger customer group. In comfort clinics the developed seats are built into prototype cars and often compared to competitive car brands. These clinics are used to both adjust and validate the seat.

In the *industrialization phase* one last verifying comfort clinic with customers is performed to evaluate the final seat. The verifying comfort clinic has the purpose to validate that the set requirements are met before the seat is sent to production.

### 4.2 VOLVO POPULATION

To meet the right anthropometric customer population VCC has identified their own Volvo population that includes different nationalities. From the Volvo population a specific span of dimensions is used for the requirements, where the whole span of the defined population shall have a perfect seated position. It is thereby important to include customers in the comfort studies that correspond to the normal curve of the set dimension span. Furthermore test persons with the maximum and minimum dimensions are often included in the development process to try out the seat dimensions. Also the foam thickness and hardness in the seat is calculated from the Volvo population.

### 4.3 COMFORT CLINICS AT VOLVO CAR CORPORATION

VCC's comfort clinics are user studies with customers and are performed to evaluate both initial comfort and cruising comfort. Initial comfort refers to the perceived comfort the first minutes in the seat while cruising comfort refers to the perceived comfort after 20-30 minutes driving.

The clinic is performed on a test track and the users fill out forms during the tests. To test the two different comfort categories the seat is first evaluated in a static test where the car stands still and afterwards the seat is evaluated in a dynamic test when the car is moving. For both comfort categories the test person rates different parts of the seat according to several questions as well as they summarize the comfort categories with a total score. For the rating a ten graded scale is used and it is possible to add comments to the questions.

For all the comfort clinics competitor seats or older VCC's seat are used as references in order to be able to compare the results to something.

### 4.4 DESIGN OF A VOLVO CAR SEAT FROM A COMFORT PERSPECTIVE

For VCC it is more important that most people sit well than that a few persons sit perfect. This point of view affect the whole seat, from hardness of foam to shape of the seat. The seat is thereby carefully designed to get the right balance between shape, foam hardness and foam thickness to fit as many people as possible.

To put the passenger in a comfortable position a VCC seat has bolsters, a concave shape behind the passenger's shoulders and is straighter behind the passenger's lumbar area.
The bolsters improve the perception of good comfort since it is comfortable to feel embraced. The backrest bolsters and the concave shape behind the shoulders improve the cruising comfort since it gives support when the car is turning. During turns it is mainly the upper part of the body that needs support since, when seated, most weight are placed around the hips and are thereby not as affected by turns. In these areas there are more important with high friction to prevent the risk of sliding around in the seat.

In the lumbar area of the seat the foam is soft, this to provide good support for all persons. Heavier persons can compress the foam and still get support while lighter persons get support from the soft foam. The lumbar support can also be adjustable to give even better support. The seat is shaped after an adult person’s back and a child’s back probably has the wrong dimensions to fit the seat’s curvature when placed on a booster cushion or IBC.

The headrest of the VCC seat is designed to be positioned right behind the head of the passenger. If the headrest put pressure on the head obliquely from above the passenger can get an unpleasant feeling of not be able to straighten their neck.
5 MASTER THESIS PROCESS AND PHASES

The master thesis development process and the different phases are presented in this chapter.

The master thesis process includes three different phases Discovery, Development and Testing & Evaluation, visualized by squares in Figure 16. In each phase new information and results become available as an output and work as an input to the next phase, these are visualized by circles in Figure 16. The working process is iterative within each phase, where decisions have been made running during the process when more information is revealed. Every phase ends with an analysis of the phase. A human-centered design (Bowler, et al., 2011) approach is also present during the whole process to assure a prototype and methodology adapted to the intended users.

Volvo Car Corporation (VCC) seating comfort development process has been used as a guideline for the whole master thesis process to make it easier for VCC to implement the final result in their process. Thereby the existing knowledge at VCC about comfort and comfort studies can more easily be used during the master thesis process.

![Figure 16 – The master thesis process](image)

The execution during the first phase, the Discovery phase, of the master thesis process is inspired by the iterative front-end process of a concept development process by Ulrich & Eppinger (2012). The iterative front-end process is used with the purpose to identify customer needs in a systematical way to assure that they correspond to the actual customer problems.

The execution of the second phase, the Development phase, is mainly performed due to the proposed anthropometric design method by Osvalder, et al. (2010). The anthropometric design method is divided into steps from defined design criteria to a tested prototype, and is used to assure that a concept is well designed due to the anthropometric dimensions of the user group. The method is used during this phase to assure that the designed
prototype has the right dimensions and fulfill a specification of requirements and five formulated comfort hypotheses.

The execution of the third phase, The Testing and Evaluation phase, is designed with inspiration from VVC's comfort clinics for adults but with methods adopted to child methods theory (See Chapter 3.2 and 3.3). Inspiration is also taken from previously performed real life safety studies with children (Stockman 2016, Osvalder, et al. 2013) and the experience gathered from the previously phases in the master thesis process.

**Discovery phase**

The purpose of the Discovery phase is to gain knowledge in the area of comfort, child traffic safety and child methodology. Furthermore it is to identify the users, in accordance with Bowler, et al., (2011), and to define customer needs (Ulrich & Eppinger, 2012). The discovery phase is visualized in Figure 17.

![Discovery phase diagram](image)

*Figure 17-Discovery phase, the rectangles represent activities and the circle the output.*

The purpose is accomplished through information gathering by different activities. Literature studies in the different fields are performed and in accordance with Ulrich & Eppinger (2012) a benchmark is executed internal and external to gain an accurate understanding for existing products and products with similarities in functionality. Interviews with experts are performed to gain knowledge about their experiences and opinions (Osvalder, et al., 2010).

A focus group with secondary users is also performed. In this thesis secondary users refers to parents since they are not using belt-positioning boosters for its main reason (Janhager, 2005). This in order to collect information covering the secondary user's perceptions, problems and targets in general (Osvalder, et al, 2010). Parents are the ones that commonly are present when children are using belt positioning boosters and therefore they are included. The focus group consists of 9 participants and is focused on belt-positioning boosters and their comfort.

The data collected from the described activities is then analyzed and organized into subgroups by the use of an Affinity diagram (Bergman & Klefsjö, 1991) to get a better overview of which factors that are important for customers. This was then interpreted into customer needs in accordance with Ulrich & Eppinger (2012).

As an output from the Discovery phase was identified customer needs that was used as a starting point for the Development phase.
Development phase

The purpose of the Development phase was to develop a prototype where the customer needs were implemented and to gain experience in the field of child methodology. The development phase is visualized in Figure 18.

![Image](image1.png)

*Figure 18-Development phase, rectangles represent the different activities and the circle the output.*

As an input to the Discovery phase is the customer needs that were formulated in the first phase. Since the customer needs are based on information formulated by adults a workshop with primary users is initially performed to assure that no aspects are missed out. The primary users refers to the children in this master thesis since they use the product for its main purpose (Janhager, 2005). The workshop is also performed to gain experience about working with children in a development process. The execution of the workshop is designed according to the proposed toolkit by Hill, et al., (2009).

The purpose is afterward accomplished by initially reformulate the customer needs into a specification of requirements according to Ulrich & Eppinger (2012) and five comfort hypotheses. To assure that the prototype is designed with the right anthropometric dimensions for the target group the anthropometric design method by Osvalder, et al. (2010) is used during the next two steps, anthropometric design and prototyping.

Two outputs are obtained from the Development phase, a belt-positioning prototype and methodology experience. The outputs are both used in the Testing and Evaluation phase; the methodology experience as a starting point for the design of user studies and the prototype as an evaluation object to validate the comfort hypotheses.

Testing and Evaluation phase

The purpose of the Testing and Evaluation phase is to validate the comfort hypotheses and evaluate child comfort methods. The purpose is accomplished by designing and executing two user studies, one static and one dynamic on road study, where the children evaluate the designed prototype and reference belt-positioning boosters. In the static study 9 children in age 7-11 participate and initial comfort is evaluated. In the on road study 7 children in age 7-10 participate and both initial and cruising comfort are evaluated as well as the positions are observed.

The methods used to collect subjective data during the user studies are based on interview questions and a questionnaire according to the method theory in chapter 3.2 and 3.3 and the study by Osvalder, et al. (2013). In order to collect objective data during the on road study video observations are used according to the studies by Stockman (2016). The testing and evaluation phase is visualized in Figure 19.
Figure 19 - Testing and Evaluation phase, the rectangles represent activities and the circle the output.

The output from the Testing and Evaluation phase is an evaluated comfort methodology and evaluated prototype features. Finally, according the output from the last phase, the thesis process ended in the result of a proposed concept idea and comfort methodology guidelines.
6 DISCOVERY

The Discovery phase and the different activities performed in the phase are presented in this chapter.

The Discovery phase started with an information gathering part to collect raw data, see Figure 20. The information gathering included a literature study, interviews with experts, benchmarking and a focus group with secondary users. The focus group was planned from assumptions based on information from the other information gathering activities.

The raw data from the information gathering was analyzed and sorted into customer statements in the identification of customer needs part with the use of an affinity diagram. As an outcome from the phase was identified customer needs. The process can be seen in Figure 20.

**Figure 20 – The Discovery phase**

6.1 INTERVIEWS WITH EXPERTS IN THE FIELD CHILD SAFETY IN CARS

Four interviews were performed with experts with knowledge in the study area or close related areas. The interviews were carried through in order to gain knowledge about child safety and child methodology.
6.1.1 Setup for interviews

The performed interviews were unstructured or semi-structured and were carried through with experts in the fields: Real life safety for children traveling in the rear seat of a car, child comfort and child methodology. The aim with the interviews was to first get a holistic view of the study area and other close related areas. Then, through further interviews along with literature studies, be able to set up delimitations and make deeper studies in the most relevant areas. The goal of the interviews was to identify and gain knowledge in relevant fields for the study.

The Interviews performed:

- Unstructured interview with Lotta Jakobsson in the field: Safety aspects for children in cars.

Lotta Jakobsson is titled Senior Technical Specialist in Injury Prevention at VCC Safety Centre. She has a PhD in Traffic Safety and appointed Adjunct Professor in Vehicle Safety at Chalmers University of Technology. Lotta Jakobsson is also a member and a research leader of the managements team at SAFER - Vehicle and Traffic Safety Centre at Chalmers. She is also chairing the ISO working group on Child Restraint Systems. The interview was performed at VCC in Torslanda, Gothenburg 2017-02-01.

- Semi-structured interview with Isabelle Stockman in the field: Execution and Result from user on road studies with children

Isabelle Stockman is titled as Crash analysis engineer and works in the group Rear impact, Rear seat, Child at VCC Safety Centre. She has a PhD in Machine and Vehicle Systems from the Division of Vehicle Safety at Chalmers University of Technology. Isabelle Stockman is also a key member of the child safety SAFER project and her PhD research focused on children aged 4-12, seated in the rear seat during naturalistic driving and pre-crash events restrained by belt-positioning boosters and three point seatbelts. The interview was performed at VCC in Torslanda, Gothenburg 2017-02-14.

- Semi-structures interview with Katarina Bohman in the field: Comfort and child methodology

Katarina Bohman is titled Senior Research Specialist at Autoliv Research. She has a PhD from Karolinska Institutet handling car safety for children aged 4-12 and has more than 21 years of experience of crash safety research and development. She is also a key member of the Child Safety SAFER project. SAFER is a Vehicle and Traffic Safety Centre at Chalmers University. Katarina has previously done comfort studies both with children and adults. The interview was performed over phone 2017-02-15

- Unstructured interview with Anna Anund in the field: Child methodology

Anna Anund is titled Research Director at the department for Human Factors in the Transport System at the Swedish National Road and Transport Research Institute (VTI). Anna also has an Associate Professor degree in Traffic Medicine and is at VTI, among other things, responsible for traffic safety aspects in connection with school transportation and safety for children. Anna has experience both from focus groups, observations and in-depth interviews with children. The interview was performed over phone 2017-03-08.

The interview questions for the semi-structured interviews can be seen in Appendix A.
6.1.2 Safety aspects for children in cars

The restraint systems are crash tested using crash test dummies sitting upright, leaning towards the seat back and laterally centered. However few occupants stay in this posture during a whole trip. Comfort is thereby an important enabler to safety. If seated comfortable in a safe sitting posture, you will stay in the position in a longer period of time and thereby be safer out on the roads. Although, it is difficult to set the exact borders for the ultimate posture for riding safe in a car, but the placement of the seat belts is the most important in case of a crash. In addition to comfort, discomfort is also a way to deal with problems regarding people’s posture. If a position isn’t comfortable people will avoid that position.

An example of a potentially less safe position is when people lean forward. This since they then have less distance to the front seat in case of a frontal impact, in addition to a larger distance to the seat back and head restraints in a rear end impact. Real world data provides evidence that a close distance to the head restraint is important for neck injury protection in case of a rear end impact.

Even though a child is tall enough according to laws and recommendations, they can still benefit from using belt-positioning boosters due to their body proportions and development. The size of the pelvis influences the lap belt geometry where larger children will have their iliac crests higher up compared to slimmer children. Thereby slimmer children will not adapt as good to the lap belt geometry without the use of a belt-positioning booster. In addition, the thigh length will influence the position of the pelvic bone, since children with shorter thigh length than the seat cushion depth, will likely slide forward to comfortably bend their knees causing a slouched posture.

6.1.3 Execution and result from on road studies with children

In a project, Rear seat safety for small occupants, where Isabelle participated, three on-road driving studies were carried out as well as two evasive maneuvers studies. The studies were conducted to increase the understanding of children’s natural behavior during a regular car ride and during emergency maneuvers in different restraint configurations in passenger vehicles. The study included children in different age ranges. The emergency maneuvers were performed by an expert driver on a closed test track, and in the on-road driving studies the child’s parent was driving the car.

For one of the three on-road driving studies performed on regular roads the children rode on an integrated booster cushion (IBC) and a high-back booster. The children were seated on one belt-positioning booster for an hour and then they had a break before trying out the other. During the ride they also filled out a form every 20 minutes in order to gather subjective data. The form focused on discomfort instead of comfort. Objective data was gathered by the use of video recording and the results/conclusions from analysis of subjective data was verified with the objective data. As an example: children answering that they were uncomfortable on a belt-positioning booster also moved a lot when seated on that belt-positioning booster.

The results show that the back support on a high-back booster places the child further on relative to the car and consequently closer to structures in front of them. Side bolsters though gives support, especially when children are resting. They also restrict the possibilities to move, compared with an IBC, which is sometimes necessary for children that needs more support to sit still. However Isabelle suggests that high back boosters can be designed with a thinner back to prevent children to be placed close to the structure in
front of them, as well as with side supports that allows the child to see out of the windows without leaning far forward.

According to Isabelle it is interesting to study both younger children in the age range 5-7 that are big enough to sit forward in belt positioning boosters, as well as older children since they sometimes stop using belt-positioning boosters too early. Some sort of balance between an IBC and a system with a lot of side supports is interesting when developing a belt-positioning booster. Isabelle Stockman also thinks that it is a good thing having the child’s parent present during a study if the child want to, in order to make the child feel relaxed and safe. Especially for younger children. Furthermore, it is important to emphasize that the child volunteer is the key person.

6.1.4 Katarina Bohman: Comfort and child methodology

When working with children and comfort the goal is to make them wanting to sit in a correct position without thinking, choosing the position just because it is the most comfortable one. Although, it can be hard to know why a seat is comfortable. Comfort is abstract and is often perceived as a fuzzy conception which can make the respondents weight in other aspects in the answer, such as feeling safe. This behavior counts for both adults and children. It can therefore be better to measure discomfort since it is an easier conception to handle for the respondent. A good way to measure discomfort is to use a 10 grade scale from maximum discomfort to no discomfort followed up with a why-question. By doing so the answer can be analyzed both quantitatively and qualitatively.

Observing how frequent children change position in cars can also be a good way to measure discomfort since children often move more frequently when sitting in an uncomfortable position. Although it is important to be aware of that some children move constantly independently of how comfortable the seat is but just because they have a lot of energy. Similarly, devices and other types of toys also affect the position. A tablet device for example can make children crouch into an unsafe position but also make them move less. It is thereby of big importance to consider how children sit and why.

When talking to children it is very different how much they speak, some speak a lot and other hardly not at all. If planning a focus group it can be a good idea to choose more talkative children. To involve too young children in the studies can make it difficult to get the wanted information out of questions. The participants should be no younger than 5-6 years, after all it the sizes of the children that most of the time is important for a comfort study and it can then be better to involve a small 6 year old than a big 5 year old. Furthermore, it is important to always remember that children are children and thereby always make them feel as safe and comfortable as possible. That can be made by being in an environment where they feel safe or let the parents be present.

6.1.5 Anna Anund: Child methodology

Generally the car industry should include children more in the development process of child restraint systems. If children would be more involved in development activities, such as co-design, it would be easier to gather user wishes and understand what children actually wants. In these kind of activities children in different ages should be asked which solutions for specific problems they want and why. Usually a lot of irrelevant inputs is collected in these kind of activities, but also relevant suggestions that should be taken seriously and reformulated into product functions.
Children generally work well together in groups since they are used to collaborate from school. It is therefore a good idea to include children in different ages in focus groups to make them discuss each other's ideas and thereby help each other with new ways of thinking. When the children are in different ages it is also possible for the older to help the younger children to enlarge their ideas. Although, children can have difficulties to think in sequences. Thereby it is important to work with concrete assignments where children can use their creativity to show their concept suggestions. To use tools, such as pen and paper or LEGO, to sketch or build can really help the children to express their ideas. It can also be a good idea to bring something concrete, such as a belt-positioning booster, and let the children touch, sit and explore the existing product. In all kinds of activities with children it is important to be well prepared and some questions should always be prepared in advance.

6.2 BENCHMARK CHILD RESTRAINT SYSTEMS

Benchmark was done to gain an accurate understanding for existing products on the market and products with similarities in functionality. Benchmark was conducted both internally at Volvo Car Corporation (VCC) and their suppliers as well as externally. The external benchmarking was mostly done through the use of internet and with inputs from experts with knowledge of the market of belt-positioning boosters. The department of Seatbelts and Child restraint at VCC helped during the internal benchmarking and provided the researchers with physical belt positioning boosters.

6.2.1 Internal Benchmark

During the internal research several different types of belt-positioning boosters and their different functions where identified. One of the belt-positioning boosters that differed from others where VCC’s comfort upholstery, see Figure 21. The upholstery is pulled over a raised integrated booster cushion (IBC), it has integrated side supports on the backrests as well as on the seat cushion. It also has an integrated head support that is installed at the standard head support. It easy to remove and is washable.

![Figure 21-The comfort upholstery from Volvo Cars](image)

Others identified belt-positioning boosters were a high-back booster from VCC with removable backrest so it could be transformed into a booster cushion. The backrest is
tillable in order to improve the comfort when resting or sleeping. A supplier to VCC, Britax, also produces a belt positioning booster with big side bolsters at the backrest and the headrest. The headrest is height adjustable.

6.2.2 External benchmark

External search where also done and regarding belt-positioning boosters company brands like Chicco, Volkswagen, Axkid, BeSafe iZi, Klippan, Britax etc. where identified. Product functions that where identified were cup holders, several possible sit angels, height adjustable backrest, lateral adjustable side supports etc. It was also identified that Volkswagen have an integrated child seat with integrated head side supports and when not needed it can be retract back into the seat.

Products with similarities in functionalities that where identified externally was Myfold, which instead of lifting the child up, like a belt-positioning booster, instead it holds the seatbelt down. The product is also foldable. Similar to Myfold, Raid safe is another company, producing an alternative to belt positioning boosters. They produces travel vests that leads the seatbelt.

Additional products to belt-positioning boosters that where identified where attachable head supports and attachable foot supports. Also head support developed for children sleeping in cars were identified. Often they look like a padded piece of fabric attached to a high back booster that holds the child’s forehead in order to prevent the child’s head from falling forward.

6.3 FOCUS GROUP WITH SECONDARY USERS

A focus group was performed with parents, the secondary users, and all had children in the age span for the target group. The focus group had its starting point in assumptions formulated by the researches from the raw data collected from interviews, literature study and benchmarking. It was carried through in order to gain knowledge about the parent’s perspective and attitudes to belt-positioning boosters.

6.3.1 Execution Focus group with secondary users

A focus group including 9 participants, who all were parents to children in the age range 5-11 years old were put together. The focus of the discussion was about the parent’s perception about comfort and use of child safety restraints. The predetermined main themes were:

- Parent’s attitudes regarding child safety restraints
- Parent’s perceptions of their children’s attitudes regarding child safety restraints
- Children’s activities and movements during rides.

The purpose of the focus group was to get an understanding for parent’s perspective about comfort and use of child safety restraints. From literature studies, bench marketing and interviews the researchers formulated assumptions according to the focus group purpose. The goal of the focus group was to confirm or turn down the assumptions and to identify other interesting aspects.
A moderator controlled the discussion and made sure that all participants had the opportunity to express themselves. An assistant took notes and the discussion was recorded to make sure that nothing important was missed out.

6.3.2 Result Focus group with secondary users

The assumptions regarded parents' opinions, knowledge and ideas concerning child restraint systems. Below the assumptions are listed and sorted into if they were validated during the focus group or not.

Assumptions that were met during the discussion:

- The Integrated Booster Cushion (IBC) is easy to use
- Safety aspects are important in purchase of CRS
- It is of great importance that children are comfortable
- Older children think that boosters and booster cushions are uncool
- Children are not included in the purchase of belt-positioning boosters
- Children entertain themselves with electronic devices in the rear seat
- Children do not sit still
- Children traveling with belt-positioning boosters use parts of the car’s interior as foot support.
- Children outgrows the high-back booster faster than the booster cushion

Assumptions that were not met during the discussion:

- Big bolsters is perceived more comfortable then small bolsters
- Parents understand the connection between safety and comfort

Other aspects that were identified during the discussion are presented below.

The belt buckle
Parents prefer that the children can buckle themselves up. Although it is sometimes hard for children to buckle themselves up because of the design of the belt-positioning booster. It seems to be easier on the IBC as well as if the belt buckles is attached to the seat cushion. If there are armrests on the belt-positioning booster it shall be designed so it is easy to buckle up the children.

The seatbelt
Children sometimes forget to put the seatbelt under the guiding loops. Parents sometimes check and tighten children’s seatbelts. Thick clothes like winter jackets make it harder to see if the belt is placed and tighten correctly.

Comfort of belt-positioning boosters
The comfort of belt-positioning boosters is commonly perceived as bad according to the parents, especially the seat cushion. Some parents have added some padding at the belt-positioning booster’s seat cushion in order to make it softer. The lumbar supports on belt positioning boosters are not comfortable. When children are getting older the high-back...
booster is too small for their shoulders. It is good with height adjustable backrests. The parents would like some accessory for booster cushions and IBCs that facilitated sleeping, especially during longer rides. The IBC is perceived as more comfortable for children. When travelling on the IBC children often put their feet up on the space in front of the IBC and the parents thinks that foot support is wanted.

Safety
Children are seldom seated in a safe position and for parents it is important with test results and the brand due to safety aspects. Side support is according to one parent good protection in the event of a crash. Children are often leaning forward when interacting with devices and they often put tablets in their lap. When children are asleep their heads falls forward. Commonly children put their feet on the seat structure in front of them.

Children’s activities during car rides
Usual activities for children are tablet devices, mobile phones, watching TV, looking out of the windows, listen to books, playing with toys, playing car games, eating and drinking. Sometimes children suffer from motion sickness when they are watching TV or interacting with tablets. Children also interact with each other and sometimes it happens that they fight.

Important aspects for the secondary user (parents)
Parents want a belt-positioning booster to be easy to mount and dismount, iso-fix is also important. They also want it to be flexible when it comes to transportation and storage. Three high back boosters with bigger side-bolsters or two together with one adult don’t fit in the backseat, which is a problem for some parents. Carpool and leasing is aspects that should be taking into account when designing a belt-positioning booster. When the IBC is not up folded it is experienced as less comfortable than a seat without IBC for adults and older children. Parents are more engaged when purchasing a belt-positioning boosters to the first-born child. Parents rather buy a neutral color since it makes it easier to resell.

Other aspects
It seems like children perceive the IBC as “cooler” than other belt-positioning boosters.

6.4 IDENTIFICATION OF CUSTOMER NEEDS

In the identification of customer needs part customer needs were identified. The raw data collected from previously parts in the phase was analyzed and organized into subgroups using an affinity diagram (Bergman & Klefsjö, 1991). The result from the affinity diagram lead to customer statements that were interpreted into customer needs by guidelines proposed by Ulrich & Eppinger (2012). Even though the primary user (child) isn’t the purchaser of a belt-positioning booster the word customers, as in customer needs and customer statements is used to refer to the primary users.
6.4.1 Formulation of customer needs

By the use of affinity diagrams all the collected raw data from interviews, focus group, benchmarking and literature study was interpreted and analyzed to concrete information that more easily could be used. The raw data was then transformed into customer needs in order to end up with comfort hypotheses and requirements in the next thesis phase.

Initially the information from the information gathering part was interpreted and rephrased during four brainstorm sessions. The purpose was to identify concrete problems that affect the children’s comfort and safety during the car ride. Each brainstorm session had different perspectives with a starting point in one of four questions:

- What affect the child’s comfort in the belt-positioning booster during a car ride?
- What affect the child’s position in the belt-positioning booster during a car ride?
- What affect the child’s safety during a car ride?
- What according to comfort and safety for the belt-positioning booster can parents affect?

The questions were formulated to make sure that the result was grounded in different point of views to minimize the risk of a biased or a one-lined result.

During each session different parameters that could affect what was asked for in the questions were brainstormed, written down on post-its and then put on a wall in groups sorted by the question. All parameters in each group were then sorted as into sub groups, according to the affinity diagram method. For each sub group one or two new parameters were formulated that corresponded to and summarized all the parameters in the sub-group.

*Figure 22 – The final affinity diagram with parameters sorted into sub groups. The notes high-lighted with red are the summarizing statements for the different sub groups.*
All the parameters from the four questions, including the new ones, were then color coded according to the initial question they originally came from and then mixed together. The affinity diagram procedure was then repeated for all the parameters (see Figure 22). The final parameters for each subgroup were set to customer statements and interpreted into customer needs that affect children's safety and/or comfort when riding on a belt-positioning booster. To interpret the customer needs, guidelines proposed by Ulrich & Eppinger (2012) was used.

1.1.1 Identified customer needs

In Table 1 the result from interpreting the customer statements into customer needs can be seen. The needs are not weighted.

<table>
<thead>
<tr>
<th>No.</th>
<th>Customer statements</th>
<th>Customer needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CRS do not allow comfortable positions for children</td>
<td>The belt-positioning booster enables children to sit comfortably</td>
</tr>
<tr>
<td>2</td>
<td>Backrest is too hard</td>
<td>The backrest is comfortable</td>
</tr>
<tr>
<td>3</td>
<td>Cushion is too hard</td>
<td>The cushion is comfortable</td>
</tr>
<tr>
<td>4</td>
<td>The cushion's length is not adjusted for child's leg length</td>
<td>The cushion's length is adjusted for child's leg length</td>
</tr>
<tr>
<td>5</td>
<td>Children outgrow the belt-positioning booster too early</td>
<td>There is belt-positioning boosters big enough for all children</td>
</tr>
<tr>
<td>6</td>
<td>Older children think belt-positioning booster is uncool</td>
<td>The perception of the belt-positioning booster is positive or neutral for all ages</td>
</tr>
<tr>
<td>7</td>
<td>Children want to see surrounding</td>
<td>The belt-positioning booster allows children to look around or/and out</td>
</tr>
<tr>
<td>8</td>
<td>Children want to perform activities in the car</td>
<td>The belt-positioning booster enable children to perform activities comfortably</td>
</tr>
<tr>
<td>9</td>
<td>Children grow fast</td>
<td>The belt-positioning booster allows children in different sizes</td>
</tr>
<tr>
<td>10</td>
<td>Children have relativity bigger and heavier heads than adults</td>
<td>The belt-positioning booster gives support for the head</td>
</tr>
<tr>
<td>11</td>
<td>Bad angle on high-back booster back</td>
<td>The belt-positioning booster has an ergonomic angle on the backrest</td>
</tr>
<tr>
<td>12</td>
<td>The children gets influence by subjective opinions</td>
<td>The belt-positioning booster is costumed to subjective perception of comfort</td>
</tr>
<tr>
<td>13</td>
<td>Big bolsters lead to a locked-in feeling</td>
<td>The belt-positioning booster gives the perception of free movement</td>
</tr>
<tr>
<td>14</td>
<td>Difficult for children to buckle themselves up</td>
<td>It is easy for children to handle the belt and buckle by themselves</td>
</tr>
<tr>
<td>15</td>
<td>Misplacement of seat belt when buckle up</td>
<td>It should not be possible to misplace the seat belt</td>
</tr>
</tbody>
</table>
Children tend to have a lot of energy and move often. The belt-positioning booster allows the child to change positions safely.

Child and high-back booster move while turning and/or braking. The belt-positioning booster has the same movement as the car in dynamic environment.

Parents prioritize other aspects over child comfort. Comfort is prioritized.

Different priorities for long and short journeys. The belt-positioning booster is adapted for both long and short journeys.

## 6.5 ANALYSIS DISCOVERY

During the Discovery phase the focus group worked as a validation and interpretation step before the process of creating customer need started. Most of the assumptions that were formulated for the focus group where met which was valuable to assure that the customer needs were formulated from validated data. Two of the assumptions were not met and this may have been since they are not correct or because the parents just have not thought about it.

What matters for secondary users are mounting possibilities, that the belt-positioning booster is easy to resell, not take too much space, do not make it more uncomfortable for grownups or older children as well as that children shall be able to buckle themselves. These are all aspects that are affecting parents in a direct way. Therefore these aspects are important, but it would be of big interest to perform activities with children in order to see their aspects regarding belt-positioning boosters, what they value and if it differs from the adult needs.

Other finding are that comfort for children is an important aspect for parents when purchasing belt-position booster, although children are rarely included in the purchase. Some parents also discussed to which amount children actually perceived something to be comfortable or not. Some parents indicated that their children seemed to have another mindset since they do not commonly complain about discomfort. This may be because children are not used to products designed for their anthropometric measurements and perhaps the adults' authoritarian position also plays a part in that children do not complain.

In conclusion; comfort for children is an important aspect for the secondary users when purchasing belt-position booster. Although, it would be interesting to be include children in the development phase to see if their opinions differs from the adults’. This since important aspect for adults as secondary users do not need to be important aspects for the primary users.
7 DEVELOPMENT

The Development phase and the different activities performed in the phase are presented in this chapter.

The Development phase, see Figure 23, was based on the output from the Discovery phase, the customer needs. To assure that no important user needs nor user wishes from the primary users had been missed in the process, a Workshop with primary users was carried though as the first part in the phase. In the Workshop with primary user different methods and activities were also tested. The setup was planned from the proposed toolkit by Hill, et al., (2009) and the interview with Anna Anund to assure that the activities and the setup of the workshop were suited for children. One of the activities in the workshop was also inspired by Co-design, where researchers and users create design specification for a product trough elaboration and ideation (Thallmaier, 2015). The co-design inspiration was used to make sure the children would be able to contribute with their ideas of how they want a belt-positioning booster to be like, in a good way.

As a second step in the Development phase the customer needs were interpreted and reformulated into Comfort Hypotheses and a specification of requirements in the Requirements & Hypotheses part. These were formulated in order to guide the development process and assure that no important customer needs were missed.

In the third part, Anthropometric design, the user test population dimensions were identified by the use of the 3 first steps in Anthropometric design method (Osvalder, et al., 2010) to assure a defined user test population with right dimensions. In the last part, Prototyping, a prototype was created from the result from the three first parts and performed by the use of step 4-10 in Anthropometric design method (Osvalder, et al., 2010). The prototype was designed to be able to include all parameters that were identified in the hypotheses.

The output from the Development phase was a comfort prototype and methodology experience. The process can be seen in Figure 23.

Figure 23 – The Development phase
7.1 WORKSHOP WITH PRIMARY USERS

Since the customer needs were based on secondary users’ opinions a workshop with primary user were set up. The purpose for the Workshop was mainly to assure that no aspects of comfort had been missed in the previously phase of the process. Furthermore, the workshop was performed to try out different methods with children and to collect user wishes.

To accomplish the purpose two groups of children in the target group was invited to participate in two workshop sessions. One group for each session. The setup was the same for the two sessions, except for a few revisions to the second session based on lessons learned from the first session. The sessions included two actives; expert panel evaluation and one co-design scenario activity. During the expert panel activity children participated as informants and tried out three different belt-positioning boosters from VCC and a VCC seat. During co-design activity the children participated as design partners in a scenario activity. The activities were performed in two different meeting rooms and two facilitators held the sessions. The setup was planned from the proposed toolkit by Hill, et al., (2009) and the interview with Anna Anund.

The sessions took approximately 75 minutes. It was calculated that the introduction and eating snacks (Swedish fika) would take 15 minutes and the two activities 30 minutes each including some breaks for changing rooms between the activities. The whole setup with time considerations for both activities can be seen in Appendix F.

In the first workshop session did nine children in the age range 5-11 years participate. The children were approximately between 110 cm to 148 cm tall and their weight was approximately between 16 kg to 45 kg. In the second workshop session eight children in the age range 5-10 years participated. The children were approximately between 110 cm to 133 cm tall and their weight was approximately between 17 kg to 29 kg.

To participate in the workshop each child and the child’s both parents had to sign an attendance agreement. The attendance agreement specified what was expected from the child during the workshop, why the workshop was executed, that the attendance was voluntary and how personal data would be handled after the workshop. It can be seen in Appendix G.

7.1.1 Execution Workshop with primary users

When the children arrived they were offered Swedish fika and all children were equipped with nameplates, which they colored themselves. Before each name the word Expert was written. An introduction was held to inform the participating children about the purpose and the structure of the study, as well as rules and that the session was voluntary. The facilitators also asked the children for permission regarding audio recording and photo shots. Afterwards the first activity started – the expert panel evaluation.
Execution Expert panel – Evaluation of existing belt-positioning boosters

For the expert panel activity four Volvo car fronts seats were placed in a certain order, different for the two workshop sessions. For the first session, counted from left to right, a booster cushion placed in the first car seat, a high-back booster with big bolsters was placed in the second car seat, a high back booster with small bolsters was placed in the third car seat and the fourth car seat was left empty. The order used in the second session can be seen in Figure 24.

![Figure 24- From the left: High back booster with adjustable backrest, High back booster with fixed backrest, booster cushion and an empty seat](image)

The children were seated in turns so all had the possibility to try out all the seats. When seated they were asked two questions; if they were sitting enjoyable and if they would like to have the booster in their "own" car. The children were equipped with two plates, one green, for yes, and one red, for no. The children raised the plate that they thought best respondent to their experience, see Figure 25. After answering the questions the children rotated to the seat next to them.

When all the children had tried the different seats on the session they were asked to stand beside the belt positioning booster they perceived as most good looking as well as the one that reminded themselves of the one they had at home. During the second session the procedure was changed and some questions were added. Before the children tried to sit in the different seats they were asked to stand beside the seat that reminded themselves of the one they used at home, the one they thought was the most good looking as well as the one they though looked worst. After they tried the different seats they were asked to point at the one they would like to use at home, the one they perceived as most enjoyable as well as the one they perceived as most unenjoyably.

![Figure 25-Children evaluates belt-positioning boosters](image)
Execution Co-design – Scenario: Design the best belt-positioning booster

For the scenario exercise the facilitators together with the participating children created two fictive persons. Predetermined was that the fictive persons was seven and ten years old. The facilitators then described a scenario where the fictive persons would buy their own belt-positioning boosters in a store.

As a warm-up the participating children together decided what was outside of the store and one of the facilitators illustrated their thoughts by drawing on a whiteboard. Then each of the children had some time to draw the kinds of belt positioning booster they thought that the fictive persons wanted as well as what they thought the fictive persons would like to be able to do when riding in a car, see Figure 26. Afterward, all the participating children that wanted to told the rest of the group about their drawings and their thoughts while one of the facilitators used the whiteboard to draw the children's ideas.

![Figure 26 – Scenario activity](image-url)

7.1.2 Result Workshop with primary users

The result presented are merged from the two workshop sessions and presented as two different activities.

Result Expert panel – Evaluation of existing belt-positioning boosters

The booster cushion and the VCC seat were perceived as most comfortable. The high-back booster with small bolsters was perceived most uncomfortable and more than half of the participants enjoyed the high-back booster with big bolsters.

The children enjoyed the red color and the patterns at the belt-positioning boosters. They thought that the vehicle seat without a belt-positioning booster had a boring color.

The most commonly used belt positioning booster was belt positioning boosters similar to the booster cushion. The second most commonly used was similar belt positioning booster as the high-back booster with big bolsters.

No comfort aspects were identified that had not been noticed previously in the process.
**Result Co-design – Scenario: Design the best belt-positioning booster**

Important aspects for children when riding in the rear seat of a vehicle can be seen in Figure 27-28.

It is important to be able to eat and store food or snacks: Bags of candy and never-ending supply of chips occurred as well as the children wanted a tray and some place to store snacks like a refrigerator. Electronic devices like smartphones and tablets and access to electricity for charging the devices are important for children. They wanted to be able to store their devices.

Regarding their comfort aspects for a belt-positioning boosters they wanted to be able to adjust the backrest angle when sleeping. Furthermore, they wanted temperature regulations as well as massage systems. They also wanted a place where they could put their shoes.

Pattern and figures on the belt-positioning boosters was also important.

![Illustrations on participants’ ideas from the scenario activity](image)

**Figure 27-Illustrations on participants’ ideas from the scenario activity**

### 7.2 REQUIREMENTS AND HYPOTHESES

In the Requirement & Hypothesis part risks related to the customer needs were identified and weighted numerically out of their relative importance. The customer needs was then weighted dependent on the quantity of possible risks and how the risks affected the customer needs. From the weighted customer needs a specification of requirements was formulated together with comfort hypotheses.

#### 7.2.1 Creation of requirements and hypotheses

As a first step to create requirements and comfort hypotheses the table with customer statements and customer needs (Table 1) was enlarged with three more columns. The enlarged customer needs table was created to find out which risks the customer statements could lead to and which improvements areas that could be made for each customer need. Therefore, the enlarged customer needs table had three new columns:

- **Reason for reposition**: In the first new column the reason for why the customer statement can lead to repositioning was stated. This was done to get an understanding if the corresponding customer need could lead to a safety risk.
• **Risks:** In the second new column possible risks were stated that could occur because of the repositioning reason.

• **Improvement areas:** In the third new column specific improvement areas for the belt-positioning booster were stated. The initial plan was to use the improvement areas as design inspiration for the concept development.

In Table 2 an example can be seen of how three comfort or safety problems were handled in the enlarged customer need table. The enlarged customer need table as whole can be seen in Appendix D.

*Table 2- Three examples from the enlarged customer needs table. The table shows how identified comfort or safety problems were reformulated into reasons for reposition, risks and improvement areas.*

<table>
<thead>
<tr>
<th>Customer statement</th>
<th>Customer need</th>
<th>Reason for reposition</th>
<th>Risks</th>
<th>Improvement areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backrest is too hard</td>
<td>Backrest is comfortable</td>
<td>Perceived stiffness and discomfort</td>
<td>* Leaning forward or rotate</td>
<td>* Softer backrest</td>
</tr>
<tr>
<td>Children want to see surrounding</td>
<td>The belt-positioning booster allows children to look around or/and out</td>
<td>*Bolster limits the child's field of vision. *Children look out through front window</td>
<td>* Leaning forward</td>
<td>* Remove/redesign factors that limit field of vision</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Lateral movement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Tilt head forward</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Rotate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Arms outside CRS</td>
<td></td>
</tr>
<tr>
<td>Children want to perform activities in the car</td>
<td>The belt-positioning booster enable children to perform activities comfortably</td>
<td>Performing activities</td>
<td>* Leaning forward</td>
<td>* Allow better support</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Lateral movement</td>
<td>* Prevent children from performing extreme positions</td>
</tr>
</tbody>
</table>

To get an understanding of the importance of the different safety or comfort problems all the identified risks were rated on a scale 1-3 by the researchers. The aspects that were taken into consideration during scoring were safety risk, relevance for the master thesis purpose and possibility to affect the risk in the thesis. For a risk to get score 3 it had to be a big potential safety risk and a risk that could be prevented to at least some extent with improved comfort and during this thesis. All the risk with the highest score can be seen in Table 3, the whole table can be seen in Appendix B.

*Table 3 – List over the identified risks with the highest scores*
All risks for each row in the enlarged customer needs table, now scored on the scale 1-3, were added together to a final risk score. The rows were then sorted after the score to see which comfort or safety problem that was most crucial and thereby which improvement that was most important. The comfort or safety problems that had a score of 10 or higher where considered most important, the problems with a score between 8 and 9 quite important and the problems with lower score less important. The weighted enlarged customer needs table can be seen in Appendix E.

When looking through the sorted list of weighted customer needs together with the suggested improvements from the enlarged customer needs table it was clear that some customer needs were more specific than others. For example the statement “The belt-positioning booster enables children to sit comfortable” was way wider than the very specific statement “The belt-positioning booster gives support for the head”. This difference also affected the improvement areas where almost all solutions could fit in “The belt-positioning booster enables children to sit comfortable”. This situation made it hard to make any specific conclusions from the result that could form the basis of hypothesis, customer needs and requirements.

A new table, called the hypotheses table, was therefore created. The purpose was to get a better balance between the customer’s needs in order to be able to formulate well balanced hypotheses. The hypothesis table consisted of the three columns: Reformulated customer need, design parameter and hypotheses. In the reformulated customer need column some of the customer needs were kept as before and the ones that were more specific were combined and rewritten to more extended customer needs. In the hypotheses table none of the customer needs were weighted, instead the customer needs with lower scores from the enlarged customer needs table were combined with other customer needs or deleted if not considered relevant for the master thesis.

To get a better understanding of how the reformulated customer needs functionally would affect the design of the concept the category “design parameters” was used in the hypotheses table. With each reformulated customer need as a starting point the physical parts of a belt-positioning booster, which would affect the customer need, were listed.

By analyzing the reformulated customer needs and design parameter together with the knowledge from the information gathering, hypotheses were written for each statement in the table. These hypotheses were then listed, outside the table, after which design parameter they mainly would affect. The hypotheses that were considered to be possible to explore in the thesis were selected and were named comfort hypotheses. Two example rows from the hypothesis table can be seen in Table 4. The whole table can be seen in Appendix C.

Combined with the work of transforming the customer needs from the enlarged customer needs table into the hypotheses table a specification of requirements was created. When going through all the customer needs they were systematically rephrased into comfort requirements. Since not much rephrasing was needed to be done the internal weighting could be kept from the enlarged customer needs table. From a meeting with the Injury Prevention at VCC Safety Centre safety requirements were also listed and weighted. All of them got the highest weighting score regarding the importance of a safe solution.
Table 4 – Three example rows from the hypotheses table

<table>
<thead>
<tr>
<th>Reformulated customer needs</th>
<th>Design parameters</th>
<th>Hypotheses</th>
</tr>
</thead>
</table>
| Children search for a comfortable position | • Soft seat cushion  
• Soft backrest  
• Foot support  
• Support for thighs and/or calves  
• Head support  
• Bolster | • Thicker foam in seating and backrest will lighten the static load and thereby make children sit more comfortable  
• Padding around critical areas for calves and thighs will make children in wider age span sit in a more comfortable position  
• Foot support will lighten load on thighs and calves and thereby make children sit more comfortable  
• Head support will allow children to sleep and rest their head in a more comfortable position  
• Smaller, soft bolsters embrace the child and thereby improve the impression of good comfort |
| Children perform activities during the ride | • Bolsters  
• Elbow/arm support  
• Head support | • Bolsters will prevent children from extreme positions  
• Elbow/arm support will help children play with a device in a straighter neck position  
• Head support will allow children to sleep and rest in position |
| Children should be able to look around/out | • Bolsters  
• Headrest | • Small bolsters will give children support while looking through window without blocking the view  
• A headrest with smaller side supports will allow children to look out throw the front and side window without leaning forward |
7.2.2 Result Requirements and hypotheses

The specification of requirements and final comfort hypotheses can be seen below.

**Comfort hypotheses**
The selected hypotheses resulted in five final comfort hypotheses named CH1-5.

**CH1**: Thicker foam in seating and backrest will relieve the static load and thereby make children:

a) Sit more comfortable
b) Keep children in the same position for a longer period of time

**CH2**: Foot support will lighten load on thighs and calves and thereby:

a) Make children in wider age span sit more comfortable
b) Decrease movement

**CH3**: Headrest with the right size on side supports will allow children to:

a) Look out through the front and side window without leaning forward
b) Sleep and rest their head in a comfortable position
c) Sleep and rest in position

**CH4**: Soft bolsters with the right size will:

a) Improve the impression of good comfort since children feel embraced
b) Give support but still give the perception of free movement
c) Prevent children from extreme positions
d) Improve support for children during dynamic impacts as turning

**CH5**: A flexible solution can allow several children a good comfort while a fixed solution can allow perfect comfort for a few children

**Specification of requirements**
The specification of requirements can be seen in Table 5.
### Table 5 – Specification of requirements

<table>
<thead>
<tr>
<th>No</th>
<th>Part</th>
<th>Requirement</th>
<th>Imp.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Comfort requirements</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cushion</td>
<td>Enough space for hips for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Cushion</td>
<td>Soft cushion</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Backrest</td>
<td>Enough space for shoulders and arms for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Backrest</td>
<td>Acceptable height on bolsters for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Backrest</td>
<td>Acceptable shape for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Backrest</td>
<td>Soft backrest</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Backrest</td>
<td>Supporting backrest</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Headrest</td>
<td>Acceptable height for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Footrest</td>
<td>Acceptable height for all children in target group</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Whole</td>
<td>Easy for children to handle the seatbelt and buckle by themselves</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Cushion</td>
<td>Length fit the upper-leg length for all children in target group</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Backrest</td>
<td>Ergonomic angle</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Whole</td>
<td>Gives perception of free movement</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Whole</td>
<td>Support children during dynamic elements</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Headrest</td>
<td>Give side support for head</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Headrest</td>
<td>Children can look out and around in the car</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>Whole</td>
<td>Gives a comfortable impression</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Whole</td>
<td>Follow the same movement as the car</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Whole</td>
<td>Allows as good comfort for adults as without CRS installed</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Safety requirements</strong></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Whole</td>
<td>Correct seatbelt geometry</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>Whole</td>
<td>Nothing fastened on seatbelt</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>Whole</td>
<td>Easy to route seatbelt correctly</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>Backrest</td>
<td>Space between child and back of front seat</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>Whole</td>
<td>Only soft materials and shapes</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>Whole</td>
<td>Certified when used in traffic</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>Backrest</td>
<td>Light load behind back and head</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Other requirements</strong></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Whole</td>
<td>Portable</td>
<td>1</td>
</tr>
<tr>
<td>28</td>
<td>Whole</td>
<td>Easy mounted</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>Whole</td>
<td>Easy to move</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>Whole</td>
<td>Easy to store</td>
<td>1</td>
</tr>
</tbody>
</table>
7.3 ANTHROPOMETRIC DESIGN

In the Anthropometric design part the user test dimensions were specified. This was accomplished by the 3 first steps in Anthropometric design method (Osvalder, et al., 2010).

Before the Anthropometric design part was started it was decided to use an Integrated Booster Cushion (IBC) as a base for the prototype. The decision was taken because of the safety requirement 25 (Certified when used in traffic) so the prototype could be included in the on the road study later on in the process.

7.3.1 Execution Anthropometric design

In the beginning of the anthropometric design process the plan was to include the same user group dimensions as for the thesis’ target group, that is, a 50 percentile for Swedish children aged 5-11. Since only information about the standing height and weight for the user group population was accessible (PC PAL, 2017) the anthropometric data was complemented by dimensions from the Dutch population (Steenbekkers, 1993). Since the Dutch population had an average taller body height, the dimensions were chosen from a comparison between the Swedish and Dutch body heights rather than use the dimensions for the same age span.

The maximum and minimum dimensions were sketched up for a standing and sitting person. To get a better understanding of the proportions two manikins were created in the computer aided program RAMSIS Industrial Vehicles. The manikins' measurements were already predetermined in the program and only age could be chosen. The standing height was again used as the reference dimension and the 6 year old manikin and the 12 year old manikin were chosen. The dimensions for the manikin can be seen in Table 6.

Table 6 – The dimensions for RAMSIS manikins used in the development process of the prototype

<table>
<thead>
<tr>
<th>[cm]</th>
<th>RAMSIS manikins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 yrs.</td>
</tr>
<tr>
<td>Stature standing</td>
<td>113</td>
</tr>
<tr>
<td>Shoulder breadth standing</td>
<td>27,5</td>
</tr>
<tr>
<td>Hip breadth seated</td>
<td>21</td>
</tr>
<tr>
<td>Head breadth</td>
<td>13</td>
</tr>
<tr>
<td>Sitting height</td>
<td>62,5</td>
</tr>
<tr>
<td>Buttock-knee length, seated</td>
<td>36,5</td>
</tr>
</tbody>
</table>
The initial plan was to use both the first and second step on the IBC to include the whole user group population. However, when the two manikins had been created the plans were changed due to it would be too many parameters to take in to consideration in the user studies if both steps on the IBC were to be analyzed. Therefore, the user group population was revised to fit the safety regulations for traveling on the first step of the IBC (See Table 7)

_Table 7 – Dimension regulations for Integrated Booster Cushion (IBC)_

<table>
<thead>
<tr>
<th>Measurements and weight regulations for IBC</th>
<th>Weight</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>22-36 kg</td>
<td>115-140 cm</td>
</tr>
<tr>
<td>Step 2</td>
<td>15-25 kg</td>
<td>95-120 cm</td>
</tr>
</tbody>
</table>

The final user group body height span was thereby set to 120-140 cm, including only children that were not allowed to travel on the second step of the IBC. When doing a comparison between Swedish and Dutch dimensions it was concluded that average 6-9 years old Dutch children were closest to the chosen length span and therefore all anthropometric dimension for those ages were set as maximum and minimum dimensions for the development process. New sketches for the minimum and maximum dimensions were created. Although, the digital manikins dimensions were considered to be close enough to be used to guide the prototype design. The 6 year old manikin where seated on the IBC’s second step during the design to be closer to the target groups lower body height.

7.3.2 Result Anthropometric design

The final maximum and minimum dimensions for the user test population and how they refer to the Swedish and Dutch population can be seen in Table 8.

_Table 8 – The final maximum and minimum dimensions for the user test population_
7.4 CREATION OF A TESTABLE BELT-POSITIONING BOOSTER PROTOTYPE

In the Prototyping part a comfort prototype was constructed from the dimensions defined in the previous phase. The comfort prototype’s purpose was to find out how a concept that was developed from the comfort hypotheses could look like and that in a later stage could be tested and validated. The starting point for the design was the specification of requirements. Since all comfort aspect that had been found during the Workshop with primary users (adjustable backrest angle, temperature regulations and massage system) were considered to be very challenging technically, these comfort aspects were not included in the prototype design.

The prototype was developed according to step 4-10 in the Anthropometric design procedure (Osvalder, et al., 2010) and was foremost created to test comfort attributes and not mechanical solutions nor aesthetic design. The procedure included anthropometric testing with crash test dummies, design in CAD with the virtual RAMSIS manikins and manufacturing of the prototype.

7.4.1 Preparation for prototyping

As a first step to develop the prototype, requirements were specified since the prototype was to be used in an on road study. This type of study refers to a study performed in a car during a ride. The prototype safety requirements were set in consultation with the Injury Prevention at VCC Safety. Except the safety requirements (See Table 5) one new the prototype requirements was created:

- The prototype come loose in case of collision

The new requirement’s purpose was to make sure that if an accident would occur the prototype would not differ from any other objects or luggage that could be used or brought in the rear seat during a regular car ride. Thereby it had to fall off in case of a collision to allow other safety equipment to work as planned. It was also important that no hard edges or materials could hurt the child in case of an unpredictable turning or breaking.

Furthermore, all the comfort requirements from the specification of requirements were taken into consideration in the development of the prototype (see Table 5).

Since the decision of using an Integrated Booster Cushion (IBC) had already been taken because of safety requirement 25, it would be easy to take advantage of the IBC’s soft cushion. By designing a new backrest that could be combined with IBC would also make it possible to take advantage of the shape and angle of the existing backrest of a car seat. Thereby the prototype could be shaped after the specific seat shape and work as a complement to the seat rather than an add-on solution.

On that basis it was decided to design the prototype for a seat in a Volvo S90 or Volvo V90. The car models were chosen since they have identical rear seats and both models have two IBC’s placed in the outer rear seats instead of one IBC in the center seat.

It was furthermore decided to include a headrest and a footrest for the prototype due to requirement 8,9,15, 16 and CH2 and CH3.
7.4.2 Initial prototype design

The starting point for the prototype was a sketching session of possible design solutions for the prototype. This activity was inspired by (Ulrich & Eppinger, 2012), with the specification of requirements in mind to explore the space of product concept that would address the needs of the customer. Focus was on backrest, side support, foot support and headrest, although solutions as seat extension was also produced. Many of the sketches showed different solutions of creating a flexible prototype where children in different sizes could adjust bolster, headrest and footrest as they liked. To get a better understanding of if it was really necessary to involve flexibility features in all parts of the prototype the next step was to study two crash test dummies on an IBC.

One H3 6-years old and one P10 TNO 10-years old dummy was used in the study as references for the minimum and the maximum dimensions for the user test population. The six year old dummy was a bit smaller than the dimensions set for user test population, although it was considered close enough to the minimum height since it was still tall enough to be legally allowed to travel on the first step of the IBC. The dummies’ dimensions can be seen in Appendix H. All dimension on the dummies were measured by hand during the study.

In the study positions and dimensions were analyzed. The purpose was to find out where to put support without limiting the impression of free movement by exploring how the:

- Head was placed according to the headrest
- Shoulders and elbows where placed according to the seat cushion and bolsters
- Popliteal were placed according to the IBC edge
- Feet were placed according to the floor
- Seatbelt’s position changed for different child lengths

Further on, since VCC is already selling a comfort upholstery that is designed as a complement for the IBC and only includes soft parts, it was of big interest to see how the product fitted the selected user group population. Therefore, both dummies were also analyzed on the IBC together with the comfort clothing.

The different dimensions and proportions for the dummies and how they were seated in the comfort clothing can be seen in Figure 28- Figure 33.
Figure 28 – The dimensions for seat to elbow (orange), seat to shoulder (green) and seat to head (red) for the P10 TNO dummy seated on the first step of the Integrated Booster Cushion.

Figure 29 – The P10 TNO dummy seated on the first step of the Integrated Booster Cushion with VCC comfort upholstery.

Figure 30 – Gap between Integrated Booster Cushion edge and popliteal and space between feet and floor for P10 TNO dummy seated on the first step of the Integrated Booster Cushion.

Figure 31 – The dimensions for seat to elbow (orange), seat to shoulder (green) and seat to head (red) for the H3 dummy seated on the first step of the Integrated Booster Cushion.

Figure 32 – The H3 dummy seated on the first step of the Integrated Booster Cushion with VCC comfort upholstery.

Figure 33 – Gap between Integrated Booster Cushion edge and popliteal and space between feet and floor for H3 dummy seated on the first step of the Integrated Booster Cushion.
From test with the dummy, it was found that:

- Only the tallest children in the user test population reach the original headrest
- Only the tallest children in the user test population get support from the head support from the comfort clothing
- If a longer fixed head support were added, that also shorter children could use, it would probably conflict with the taller children’s seatbelt or shoulders
- The smaller children do not seem to get any support from the side bolsters
- There is a risk that the IBC’s seat cushion is too narrow for the older children
- The taller children get a big gap between the edge of the IBC and the popliteal
- The length of the IBC seem to fit the smaller children well
- All children seem to be in use of a foot support, but in different heights

From the result from the dummy study it was decided to design an adjustable foot support and headrest and a backrest that would fit all sizes in the user test population.

The backrest would be designed in a similar way as the comfort upholstery and thereby not include any hard parts. Although more shaped foam would be added to the backrest and the shape of an existing Volvo car seat was to be used as inspiration to get better dynamic support. The back side of the backrest would also be shaped after the seat of a Volvo V90/S90 to achieve a slimmer fit. Furthermore, it would not stop below the seat headrest as the existing comfort clothing, instead it would continue to the top of the headrest to fill in the gap between the seat and the seat headrest.

### 7.4.3 Detailed prototype design

From the decisions taken after the crash test dummy study a new sketch session was performed. With the user test dimensions in mind sketches on the backrest, foot support and headrest were produced. The final sketches were then used to design final models in a Computer Aided Design (CAD) program. The CAD-models were modeled in an existing CAD-model of the V90 car seat with an up folded IBC to get the right circumstances and dimensions for the prototype models. The design was iterated when the CAD-model was build and the RAMSIS manikins were used as references for the design.

**Backrest**

For the backrest the shape, softness and placement of bolsters were the main considerations based on requirement 3-7 and 13-14 and CH1 and CH4. Much inspiration was taken from the considerations taken on VCC when designing seats for adults. An important factor for the designed shape was to use as soft foam as possible around the waist and shoulders, which heavier children would compress but still would give support to smaller and thinner children. Thereby the bigger children would get bigger space and still get supported.
The final sketch of the backrest with the anthropometric dimension considerations can be seen in Figure 34.

**Figure 34 - The final sketch of the backrest with anthropometric dimension considerations**

The final design from the sketch of the backrest was looped several times during the CAD-modeling. With help from the RAMSIS-manikins the position and shape of the bolsters were adjusted to not interfere with the elbows for the taller children nor the shoulders for the smaller children. The final CAD-model for the backrest can be seen in Figure 35.

**Figure 35 – The final CAD-model for the backrest**
Headrest and footrest

For the headrest the most important design consideration was to get the right dimensions on the side supports in order to give support without blocking the field of vision. Furthermore, the headrest needed to be strong enough to hold the head load, but weak enough to break in a crash according to the prototype safety requirements.

The initial design plan for the adjustable headrest was to create a shape in a Styrofoam like material called PPP and cloth it with foam. It would then be fastened with Velcro on the backrest. Thereby it would be adjustable in different heights and soft enough to be safe to include in on the road study. Although, it was later in the process found out that the solution put the head in forward tilting position that was too extreme (See 7.4.4 Manufacturing of the belt-positioning booster prototype). Therefore it had to be redesigned with a short limit of time which resulted in that several of the safety requirements were not fulfilled. The decision was thereby taken that the headrest was only to be included in the static test.

The sketch for the initial design plan for the headrest can be seen in Appendix I. The design considerations was based on requirement 8 and 14-16 and CH3. The final design was directly designed as a CAD-model from the dimensions given in the initial design sketch and can be seen in Figure 36. The width between the side supports was set according to the extreme user group dimensions of the head breadth and the height of the side supports according to the extreme user group dimensions of the head height.

![Figure 36 – The final CAD-model for the headrest](image1)

![Figure 37 - The final CAD-model for the footrest](image2)

The foot support was designed with the consideration to easily adjust the height and to make sure no hard edges or corners were included. The length of the footrest was set according to the user group dimensions of feet length. No major changes was made in the CAD modeling procedure more than that the straps were moved to the outer position. The final design sketch with final dimensions can be seen in Appendix J and the CAD-model in Figure 37.

7.4.4 Manufacturing of the belt-positioning booster prototype

From the CAD-files drawings were created to manufacture the prototype. All parts were created by hand, except the hard parts for the headrest and foot support.
The prototype backrest was shaped by gluing 2 cm sections of foam together (See Figure 38). To be able to manufacture it with this method a harder foam than planned had to be used. The shape was tested (See Figure 39) with the H3 6-years old crash test dummy as reference to investigate if the backrest affected the belt geometry. The outer shape was afterward adjusted and then backrest was then clothed. In this initial design plan for the headrest was also tested (See Figure 40) and from the result abandoned (Described why in 7.4.3 Detailed prototype design).

To make the backrest match the color and material of the IBC it was decided to use the seating part from the existing comfort clothing to cover the IBC as a complement to the prototype. Thereby a black fabric, as similar to the fabric on the comfort clothing as possible, was used for clothing to the prototype backrest.

![Figure 38 – The backrest was shaped by gluing 2 cm sections of foam together](image1)

![Figure 39 – The shape of the backrest was tested with a crash test dummy before shape was adjusted and backrest clothed](image2)

![Figure 40 – The initial design plan for the head rest tested. After the test the whole headrest redesigned due to bad head position.](image3)

The final headrest fastened in the plastic structure of an existing headrest for a Volvo V90 seat. It was manufactured by fastening two clothed foam blocks on an aluminum construction. The foot support created from a shaped block of RAKU-TOOL 351 that was clothed with leather and a high friction material where the feet were placed. The straps were created in a leather material.
7.4.5 Result Prototyping

The comfort prototype is used together with an IBC and consists of four parts; backrest, headrest, foot support and a seat cushion cover. All parts are black to give a coherent impression. The seat cushion cover was not created in the thesis but was taken from the existing comfort upholstery, its only purpose is to keep the design coherent. The comfort prototype as a whole can be seen in Figure 41- Figure 42.

![Figure 41 - The prototype mounted in a car. The foot support is not visible in this figure.](image1)

![Figure 42 - The prototype mounted without headrest and seat cushion cover.](image2)

**Backrest**

The backrest is build up by foam with density 75 kg/m³ which is clothed with a black fabric with 8 mm foam backing. It is fastened with Velcro straps on the seat and a piece of elastics around the headrest (See Figure 43 and Figure 44).

It is shaped with bolsters which are placed around the waist of the child. Around the shoulders it has a rounded shape to stabilize the child when the car turns. An extra padding area with 30 mm foam is added in the lower back to fill in the gap between the seat and IBC and support the lumbar area. Padding was also added along the whole back to cover on the joint between headrest and back seat. A sketch of the backrest with final dimensions can be seen in Figure 45 and the final backrest in Figure 41 and Figure 42.
Figure 43 - The backrest is fastened with Velcro straps on the seat

Figure 44 - The backrest is fastened with a piece of elastics around the seat headrest

Figure 45 - A sketch of the backrest with final dimensions

*Including 30 mm chamfer from 30-10 mm
Headrest

The headrest consists of two side supports built up by foam with 55kg/m³, clothed with a black fabric with 8 mm foam backing. The side supports are 18 cm high, 4.5 cm thick and 10 cm deep and are fastened on an aluminum structure which is fastened in an existing headrest. It is adjustable vertically which help from two knobs (See Figure 46). The whole headrest can be seen in Figure 47.

Footrest

The footrest consists of one block that is fastened in the ISOFIX by two leather straps (See Figure 48). The block is 40 cm broad, 14 cm deep and 8.5 cm high and is shaped to rest against the flat surface under the seat. When extracted fullest the underside is shaped to stably rest on the floor. Underneath the front the edge is chamfered with a 6 cm radius. The length of the straps is adjustable and the distance between the wholes are 3 cm (See Figure 49). The foot support can be seen in Figure 50.
7.5 ANALYSIS DEVELOPMENT

A comfort prototype, designed around the IBC, which consists of a backrest, an adjustable headrest and an adjustable foot support has been developed and can be used for the user studies in the next phase. Although the headrest needs to be removed for the on road study because of safety reasons. It was not possible to include the identified comfort aspects from the workshop in the prototype design, due to technical difficulties.

From the expert panel activity in the workshop it was hard to obtain some exact opinions and perceived experiences. This since it was obvious that aspects like group dynamics, influence from other children and age as well as maturity affected the children's behavior and responses and therefore also the result. Although, it could in the workshop be identified that the backrest of the high-back booster with smaller side supports did not fit children taller than 130cm and should therefore not be included in further studies.

That children influence and affect each other may not be a problem during co-design activities but is a problem when testing and evaluating prototypes and concept features. According to Doveborg & Pramling (2001) it is common that children affect and influence each other when performing activities and it was noticed that the children influenced and kept an eye of each other during the expert panel activity. It seemed like some children wanted to do as their older siblings or the older children and mainly the younger, did not want to be the only child with a specific opinion (see Figure 51). Comfort evaluations with children may thereby be more valuable to perform with one child at the time.

Additionally, dependent of what activity that should be performed, age matters. For testing and evaluation it seems to be easier to work with children older than six years old, because of their linguistic abilities as well as their abilities to think more abstract and relate to things and problems in their everyday life. According to Karlsson (2013) older children possess linguistic and emotional abilities that smaller children miss. Furthermore, Hansen Orwehag (2013) argues that younger children's attention is of short duration which was also noticed during the sessions. Although, it was also noticed that this does not apply to all children since children's maturity differs.

Furthermore, when researching with children the instruction has to be clear and not possible to interpret and preferably instructions and test setups shall be tested before execution. Also follow-up questions can validate children's answers as well as facilitate for the children to express themselves verbally.

The methodology experience and considerations from the workshop setup can be used for design of the two user studies.

Figure 51- Expert panel, children seems to influence each other

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The methodology experience and considerations from the workshop setup can be used for design of the two user studies.
8 TESTING AND EVALUATION

The Testing and Evaluation phase and the different activities performed in the phase are presented in this chapter.

With the output from the Development phase, a comfort prototype and methodology experience, two user studies were designed and carried through in the Testing and Evaluation phase. The studies were designed in order to verify the hypothesis, test the comfort of the prototype and test as well as evaluate developed comfort methodology.

In the first part, User study one – Static study, one static study was performed where the comfort prototype and three different belt-positioning booster’s initial comfort were evaluated. From the result from the static study a reference belt-positioning booster was chosen. The reference booster and the comfort prototype’s cruising comfort were then tested and evaluated in the second part, User study two – On road study. The methodology for the studies was iterated through the process and lessons learned from user study one was used in the design of user study two.

The output from the Testing and Evaluation phase was evaluated prototype features and evaluated comfort methodology. The process of the testing and evaluation phase can be seen in Figure 52.

![Diagram of the testing and evaluation phase]

Figure 52-Testing and Evaluation phase

To participate in the user studies each Test Person (TP) and the TP’s both parents had to sign an attendance agreement. The attendance agreement specified what was expected from the TP during the study, why the study was executed, that the attendance was voluntary and how personal data would be handled after the study. The attendance agreements can be seen in Appendix K and Appendix L.
8.1 USER STUDY ONE – STATIC STUDY

User study one was planned based on the comfort hypotheses CH1-4 (see chapter 7.2.2). The arrangement of the user study will be presented and decisions made will be motivated. Then the development of evaluation method will be presented including a comfort and discomfort interview form and a comfort and discomfort questionnaire. Decisions taken regarding the development of the evaluation methods will be motivated. The execution will be presented in the next chapter.

User study one was a static study performed to evaluate initial comfort together with primary users from the defined user test population. The static study included four activities. First the TPs were measured, in order to be able to compare anthropometric measurements with the TPs comfort and discomfort experiences. After that three belt-positioning boosters and the prototype was evaluated in cars parked indoor. The evaluation was performed with an interview form, a questionnaire and observations. In the third activity the TPs played a game on a tablet when seated in the prototype and in the last activity the seat comfort of three different foam cushions was evaluated.

No detailed comparison between dimensions and foam thickness and hardness for the reference belt-positioning boosters were aimed in the study.

In total nine TP's participated and they were 120 cm to 144 cm tall. A pilot test was performed to test the arrangement before the actual performance. The pilot test person was 9 years old and in the taller length span of the target group (139 cm).

8.1.1 Planning user study one – static study

User study one had its starting point in the comfort hypothesis CH1-4 (see 7.2.2). Initially the comfort hypotheses were sorted by affected body area; head support, back support, foot support or buttock support. If a comfort hypothesis affected more than one body area, such as CH1, it was put under all areas it affected. The comfort hypotheses was then transformed into test hypothesis for each body support area.

In order to identify what to examine during the user study, to confirm the test hypothesis, as well as how they should be examined, subjective and/or objective test activities were listed under each test hypothesis. Lastly comfort goals that corresponded to the test hypotheses were set for the user study, to be able to reflect upon the result. An example of the procedure can be seen below. All sorted comfort hypotheses, test hypotheses and comfort goals for user study one can be seen in Appendix M.

Comfort hypotheses **buttock support**

**CH1**: Thicker foam in seating and backrest will lighten the static load and thereby make children:

a) Sit more comfortable
b) Keep children in the same position for a longer period of time

Test hypotheses **buttock support**

**TCH1**: The foam thickness and hardness on seat cushion matter for perceived comfort
Subjective: Let children evaluate different foam hardesses and thicknesses combinations for 3 cushions

Comfort goal for test buttok support

- Find out what children think about different foam thicknesses and hardesses on the cushion

8.1.2 Development of the evaluation methods

In order to collect data from the test persons participating in user study one – static test, an interview form was developed for the moderator as well as a questionnaire with two rating scales and an illustration task for the TPs. For the finished interview form see Appendix N and for the finished questionnaire see Appendix O. Notes from observations could also be written in the interview form.

As a starting point for the evaluation methods for user study one, method goals were defined from the comfort test hypotheses and the comfort goals.

Method goals

1. Find out best way to ask questions for evaluating comfort
   a. Find out how well children can evaluate different aspects of comfort from rating scale questions
   b. Find out how well children can evaluate different aspects of comfort from general questions
   c. Find out how well children can evaluate different aspects of discomfort with a coloring exercise

2. Find out if children can distinguish a difference between the comfort of different parts of the chair

Development of comfort and discomfort interview form

Open questions where developed in order to let the TPs evaluate the belt-positioning booster by “how it feels” rather than answering if it feels comfortable or not. The questions were formulated to evaluate the overall comfort and discomfort as well as comfort and discomfort for different pressure areas (body parts where pressure is distributed when seated). The chosen pressure areas where decided by the comfort hypothesis deviation: Under the buttock, behind the back and arms, as well as around the head and neck.

The Comfort and Discomfort model by De Looze, et al., (2003) (see Figure 5) inspired the development of questions and the questions where decided to be open. This in order to examine how children generally should manage to express themselves regarding perceived comfort and discomfort. It was also of interest to identify if they would express themselves in terms either related to comfort or discomfort when trying a belt-positioning booster, or if they would distinguish the concepts and speak in terms related to both comfort and discomfort. This should also achieve the method goal: 1b and 2.

Furthermore, in the interview form questions with response statements were included, inspired by subjective data collection methods by (Osvalder, et al., 2013) and (Helander & Zhang, 1997). The test person should answer to the question by selecting between two
statements that were intended to be associated with either a feeling related to comfort or discomfort. Statements that concerned comfort were in accordance with De Looze, et al., (2003) associated with feelings of relaxation and wellbeing as well as statements that concerned discomfort were associated with feelings of pain, numbness, ache and stiffness. Example: Belt-positioning booster is perceived: Spacious versus tight, Soft versus hard etc.

**Development of Comfort and Discomfort questionnaire**

For the questionnaire two different scales were used in order to achieve the method goal: 1a. A four point scale were used without a middle option in order to make the child take a stand (Sorbring, 2013). The four point scale where designed with four facial expressions, see Figure 53. The facial expressions where chosen so that they ranged from happy to perceived pain/sad. According to Sorbring (2013) it is important to be aware of that facial expressions demonstrates a feeling and therefore facial expressions should be used when a feeling should be measured. Pictures with facial expressions is used in studies with children in different ages (Sorbring, 2013) and therefore it felt obvious to include.

![Figure 53 – The four point scale with facial expressions](image)

Noticed during the pilot of user study one was the lack of options for the scale. The TP often wanted to express an opinion between the two happy smileys and between two statements. Therefore a numerical scale ranging from 1-10 was also used for the actual test, were 1 indicated much pain and 10 as comfortable as it gets. This scale were tried in order to see how the children would understand a more abstract scale and should be verified with the children’s answers to questions as well as the facial expressions. Since VCC uses a 10 point scale in their comfort evaluation and it seemed like a reasonable choice. Both scales where linear scale and therefore follow up question regarding comfort and/or discomfort experience was needed.

Illustrations can help to make the children’s answers less personal (Gallahager, 2009) and therefore an illustration of a seated human from different angels where used, see Figure 54. To achieve the comfort goal: 1c, the children could color where on the illustration they perceived discomfort. The illustration used and the procedure is inspired mainly by (Osvalder, et al., 2013) but also by (Corlett & Bishop, 1976). Osvalder, et al., (2013) states that subjective estimations of perceived discomfort are an effective and dependable measure to use. It also seemed important to measure perceived discomfort separately since according to Hägg, et al., (2011) emergence of discomfort shall be investigated. It should be added that absence of discomfort in the illustration doesn't necessarily indicates that it is comfortable.

![Figure 54 – The illustration of a seated human from different angels](image)
8.1.3 Arrangement for user study one – static study

In order to be able to evaluate the prototype's overall comfort as well as comfort for different parts of the prototype, it was decided that three belt-positioning boosters would be used as references. This also to see if the TPs were able to identify differences and compare comfort between different alternatives. It was furthermore to compare the different parts between the prototype and the other belt-positioning boosters and find a reference chair to the second user study.

The three belt-positioning boosters was selected from the ones available at VVC and were chosen to highlight different comfort features. The different reference belt-positioning boosters are listed below:

- Booster cushion from VCC: The same booster cushion as the one used in the workshop with primary users was chosen. This since the workshop result indicated that it is a commonly used belt-positioning booster. Furthermore, it does not have a backrest, and thereby no bolsters, and does have guiding loops which were both interesting aspects to compare to the prototype.

- High-back booster with big bolsters from VCC: This high-back booster was chosen since the high back booster with smaller bolsters was not appreciated during the workshop with primary users and would not fit the target group's dimensions. Furthermore, it was considered interesting to try out a high-back booster with big side headrest supports and big bolsters as a comparison to the prototype.

- Integrated Booster Cushion (IBC) from VCC: The IBC was selected since the prototype were based on the IBC and it would thereby be interesting to see how the perceived comfort changed when adding the prototype parts. Furthermore, from literature studies and interviews the IBC’s comfort was perceived as good.

The user study was decided to be performed in real cars in order to achieve a realistic environment. Since it during the Workshop was obvious that children are affected by group dynamics and influence each other, the user test was decided to be performed with one child at the time. Since two moderators were available, two children could perform the test simultaneously as long as they were not located to close to each other.

From the focus group it was identified that the children sometimes complain about the belt-positioning booster’s hardness. Since the comfort hypotheses CH1 required to be evaluated and no changes could be made for the prototype's seat cushion, three different foam cushions where evaluated separately. This procedure where done to get a hint on which foam density and thickness children perceived as comfortable. Furthermore the procedure where performed to examine children's capability to evaluate the different foams' densities and thicknesses.

Identified from the focus group as well as in accordance with Osvalder, et al., (2013), tablet devices affect children's sitting postures. Therefore the child got the task to play a game on a tablet in the prototype to investigate if something in the prototype was bothering the child while playing. This to evaluate the test hypothesis TCH4 b).
8.1.4 Execution of user study one – static study

The first user study was a static study divided in four activities. First the TP was measured, measurements can be seen in Appendix P.

The second activity was to try out four different belt-positioning boosters in cars and answer to questions as well as fill out a questionnaire for every belt-positioning booster. The belt-positioning boosters were tried out in the presented order: a booster cushion (see Figure 55), a high-back booster (see Figure 56), an integrated booster cushion (IBC) (see Figure 57) and the developed prototype (see Figure 58). For every belt-positioning booster the participating TP where asked to buckle themselves and when seated correctly they were photographed in a side view. Marks where placed on the TP’s leg and at the side of the booster to see how the TP’s buttock where positioned in relation to the belt-positioning booster.

The TPs were equipped with a questionnaire (see Appendix O) and the executor with an interview form (See Appendix N). The interview form included questions linked to the TP’s questionnaire and questions about the child’s perceived comfort or discomfort for different body regions when seated on a belt-positioning booster. It also included a question of how the TP perceived it would be to sleep in the belt-positioning booster. After the procedure had been repeated for all belt-positioning boosters the TP where asked which one was their favorite and what was important for them to be able to travel comfortable on a belt-positioning booster. If something of interest was observed during the evaluation it was written down by the moderators.

During the third activity the TP used a tablet device for a few minutes when seated in the prototype. After the TP was asked question of how the TP perceived the prototype’s comfort when interacting with the tablet device.

For the fourth activity the child where asked to sit on three different "cushions". When seated they had their back against the wall and their feet above the floor, see Figure 59. First they tried a thinner cushion (15 mm) with the foam density
55kg/m³ and after two of the cushions that had the same thickness (40 mm) but different foam hardness 55kg/m³ and 35kg/m³. All cushions had a backing on 4 mm, the textile was Bella small. When the child where seated on the cushion he or she where asked about the cushions comfort, if it felt hard or soft and if they felt the chair beneath trough the cushion.

8.1.5 Result from user study one

The full result from user study one can be found in Appendix Q.

From the facial expression rating scale all belt-positioning boosters are compared with an average score, where the four facial expressions are translated to numbers (see Figure 60). The integrated booster cushion (IBC) has the highest score (3,3), followed by the booster cushion (3,2) and the high back booster (3,1) and last the prototype (3,0).

![Facial expression rating scale translated into numbers](image)

*Figure 60 – Facial expression rating scale translated into numbers*

From the numerical scale with grades 1 to 10 (1 is equal to “a lot of pain” and 10 to “As comfortable as it gets”) the IBC also get the highest score (8,1). The IBC is followed by the booster cushion (7,1), then the high-back booster (6,8) and lastly the prototype (6,2).

Opinions about the booster cushion from user study one

The booster cushion is overall experienced as a belt-positioning booster with good comfort. The discomfort, pain or scratch areas for the booster cushion is marked with red and can be seen in Figure 61. Regarding the discomfort for the head and neck four children out of nine experienced discomfort. They though it was too hard and two of the TPs (sitting height 72, 5 and 73, 2 cm) pointed out the gap between the back and the head support as bothering. Overall all TPs perceive that their back and shoulders are comfortable. Five out of nine perceive discomfort under their buttocks and thighs witch seems to depend on the cushions hardness (bigger children 135, 5 – 144 cm tall) as well as three complained on that the cushion was shaped like a slope (138, 5 – 139 cm tall).

![Fill in color, booster cushion](image)

*Figure 61 - Fill in color, booster cushion*
Opinions about the high-back booster from user study one

For the high-back booster the perceived discomfort, pain or scratch is marked with red in Figure 62. Five out of nine perceive the backrest to be too narrow since their arms do not fit between the bolsters. Two of them are the two shortest children (121, 5-124 cm tall, with shoulder width 26, 5 and 28 cm) and the other three are in the bigger range of the TPs (138,5 – 143,5 cm tall, with shoulder width 31, 5 cm). Four perceived the headrest as not satisfying, they perceive it as either too hard, too narrow or both. All of the children perceived the seat cushion as at least rather comfortable. Seven of the TPs think that it would be comfortable to sleep in the high back booster thanks to the headrest's side supports.

Opinions about the integrated booster cushion from user study one

The IBC is overall experienced as a belt-positioning booster with good comfort. Discomfort, pain or scratch is marked with red in Figure 63. Four children out of nine pointed out the gap between the back and the head support as bothering, (sitting height 71, 5 – 73 cm). Seven children do not experience any discomfort regarding their back and shoulders. Regarding the seat cushion four children experienced the cushion to be hard under their buttock and/or their thighs (Three of the bigger children 138 – 144 cm tall and one child in the middle range 131, 5 cm tall). Three children perceived pain at their calves due to the hard edge below the seat cushion (these children are 131-138 cm tall and the height of their popliteal are 36 – 38, 5 cm). Two children thought that the IBC is too small, both too short and too narrow (these children’s hip width are 27-30 cm and the distance between their buttocks to their popliteal is 37-38 cm).

Opinions about the prototype from user study one

For the prototype discomfort, pain or scratch is marked with red in Figure 64. Regarding the head and neck support most children experienced it to be comfortable, though two children thought that the side supports could be longer in a forward direction. Three children also experienced the head support and the side support to be a bit too hard. The cushion hardness where experienced similar as the IBC and three children wanted it to be longer in a forward direction (the distance between their buttocks to their popliteal is 37-38 cm).

Eight children experienced the backrest as too narrow because of the side bolsters. Some children experienced that they couldn’t have their arms as close to their body as they
wished and some experienced their shoulders to be pushed forwarded and the side bolsters to be too hard. Some also experienced the backrest as hard. The two children in the middle length range \((\text{approximately 131-136, 5 cm})\) gave the prototype a low overall score on the numerical scale as well as the facial expression 2. The smallest children and the taller children rate the prototype at least 6 on the numerical scale give expression 3 and 4 on the facial expression rating scale.

Using a device

The observations from when the children played games on a tablet-device shows that children place the tablet in their lap and then lean forward with their head and shoulders during the interaction. Eight children say they do not think about the prototype when they use the tablet.

Foam cushions

Most children think that the thinner foam cushion \((15 \text{ mm and } 55\text{kg/m}^3)\) is a bit too hard. All children enjoyed the two thicker foam cushion rather much. Some think that the thicker foam cushion \(55\text{kg/m}^3\) is a bit too hard and some think that the thicker foam cushion \(35\text{m}^3\) is a bit too soft.

8.2 USER STUDY TWO – ON ROAD STUDY

User study two was an on road study performed to evaluate initial comfort, cruising comfort as well as the use of subjective evaluation methods in relation to objective observations. It was performed together with primary users from the defined user test population. In the study two cars were driven the same tour, which took approximately 25 minutes. The children were recorded, to observe the children’s positions, during the whole tour and they answered questions (almost the same is in user study one) as well as fill in a questionnaire (same as in user study one) before and after the ride. The belt-positioning boosters that were evaluated were the integrated booster cushion (IBC) and the prototype.

In total seven TP’s participated and they were 121 cm to 143 cm tall. The user study were tested with two adult test persons before the actual performance. This was mostly done to double check the route, the study’s duration as well as the video cameras. The subjective method was considered already tested since no major changes was done from user study one.

8.2.1 Planning of user study two

The planning of user study one have its base in the comfort hypotheses CH1-4 see 7.2.2. The results from user study one affected the planning and arrangement of user study two and the outputs implemented from user study one will be presented. Thereafter the arrangement and development of methods will be presented. Decisions taken regarding the outputs from the user study one, the arrangement and the development of the evaluation methods will be motivated. The execution will be presented in the next chapter.

The comfort hypothesis from CH1-4 (see chapter 7.2.2) where used as a base for both the user studies. Also for user study two the comfort hypotheses were divided into support
areas for the head support, back support, foot support and the buttock support. The comfort hypotheses was then transformed into test hypothesis, similar as in user test one. This to identify what should be examined during the user study and how it should be examined. Goals for the test for the user study two were also set in order to be able to reflect upon the result. All Comfort hypotheses, test hypotheses and goals for user study two can be seen in Appendix R.

User study two goals

- Find out if the results from objective and subjective methods differ, and if they do in which way.
- Find out if the comfort impression differ before and after the car ride.
- Find out if the result from the static and dynamic user tests differ.
- Find out how children respond when asked to measure comfort with scale questions.
- Find out how children respond when asked to measure comfort with a coloring exercise.
- Find out if children can distinguish a difference between the comfort of different parts of the chair.

8.2.2 Chosen reference belt-positioning booster for user study two

From the static test the integrated booster cushion (IBC) got the highest average score on the numerical scale as well as the facial expression scale. The prototype got the lowest average score on both scales. A discussion was held whether using the IBC as a reference or the high-back booster. The IBC have in previous on road studies (Osvalder, et al., 2013) lead to more rotation and lateral movement than high-back boosters. Two of the comfort goals for the test developed from the comfort hypotheses for the user study two were:

- **GCH4 b)** Find out if the bolsters improve the child's position and/or comfort when turning (dynamic environment)
- **GCH4 f)** Find out if the bolsters keep the children in a better position during a ride (or “affect the children's position”)

The IBC was used as a reference since it without headrest side support nor bolsters as well as considered most comfortable in the static study, was considered to give the biggest contrast to the prototype. The IBC would be a good reference to investigate whether the prototype's bolsters were big enough to stop the child from lateral movement and rotation. The seat cushion, except the soft seat bolsters from the comfort upholstery, would also be the same for both the reference and the prototype and thereby it would be possible to see how the backrest and the foot support would affect the child in a driven car as well as the TP’s reaction. Since the prototype’s head support could not be used due to safety requirements it also seemed more relevant to use the IBC as a reference. Thereby it would be less different parameters that affected the position between the prototype and the reference.
8.2.3 Arrangement and development of evaluation methods for user study two

The same cars as used in user study one were used for user study two, one S90 and one V90. The predetermined route was driven two times, one time when the TP evaluated the IBC and one time when the TP evaluated the prototype. This in order to prevent major changes in comfort/discomfort experience due to road conditions. The TP’s parents drove the cars and this to imitate an everyday experience for the children as well as the parents present can make children feel safer. Furthermore it was considered that it might would comfort the parents to drive their own children.

During user study one it was identified that only one out of nine TPs thought about their comfort/discomfort experience when playing a game on a tablet device. Together with the knowledge from the focus group and (Osvalder, et al., 2013) study's concerning that children are leaning forward when interacting with a tablet device during a car ride, it was decided that the children would not be allowed to use any devices during the study.

Since one of the goals for the user study was to find out if the comfort impression differ before (initial comfort) and after the car ride (cruising comfort) questions were asked one time before the ride and one time after the ride. The evaluation methodology were considered as good during user study one and therefore only small changes were done in order to be able to use a similar setup for user study two. The interview form for initial comfort was identical to the interview form used for the belt-positioning evaluation in user study one, while the question about sleeping was exchanged to a question about how it felt when the car turned for the cruising comfort. The same questionnaire was used for both initial and cruising comfort.

One of the other goals was to find out if the results from objective and subjective methods differ, and if they do in which way. In order to collect objective data observation by filming the TPs were set up. Two cameras (GoPro Hero 5) were mounted in each car. One filming the TP from the front and one from the side. This in order to don’t miss out any movements. The TP were also asked to clap their hand before the drive started so that the two recordings could be synced when the data should be analysed. The used frame rate was 30 frames per second and the resolution was 720 pixels. This settings was tested before the execution of the user studies. To try to eliminate the risk of that more movement would occur for the second belt-positioning booster because of restlessness or boredom some children started with the IBC and some with the prototype. During the rides observations were also performed by the moderators.

8.2.4 Execution of user study two

The second user study where an on road study where data was collected through interviews, a questionnaire, observations and video recordings. Two cars were used in the study, in one car the prototype was installed and in the other an integrated booster cushion (IBC). Each child participating in the study tried out both the prototype and the IBC during two rides for approximately 25 minutes each. The same route was driven for the both rides. The child’s parent was driving the car and one interviewer were also present in the car. Two video cameras were placed in each car. One recording the child from the front and one from the side.

Before entering the car the children were measured (see Appendix P for test person dimensions) and before the driving rout started the children filled out a form (See Appendix O) and answered some questions (See Appendix S) about their initial comfort
experie

The interviewer then moved from the rear seat to the passenger seat and turned on the video cameras. During the ride the children were not allowed to use any electric devices but they were allowed to eat apple and drink. They were also allowed to have a conversation with the parent and the interviewer in the front seat and look out through the windows. When the driving route was finished the interviewer turned off the cameras and moved back to the rear seat and once again the child filled out the same form and where asked the same questions except that the question “How did it feel when the car turned” was added. Then the whole procedure was repeated once again for the other belt positioning booster.

8.2.5 Analysis of videos from user study two

For each TP four videos were analyzed, two videos with different views for each belt-positioning booster. The purpose of the analysis was to identify how much the TP’s moved, how much of the positions that could be referred to discomfort and if it was any difference in movement between the IBC and prototype.

Two persons were analyzing the material and watched the videos together, the videos were played parallel and were synced so the positions could be watched from two views at the same time. One of the persons analyzing had more reasonability for watching the side view and time the different positions and the other person had more responsibility for the front view and to take notes during the observation.

The potions were divided into four subgroups:

- Acceptable position
- Indicate discomfort
- Indicate activity or boringness
- Not sure why out of position

The subgroups were defined before the analysis started and the positions were thereby divided directly on the right subgroup when the videos were analyzed. The definition of each subgroup can be seen in Table 9. After each pair of videos had been analyzed the persons analyzing filled out the same kind of exercise that the TP’s had used to mark out areas of discomfort with a red pen. The persons analyzing based their filled in areas of discomfort on signs from the videos indicating that the TP’s felt discomfort. The goal was to later compare the figures from the TP with the one from the persons analyzing and see if the marked areas of discomfort were in accordance. It was also done in order to take into account the possible scenario of a child sitting in an acceptable position but still show signs discomfort.

Table 9 - The definition of positioning subgroups

<table>
<thead>
<tr>
<th>Acceptable position</th>
</tr>
</thead>
<tbody>
<tr>
<td>The child sits in a position where the belt geometry is good, both over lap and chest. A minor lateral movement with the upper body is OK as long as the belt geometry is correct. Although it is not defined as an OK position if the child actively try to move away from a centered position or cannot stay in a centered position because of turning or other dynamic movement from the car.</td>
</tr>
<tr>
<td>Shoulders and back has to be in contact with the backrest. Rotation or movement of the head is OK and the head is allowed to not rest at the headrest. The hips has to be centered and the legs have to hang or rest on the floor/foot support.</td>
</tr>
</tbody>
</table>
## Indicate discomfort by position

The child actively search for a new position because of signs of discomfort. Such positions can be: Search for better support with head or feet, twist in the seat to get away from discomfort or touches areas on the body with signs of discomfort.

## Indicate activity or boredom

When the child get out of position with a specific purpose, such as energy overload, reaching for something, looking out through window or talking to driver.

## Not sure why out of position

When it is not clear if child is out of position because of discomfort, activity or boredom.

### 8.2.6 Result from user study two

The result from the two belt-positioning boosters initial comfort experience and comfort experience after have been driving for approximately 25 minutes (cruising comfort) is presented in this chapter. Both result from subjective data collection, interviews and questionnaires as well as objective data collected by observation through video recordings.

#### Subjective result for user study two

The full result from the interview form and the questionnaire can be found in Appendix T.

The result from the facial expression rating scale (translated into numbers as in user study one) and from the numerical scale (with grades 1 to 10 where 1 was equal to “a lot of pain” and 10 to “As comfortable as it gets”) is presented in Table 10. The score presented is the average score from all TPs.

**Table 10-Average rating from the facial expression scale and the numerical scale**

<table>
<thead>
<tr>
<th></th>
<th>Facial expression scale (1-4)</th>
<th>Numerical scale (1-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial comfort experience</td>
<td>Cruising comfort experience</td>
</tr>
<tr>
<td>Integrated booster cushion</td>
<td>3,7</td>
<td>3,4</td>
</tr>
<tr>
<td>Comfort prototype</td>
<td>3,3</td>
<td>3,4</td>
</tr>
</tbody>
</table>

The perceived discomfort, pain or scratch for the IBC is marked with red in Figure 65, both for initial and cruising discomfort experience. Initially two TPs experience the edge below the IBC as hard. After the route one more TP experience the edge below the IBC as hard. *The three TP's length range were 132-138, 7cm.*
One TP initially experiences the headrest as hard, *(length 138,7cm and sitting height 71,6)*, and two other TPs experience the headrest as hard after the drive, *(length 136,7cm-138,3 and sitting height approximately 73cm)*. Two TPs, one in the upper length range and one in the lower, experience that they slide when the car turned. Four TPs said that they were seated well in the turns and one TP do not think about the turns. After the ride one TP also want the IBC to be wider and longer, *(length 138, 7 cm, buttock to popliteal 39, 5 cm and hip with 27,5cm)*.

![Figure 65-Illustrations with marked discomfort on the IBC: To the left initial discomfort experience and to the right cruising discomfort experience](image)

For the prototype discomfort, pain or scratch experiences is marked with red in Figure 66, both for initial and cruising discomfort experience.

Three TPs experience the backrest on the prototype as too narrow and/or too hard due to the bolsters, *(length 136, 7-143, 5 cm, sitting height, 71, 6-75, 5 cm, shoulder with 31, 2-32, 2 cm and elbow with 34, 2-36, 5 cm)*. Two TPs experience that the prototype give them support when turning, *(length 136, 7-138, 7)*. Three TPs express that they sit good in turns and two do not think about the turns.

After the drive three TPs state that they enjoy the prototype cushion’s side bolsters, *(length 131, 4-138, 7 cm and hip with 26, 3-27, 6cm)*. Two of them want them to give even more support. The same TP as want the IBC’s cushion wider and longer also want the prototype’s cushion to be longer but the width is experienced as good. The smallest TP *(length 121 cm)* do not enjoyed long car rides and express that it is because of boredom and perceive stiffness under buttock.

![Figure 66 Illustrations with marked discomfort from the prototype: To the left initial discomfort experience and to the right cruising discomfort experience](image)

**Objective result for user study two**

The result from the video analysis shows that the time the test persons sat in an acceptable position is 83% for the prototype and 70,1 % for the IBC. The indication of discomfort is 1,3 % for the prototype and 4,5 % for the IBC. The percentage of each subgroup and how it differ for all TP’s can be seen in Table 11 and Table 12.
Table 11 - Result from video analysis - prototype

<table>
<thead>
<tr>
<th>Evaluated prototype</th>
<th>Acceptable position</th>
<th>Indicate discomfort</th>
<th>Indicate activity or boredom</th>
<th>Not sure why out of position</th>
<th>Total time</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>First</td>
<td>96.2%</td>
<td>0.0%</td>
<td>3.3%</td>
<td>22.55</td>
</tr>
<tr>
<td>TP2</td>
<td>Second</td>
<td>73.3%</td>
<td>0.0%</td>
<td>26.7%</td>
<td>22.12</td>
</tr>
<tr>
<td>TP3</td>
<td>First</td>
<td>96.0%</td>
<td>0.4%</td>
<td>3.6%</td>
<td>26.32</td>
</tr>
<tr>
<td>TP4</td>
<td>Second</td>
<td>91.5%</td>
<td>0.0%</td>
<td>8.5%</td>
<td>23.04</td>
</tr>
<tr>
<td>TP5</td>
<td>Second</td>
<td>83.8%</td>
<td>0.0%</td>
<td>5.3%</td>
<td>24.20</td>
</tr>
<tr>
<td>TP6</td>
<td>First</td>
<td>94.2%</td>
<td>0.0%</td>
<td>5.7%</td>
<td>24.26</td>
</tr>
<tr>
<td>TP7</td>
<td>Second</td>
<td>41.3%</td>
<td>9.2%</td>
<td>12.9%</td>
<td>36.5%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>83.0%</td>
<td>1.3%</td>
<td>9.1%</td>
<td>6.6%</td>
</tr>
</tbody>
</table>

Table 12 – Result from video analysis – Integrated Booster Cushion

<table>
<thead>
<tr>
<th>Evaluated IBC</th>
<th>Acceptable position</th>
<th>Indicate discomfort</th>
<th>Indicate activity or boredom</th>
<th>Not sure why out of position</th>
<th>Total time</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>Second</td>
<td>64.5%</td>
<td>20.7%</td>
<td>9.2%</td>
<td>22.48</td>
</tr>
<tr>
<td>TP2</td>
<td>First</td>
<td>47.4%</td>
<td>1.1%</td>
<td>51.5%</td>
<td>23.37</td>
</tr>
<tr>
<td>TP3</td>
<td>Second</td>
<td>94.3%</td>
<td>0.2%</td>
<td>2.7%</td>
<td>23.15</td>
</tr>
<tr>
<td>TP4</td>
<td>First</td>
<td>96.0%</td>
<td>0.1%</td>
<td>2.2%</td>
<td>19.19</td>
</tr>
<tr>
<td>TP5</td>
<td>First</td>
<td>93.5%</td>
<td>0.2%</td>
<td>5.1%</td>
<td>23.12</td>
</tr>
<tr>
<td>TP6</td>
<td>Second</td>
<td>58.6%</td>
<td>9.1%</td>
<td>31.9%</td>
<td>22.01</td>
</tr>
<tr>
<td>TP7</td>
<td>First</td>
<td>42.7%</td>
<td>0.6%</td>
<td>9.2%</td>
<td>25.03</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>70.1%</td>
<td>4.5%</td>
<td>16.2%</td>
<td>9.1%</td>
</tr>
</tbody>
</table>

The most common indication of discomfort for the prototype is that the TP try to off-load the pressure on the back by either wriggle or push the lower back forward by pushing the shoulders against the backrest. Other indications that can be seen is wriggling to fit better between bolsters, hands touching lower part of the back and wriggling to move further back on the seat cushion. The marked discomfort areas for the prototype can be seen in Figure 67.
The most common indication of discomfort for the IBC was that the TP placed the feet on the surface in front of the IBC. Other indications that could be seen was wriggling to relive load on the back, wriggling to get further back on the cushion and arms behind the head for support. The marked discomfort areas for the IBC can be seen in Figure 68.

**Comparison between objective and subjective result**

The result from the subjective data collection and the objective data collection shows commonalities regarding TPs perceived comfort and discomfort experiences. The most common indication of discomfort for the IBC was that the TP placed the feet on the surface in front of the IBC or by placing one leg over the other. Discomfort at TPs calves due to a hard edge were identified from the result from the subjective data collection. This were also identified from the result of user study one.

The most common indication of discomfort for the prototype was that the TP tried to off-load the pressure on the back by either wriggle or push the lower back forward. Other indications that could be seen was wriggling to fit better between bolsters. Discomfort due to narrow bolsters and hard foam were identified from the result from the subjective data collection. This were also seen in the result of user study one.

8.3 ANALYSIS TESTING AND EVALUATION

Children can distinguish comfort experience from discomfort experience. Although, it seems like children easier point out perceived discomfort and easier express themselves regarding the source to discomfort.

Some children indicated that the scale with the facial expression should have more options and noticed was also that no children marked the facial expressions that looked to perceive most pain. The numerical scale worked well and the children did not seem to be bothered to mark 1. Furthermore, they responded well to evaluation of comfort and discomfort experience of different body areas. To ask general questions with follow up questions gave a good response and a result that was detailed. This respond to the three goals for the user tests: Find out how children respond when asked to measure comfort/discomfort with scale questions, Find out how well children can evaluate different aspects of comfort/discomfort from general questions and Find out if children can distinguish a difference between the comfort/discomfort of different parts of the chair.

The illustration in the questionnaire made some children a bit confused regarding if they should mark perceived discomfort at all the illustrated angles. The information should therefore have been clearer and the hair on the illustration should not have been coloured black since this made it hard to mark perceived discomfort. Although, all children marked perceived discomfort in a way that agreed with their responses to the interview questions, which respond to the goal of user study one and two: Find out how children respond when asked to measure comfort with a coloring exercise.
The children seemed able to evaluate both initial and cruising comfort/discomfort as well as to separate the experiences and relate to them. Example: The cushion still feels soft and comfortable. Thereby the goal from user study two: Find out if the comfort impression differ before and after the car ride, is met.

Video analysis can give indications on experienced comfort or discomfort from test person but it doesn't revile the source of the experience. Children need to perform activities while traveling by car otherwise they become restless.

**Similarities between objective and subjective result**

The result from the objective methods and subjective methods somehow differed but the most critical areas were noticed with the use of both methods separately. Though the result from the subjective methods gave a more specific explanation of the source to discomfort. Which responds to the goal of user study two: Find out if the results from objective and subjective methods differ, and if they do in which way.

The goal: Find out if the result from the static and dynamic user tests differ is met. The result differs in some way and this may be because of the test environments as well as the dynamic impact of user study two. The result from user study two indicated that the comfort of the prototype seemed to be more appreciated after some time then initially. Besides that many of the identifications from the static study and the dynamic study are similar.

**The prototype backrest**

Because of manufacturing possibilities a foam with higher density than planned was used for the prototype backrest. Also glue joints made the foam even harder. The backrest was perceived as hard during the user studies and a softer foam would probably have been more appreciated. Perhaps then bigger children’s elbows and shoulders could have fallen in a bit in the bolsters and maybe the space between the bolsters would have been perceived as wider.

It is also possible that the children would not have perceived the backrest as so hard if the distance between the bolsters were bigger. Probably the bolsters are placed too close to each other, no matter foam hardness, since the TPs indicated discomfort on arms and described that they were pushed forward. It is not possible to validate from the results which of the children’s indications of discomfort that depend on the actual shape and which depended on the foam hardness. Even though it is clear that the shape and foam hardness are closely related and depend on each other.

The backrest is also perceived hard according to cruising comfort, but is more appreciated than for initial comfort. The bolsters in combination with the rounded shape behind the back seem to help the children to stay in position during the ride. Another solution to make the shape of the backrest fit more children could be to let the distance and the height of the bolsters be adjustable.

**The prototype seat cushion**

The seat cushion for the Integrated Booster Cushion (IBC) is too narrow and short for larger children. Likewise for larger children it is too narrow between the guiding loops on the booster cushion. When adding soft side supports on the seat cushion, as for the prototype, the seat is perceived wider. The use of a flexible width and length for the seat cushion would allow a better fit for a larger span of children.
The foam cushion testing shows that the thinnest foam cushion was perceived as too hard. The thicker foam cushions were both perceived as comfortable by most children and the optimal combination of foam thickness and hardness probably need to be investigated further. The IBC was both perceived as hard and soft by different TPs.

**The prototype headrest**

The use of a headrest is not validated in dynamic test, but questions in static test validates that the TPs prefer side supports when sleeping and resting. That result was seen both for prototype and high-back booster. The accurate length, in a forward direction, of side supports needs to be investigated further since 2/9 TPs wanted them to be longer. Although, from what could be observed during user study one the prototype head rest did not seem to block the TPs’ field of vision.

Vertical adjustability for the headrest side supports are crucial to make it possible for all children use them. The prototype is perceived as too hard behind the head by some, but the gap between the headrest and the original seat was not noticed which shows that it is possible to cover the gap and that soft foam behind head is important.

**The prototype foot support**

It is not validated that the foot support improves the comfort since too few TPs needed a foot support in the user tests. Although, if a foot support is included it advantageous if it the angle can be adjustable.

**Anthropometric measures and comfort/discomfort experience**

When comparing the TP’s anthropometric dimensions and the TP’s comfort/discomfort experience it was noticed that it was hard to identify any relationship. Probably this mostly dependent of the small amount of TPs participated in the two user studies. Most truly a greater amount of TPs would allow linkages between anthropometric measures and comfort/discomfort experiences to be identified.
9 RESULT

In this chapter the thesis result, comfort characteristics and methodology guidelines, is presented.

9.1 CHILD SEATING COMFORT CHARACTERISTICS

Seven comfort characteristics have been identified that enable children in different ages to ride comfortably in a safe position in the rear seat of a car. A concept idea illustrating the flexibility of the comfort characteristics are showed in Figure 69.

Figure 69 - Flexibility of comfort characteristics for concept idea. Dashed lines represent either flexible or fixed solution, lines represent flexible solution
The comfort characteristics are developed for a belt-positioning booster and are listed below. A belt-positioning booster should include or enable:

1. A vertically adjustable headrest with side supports that are removable or retractable
2. A backrest with bolsters that are either fixed or adjustable
3. Enough space for shoulders, back, arms, hips and head
4. Bolsters and headrest side supports are big enough to give support but do not limit the child's perceived movement possibilities.
5. A cushion that is adjustable in length and either fixed or adjustable in width
6. Seat cushion, backrest and headrest are perceived as soft
7. A vertically adjustable foot support with flexible angle that is removable or retractable

All the comfort characteristics are further defined below.

1. **Vertically adjustable headrest with side supports that are removable or retractable**

   Children value the ability to sleep in the car and side supports on the headrests improves the possibility to rest and sleep comfortable according to the participating children in the static study. According to the parents in the focus group, there is a risk that the side supports are perceived as unnecessary and inconvenient during shorter trips and thereby also uncomfortable. The side supports should therefore be removable or retractable for these occasions. To fit children’s different lengths without risk that the side supports interact with the seatbelt the whole headrest need to be vertically adjustable. Children that did not reach the original seat head support in the static study perceived it as uncomfortable.

2. **Backrest with bolsters that are either fixed or adjustable**

   Bolsters need to be included in the belt-positioning booster to keep children in a more centered and acceptable position for a longer period of time during the ride according to the results from the on road study. Furthermore, the bolsters can be integrated with a rounded shape behind the shoulders as in the prototype to keep children in position.

   To avoid discomfort it has to be enough space between the bolsters for all children in the target group. This can be accomplished by making either fixed or flexible bolsters. A fixed design demand a carefully considered combination of the right shape and foam firmness to allow a span of children with different dimensions. This since the bolsters are perceived as uncomfortable if the shape does not fit and the foam is too hard. A flexible design for the bolsters can allow a better flexibility of the backrest shape. The height of the bolsters should then be flexible as well as the distance between the bolsters.

3. **Enough space for shoulders, back, arms, hips and head**

   According to the test persons in the user studies, children need to perceive that they fit well in the belt-positioning booster in order to feel comfortable. Thereby, the backrest should embrace the child without the giving the perception of being push forward or not having enough space for shoulders, back and arms. For the same reason, the seat cushion needs to allow also bigger children space for the hips. The perception of falling off the booster or not fit between too narrow guiding loops is perceived as uncomfortable.
The seat cushion needs to be wider than 325 mm if no side bolsters are included in the design. If the space between the headrest’s side supports are too narrow they rub against the children's ears and give an uncomfortable impression.

4. **Bolsters and headrest side supports are big enough to give support but do not limit the child’s perceived movement possibilities.**

According to the result in the user studies, it will improve the child’s position, and in some cases comfort, to give the child the right support around upper body and the head. Especially when the child wants to sleep. Although, if the side supports are exaggerated the risk is big that instead block the child's field of vision or possibilities to move comfortable. Thereby it will instead lead to perceived discomfort or extended movement if the child try to get away from the bolsters.

The static study shows that to get the right depth for the side supports, 12 cm is a good starting point. Then the field of vision should not be blocked and most children perceive the comfort as good.

5. **Cushion that is adjustable in length and either fixed or adjustable in width**

In the user studies the length of the belt-positioning boosters are good for shorter children but are often perceived as too short by taller children. On the other hand, if the cushion is too long the risk of slouching increases and thereby also the safe risk. The belt-positioning booster thereby needs to be adjustable in length to be both safe and comfortable for all children in the target group.

Since a too narrow seat cushion was perceived as uncomfortable during the user studies, the width needs to fit all children's dimensions in the age span for the belt-positioning booster. Furthermore, the user studies show that the seat cushion is perceived as more comfortable if the child feel the support by bolsters on the sides of the seat cushion. Thereby should an adjustable dimension between the side bolsters on the seat cushion accomplish a better perceived comfort for children with different dimensions. Although, as long as the seat cushion is wide enough, a fixed solution with the right foam and shape would also work.

6. **Seat cushion, backrest and headrest are perceived as soft**

All children in the user studies enjoy the feeling of softness and the perceived softness strongly affect the perceived comfort. Behind the back, around the head and under the buttock are the foam thickness and softness important factors for comfort.

According to children in the user studies, the belt-positioning booster is perceived as too hard when:

- When the foam behind the back has a density of 75 kg/m³ and includes glue joints, even if mounted directly on original seat and no hard components are included.
- When the foam under to buttock has a density of 55 kg/m³ and is 15 mm thick.
- When the foam behind the head and on the headrest side supports has the density of 75 kg/m³

According to children in the user studies, the belt-positioning booster is perceived as soft when:

- The foam under the buttock is 4 cm thick and has the density 55kg/m³ or 35kg/m³.
7. Vertically adjustable foot support with flexible angle that is removable or retractable

A foot support was identified as needed for the children by the parents in the focus group. None of the children in the user studies reacted negatively on the foot support regarding the comfort, although some children expressed that having it in a different angle would improve the comfort. If the foot support is included it should therefore have a flexible angle and be adjustable in height due to children’s different body height. Since the taller children reach the floor while they still need a belt-positioning booster the foot support should be removable or retractable.

9.2 CHILD SEATING COMFORT METHODOLOGY GUIDELINES

When evaluating child comfort for belt-positioning boosters in rear seats of cars these 13 guidelines should be taken into consideration:

1. **Include children in evaluation process**

   Children are the primary users and to get a reliable result they should be the ones evaluating the comfort level of a concept or product of a belt-positioning booster. By only include anthropometric dimensions and adults thoughts of comfort, knowledge of children’s subjective opinions will get lost. Therefore it is beneficial to arrange comfort evaluation studies with children.

2. **Ethical considerations**

   When including children as testers in an evaluation process there are several ethical considerations to take into account. The participants have to know the aim of the study, that their participation is voluntary and is performed on their conditions as well as that they are allowed to end the study without consequences. The participants rights, overall information about the study and that personal information will be handled according to the law, need to be summarized in an attendance agreement that both guardians, and preferably also the child, have to sign before the actual participation. It is important that the participating child is aware of the information stated above to assure that the participants can feel comfortable in the test environment.

3. **Power balance between children and adults**

   The power distribution between adults and children is usually unequal, such as that adults have the right to decide and know the difference between right and wrong. This is not the case in an evaluation study were the children are the testers. This since children are invited because they know something the development team do not. It is important that the children understands that their opinions and though are the one that maters and not what the children think is the right thing to say. It is important to create an as even power balance between the child and the researcher as possible. This can be achieved through invite children as experts as well as to converse with the children before the performance. Another is to avoid leading questions as much as possible.
4. **Clear instructions and use of language adapted to meet the test persons**

Minimize the risk of children interpret or understand instructions and/or questions differently than planned. This is accomplished by have a clear introduction with short sentences and include easy and straightforward questions. Always start with an open question, it can be followed up with a more specific question to verify that the answer was understood in the right way. It is important to pilot the evaluation study in order to verify the instruction and the arrangement.

5. **Age considerations for the participating children**

When children reach the age of 6-7 years they have developed their linguistic abilities and their abilities to think more abstract and relate as well as draw conclusions from previous experiences. These abilities make them respond well in an evaluation setting including different evaluation methods, similar to the subjective methods used during the user studies presented in this master thesis project. It is possible to evaluate comfort with younger children as well, but the evaluation methods need to be simplified and be performed during a shorter time because of a smaller attention span for younger children.

6. **Group vs individual evaluation**

Children tend to influence each other when evaluating in a group setting. To assure as unbiased evaluation result as possible children should evaluate one by one. Although, if a discussion is wanted about the comfort a small group can evaluate together to afterward help each other to express their thoughts in a discussion setting.

7. **Subjective and objective comfort evaluation methods**

When evaluating comfort with children subjective methods give a more detailed result and it is easier to identify the reason for discomfort when talking to the child than observing it. Overall subjective methods work well when evaluating comfort with children in the age span 7-11. Although, for children that are too young to express opinions in a satisfying manner objective methods can give indications of perceived discomfort by observing positions and behavior in the car.

8. **Quantitate and qualitative data**

Children old enough to express own opinions and reflect over the result correspond well to both questions including scales and general questions. Numerical scales with 10 steps works well and in order to give the child the right amount of options a scale shall include more than 4 options. Scales with facial expressions also works well. Comfort evaluations with children should include both quantitative and qualitative questions in order to easily analyze the result quantitatively and identify the reasons for discomfort qualitatively. For younger children it can be hard to understand the abstract level of a scale and thereby it is better to only include qualitative questions.

9. **Verification through the use of multiple methods**

All children are different and some can have harder to understand questions than adults. It is therefore a good idea to include different kind of evaluation methods during the evaluation session to validate the answers. It can be done by including different kinds of scales, a scale together with a coloring task, similar to the illustration used in the user studies, or combining open questions with antonym word pair tasks. It also works well to include follow-up questions to validate children's answers. During on road studies a moderator shall be present in the car.
during the ride in order to observe and interact with the child to be able to identify reasons for the user’s behavior.

10. **Comfort/discomfort experience of different body areas**

A comfort evaluation should include questions and scales for overall comfort/discomfort experience. It should also include comfort/discomfort experience regarding different body areas and this can be assessed with general questions as well as scales for the experience regarding the body areas. Suggested body areas: Under the buttocks and thighs, behind the back, shoulders and arms, behind and around the head and neck as well as under and around the legs.

11. **Evaluation of comfort vs discomfort experience**

Children can evaluate both comfort and discomfort. Although, they have harder to identify reasons for perceived comfort than reasons for perceived discomfort. High comfort can only be obtained if the feeling of discomfort is low. Therefore it is important to identify discomfort and the source to the discomfort experience. Older children, approximately seven years and older, are able to identify comfort around one part of the body and discomfort around another part.

12. **Comfort experience changes over time**

Children are able to identify a difference between initial comfort and cruising comfort. Thereby comfort evaluation studies should include both studies of initial comfort and cruising comfort.

13. **Safety regulations for on road studies**

There are many safety regulations for driving with children on roads. If the plan is to evaluate a concept's comfort some kind of certified child restraint system needs to be integrated in the concept prototype to protect the child in case of collision.
10 DISCUSSION

In this chapter all phases will first be discussed and afterward a discussion about thesis methods and thesis result will be held.

10.1 Thesis Method Discussion

In this chapter different aspects of the thesis method is discussed, first from each phase and in the end more overall aspects.

10.1.1 Method discussion - Discovery phase

From the discovery phase knowledge in the child comfort field was gathered from several different perspectives; theory, existing products, experts’ knowledge and parents’ experiences. To keep the strength of different perspectives during the creation of customer needs four different perspective questions were used as a starting point for the brainstorming sessions. That these different perspectives were used all through the discovery phase was a great advantage for the later process since it was all from the beginning known why products looks as they do, what safety aspects that affects the comfort as well as which comfort parameters that were needed but have not yet been prioritized.

However, all customer needs were written from adults points of views since no children had been included in the thesis so far. According to Johansson & Karlsson (2013) adults sometimes thinks they have an idea of knowing what children think and wants. Furthermore, Doveborg & Pramling Samuelsson (2001) argue that children’s experiences and thoughts often surprises adults since adults commonly design things for children out of their own experience and thoughts. Thereby, children preferably should have been included even earlier in the thesis process to assure that the right customer needs were formulated from the beginning, for example by confirm or turn down the defined customer needs in order to secure there probability.

A focus group similar to the one with parents could have been valuable to perform with children to identify the children’s attitudes, experiences and wishes regarding belt-positioning boosters before the customer needs were defined. However it was a good starting point to include the secondary users, since they are the ones interacting with the products and the primary users during the use. It is also easier to gather specific information from adults. Furthermore, the children’s comfort aspects were identified for the rest of the process, to compensate that they were left out in the initial phase. Thereby if any parameters were missed in the initial phase it was hopefully compensated for in later stages of the process.
10.1.2 Method discussion – Development phase

According to Doveborg & Pramling Samuelsson (2001) children as well as adults takes things in everyday life for granted, though what is taken for granted seems to differ between adults and children. This was obvious since none of the parents could come up with the ideas of comfort solutions that the children did, even though there were solutions that are often seen for adults’ seats. Although, the user wishes and comfort aspects that were collected from the primary users during the workshop session were not included in the prototype design due to technical difficulties. If the prototype would have included children’s wanted comfort features, as the intension was with the workshop, it would probably have affected the comfort experience positively for the children. Thereby the decision of including a workshop as a complement to the first phase can be seen as positive.

Furthermore, the choice of designing the prototype by the anthropometric design method by Osvalder, et al. (2010) was a good idea according to theory. Although, the method is not developed specifically for comfort experience. Since the comfort experience is affected by more parameters than just dimensions (De Looze, et al., 2003) it would probably have gained the prototype design if children could have been used during the development process rather than virtually manikins and crash test dummies. Children would have been have to identify aspects as subjective opinions and experience of the shape, foam hardness. These aspects where hard to identify with just objective measurement methods. Although, the anthropometric measures worked satisfactory regarding measurements for the head side supports and the foot support. Together with knowledge regarding comfort from VCC it also gave indications regarding the design of the backrest and the side bolsters.

In the prototype development process identified safety requirements also limited the design options for the prototype. Since the safety requirements only counted for the on road study a discussion between the researchers and supervisors was held during the process regarding development of two prototypes: One where safety aspects were considered and one that could focus only on comfort requirements. The conclusion though, was to only develop one prototype that could be used for both studies to maintain the possibility to compare the comfort result. Thereby it was possible to identify differences in experience regarding initial comfort and cruising comfort as well as if there were any differences for how well the methods worked during the two studies.

10.1.3 Method discussion - Testing and Evaluation phase

It was shown during the user studies that children in the age span for the user studies, 7-11 years, are able to evaluate comfort and discomfort experiences and that data can be collected by the use of subjective methods and objective methods. The decision of only include children from 7 years and up seem to have affected the comfort result in a positive way. This decision though lead to that it from our study is hard to validate how young children are when starting to develop a more abstract way of thinking. Although, Karlsson (2013) writes that there are researchers including (Angeliki & George, 2008) which consider that children around eight to ten years and upwards have developed an understanding for abstract ideas. Thereby, the children included in the study were probably in the right age for the evaluation methods used.

That the researchers were present during the comfort evaluation was experienced as positive since the children sometimes had problems to tell why they perceived comfort
and/or discomfort. According to Sorbring (2013) one advantage with having the researcher present during the performance of questionnaires is that the researcher can be sure that the child has understood his or hers rights as well as that the researchers could ask follow up questions if the child seemed to be uncertain or to verify the child's answers.

Although, Sorbring (2013) also argue that the participant’s answers may though become less sincere because of the present of an adult and therefore it is important to create an equal relation between the researcher and the child. To try avoid this aspects the children were invited as experts and open and general questions were initially asked in order to not limit the children's answering options. Furthermore, Sorbring (2013) writes that to cover as much as possible when developing a questionnaire regarding a subject, several sub themes can be created and to make children take a stand scales can be used in relation to questions or claims. This aspect could have been taken advantage of more, at least in the static study, since it was also noticed that the children could separate comfort and discomfort experience both for one body part and for the overall experience. Thereby, in addition to the overall numerical scale, more rating scales could have been used to evaluate comfort/discomfort experience regarding different pressure areas, like example their back and arms and their buttock. By including more scales it would also be possible to make the user study more similar to the comfort clinics that VCC are performing with adults today as well as more quantitative data could have been gathered.

Overall, the use of scales were generally working in a satisfying manner and the use of two scales also verified the children's answers. Furthermore, opposite statements related to comfort or discomfort as well as an illustration of a body where discomfort was marked worked satisfactory.

Although, for user study two the interview form and the questionnaire could have been shorter. Hansen Orwehag (2013) states that when developing methods for research with younger children it is important to consider that younger children's attention is of short duration. This seemed to have been the case for the on road study, even if the children were older. Fewer questions and tasks may facilitate for the children to keep focus. Furthermore, more questions could have been asked even during the ride to collect impressions and keep the focus on the comfort aspects. Though it worked satisfying to use the same arrangement when collecting data initially and in the end of the drive in order to be able to notice differences.

In a study by Osvalder, et al. (2013) the children were busy with a number of activities for the majority of travelling time and thereby frequently changed positions. This was something that was tried to be avoided by not letting the children perform other activities than looking through the windows, talk and eat. Even though, during the car ride some activities that would not affect the children's sitting positions much could have been included. Maybe a short movie, some tasks like riddles, or an audiobook could have been used to prevent the children to be bored. User study two also strived to imitate an everyday experience and this may have caused that some of the TPs lost concentration. Furthermore, there were things happening outside of the car that distracted the children during the study, such as keeping track of the other car in the user study.

According to Ziolek (2014) it is also important to be aware of that the initial fatigue can bias the results. Therefore vehicle seat rated in the end of a test day of an on road study could be given lower comfort scores. The subjective data can then be compared with objective data like observations and body measures. The objective method used in the second user study worked well concerning identification of the TP's position but perhaps it is not a well working method for comfort evaluation by itself. Positioning indicating discomfort was noticed. This for example that some children put up their feet when riding on the IBC also indicated discomfort at their calves when evaluating subjectively. Though the video observations alone do not identified the source to the experienced discomfort.
10.1.4 The included test persons

A bigger amount of test persons could have given a more specific result from the user studies. This especially if the anthropometric dimension spread was greater. Then probably conclusions could have been drawn regarding body dimensions and comfort/discomfort experiences. No test persons had bigger bodies, most of them were rather thin and the result would have been more reliable if the distribution had been greater.

The children included in the workshop sessions and the user studies were all children to employees at VCC. This probably made the children more thrilled about being included since they with their participation could help at their parents work. This could have helped the children to stay focused and taking it serious and in that way made it easier for the moderators to perform the study. Though it is believed that the result from the studies have not been affected in a negative way by this.

Even though the primary users should have been included more during the study it was a strength that they were included both as design partners and testers. According to Druin (2002) the child in the role of a tester can contribute with their experience that can be used in further iterations, and by include them as design partners children can contribute with their expertise and point of view equal to the adult designers.

10.1.5 Comfort vs. comfort methods

Overall the study focused on many parameters regarding comfort and discomfort and more delimitations could have lead to more specific results regarding the concept idea. For example the study could have been delimited to only work with how a comfortable headrest should be developed or only the backrest and the bolsters. Than more specific results like measurements, foam hardness and shape for the whole target group could have been produced for the specific parts. Though it was an advantage to try out many different comfort aspects for the methodology since the primary users were able to evaluate different aspects.

Even though that the arrangement and the methodology for user study two needs improvement it was identified that the result from user study one and user study two differed. This as well as differences were identified regarding initial comfort experience and cruising comfort experience. Therefore it was a strength that both a static and an on road study were performed.

10.1.6 Ethical considerations

Since the child's experience of adults often include the adult's authoritarian position (Johansson & Karlsson, 2013) and this structure of our community can prevent children to voice their opinions (Christensen & James, 2000) the all user studies were designed on the children's conditions. To make the children aware of the importance of their participation, they were invited as and called experts, during the workshop they were even equipped with expert nameplates, which seemed to be appreciated. Thereby the children already from the start knew that they were better than the adults in this subject. Even though some parents at some circumstances tried to influence their children to concentrate better or to express themselves, the presence of the parents was overall good since it seemed to comfort the children. Some children did for example not want to participate in the expert
panel activity during the workshop and the parent could then keep the child company during the activity and support the child to try out the seats afterwards when there were less other children in the room.

10.2 RESULT DISCUSSION

In this chapter different aspects of the thesis result is discussed, first from each phase and in the end more overall aspects.

10.2.1 Result discussion – Development phase

The choice of using an Integrated Booster Cushion (IBC) as a base, in order to use a certified belt-positioning booster under the buttock, affected the design of the prototype seat cushion. Since the IBC was never included in the Expert panel evaluation during the workshop sessions the researcher had not been able to collect information about the children’s ideas about it. Although, it seemed like the best alternative since it was noticed in a study by Osvalder, et al. (2013) that children enjoyed the soft seat cushion and furthermore, the result from the performed focus group indicated that children perceived the IBC as comfortable. Thereby it seemed as a good chance to include a soft seat cushion in the prototype design without making any modifications to the cushion. Furthermore, it was considered more difficult to re-design a high-back booster than adding a backrest to an IBC.

10.2.2 Result discussion - Testing and Evaluation phase

Hägg, et al., (2011) state that that it is important to be aware of that the perception of comfort and discomfort differs over time. These tendencies could be seen foremost for the prototype when comparing the results from user study one and two. In user study one almost all children perceived discomfort due to the backrest but in user study two only three out of seven experienced the bolster as too narrow and hard. The prototype also got a higher cruising comfort score than initial comfort score. Perhaps children think they want more space in a static setting but tighter bolsters are perceived as more comfortable when they actually ride in a car. Although, it is clear from both user study one and to that children needs to perceive softness around head, back and under the buttock to feel comfortable. They also need to fit in the belt-positioning booster, while the dimensions and shape are of big importance.

Osvalder, et al., (2010) argue that it is difficult to quantify subjective comfort evaluation methods and draw conclusions for a whole population from the subjective result. They further argue that the subjective result thereby should be linked together with objective observations of changes in behavior to get a better understanding and to increase the reliability. The objective results in user study two shows that the TPs were seated more time in a good position when seated on the prototype than on the IBC. Thereby a linkage between the subjective and objective result was accomplished which validates the fact that the comfort for the prototype was changing over time.

Even though both the objective and subjective result showed that the prototype was more appreciated after some time the aspect of restlessness or boredom can have affected the result. De Looze, et al., (2003) suggest that comfort is influenced of human’s individual
expectations and emotions, and for some TPs it could be seen that the score dropped more and more during the test independently on which booster they tried. Also if looking on the total time the TP was in an acceptable position, some tendencies can be seen that the TPs tend move more on the second booster they try. Although, no mayor differences can be seen when comparing the time when the TP indicate activity or boringness. Thereby, the objective result should not be affected too much of the restlessness aspect.

Another thing that might have affected the result was that it was sometimes hard to identify the reasons to why children moved. Movements in order to speak to the parent and the moderator in the front seat as well as movement to look out of one of the cars different windows were common and easy to identify. Though movement that could be due to discomfort like wriggling were harder to identify and specify. It was hard to differ if children for example held on their back because of discomfort or if scratching. One of the TPs also showed tendencies of wriggling when he/she was given attention from the parent or moderator and it was hard to identify if this was the case or if he/she was experienced discomfort by just looking at the video. This interpretation of positions could have affected the deviation of time in different positions, but not the total result.

### 10.2.3 The prototype’s affection on time in position

For the second study it could be seen that children were seated in an acceptable position for a longer amount of time for the prototype than for the IBC. In a study by Osvalder, et al. (2013) it is shown that children seated on an IBC tends to let their feet rest on the adult cushion base bellow the IBC. This was a behavior that could be seen for the IBC in the on road study as well, but never for the prototype even though it is based in the IBC. This could eighter be because of the shorter seat cushion on the prototype or the fact that the seat cushion cover coved the hard egde and thereby made it a bit softer.

During a nighttime study carried through by Forman, et al. (2011) it could be seen that the bolsters have an importance for children's lateral position while sleeping. Although, big side bolsters on high back boosters seems to increase a forwardleaning position for children (Andersson, et al., 2010). This was not something that could be tried during the on road study, due to the safety requirements of the prototype headrest, although several of the participants in the static study expressed a need for side support to be able to sleep. Only two children thought the side supports of the headrest on the prototype were too small and noone explain on blocked field of vision. This shows good tedences of find a dimension that both allows children to sleep and stay in position.

A study by Osvalder, et al., (2013) showed that children seated on a high-back booster spent less time sitting with the upper back and shoulders in contact with the backrest compared to the IBC. Even though, a study by Jakobsson, et al. (2011) they conclude that children using a belt-positioning booster are less likely to move laterally and Andersson, et al. (2010) performed a study where the children were positioned almost constantly between the side supports in the two different high-back boosters during the ride. The on road study in this master thesis was not designed to separate the lateral and forward positions but only when the child were out of position. Thereby, it is hard to validate if smaller bolsters both make children move less laterally and forward, which is something that should be invastigated further.
10.2.4 Methodology guidelines

During the process different kind of methods have been tested and evaluated to learn and test as much as possible about child comfort evaluation methodology. The methodology guidelines have thereby been defined and verified during the process, which has included different elements and perspectives. Furthermore, the outcome of the prototype not being experienced as very comfortable during the user studies turned out to be advantageous for the methodology guidelines. By receiving a bigger range of opinions, both positive and negative, that could be taken into consideration in the methodology exploration it could be validated that children know how to evaluate both comfort and discomfort, and give both high and low ratings regarding both aspects.

10.2.5 Comfort hypotheses

Five comfort hypotheses (CH1-5) were formulated to be answered during the process and by the final result. All hypotheses are not possible to either turn down or confirm, mainly due to complications during the process that did not make it possible to test all parts of the prototype as planned.

**CH1:** Thicker foam in seating and backrest will lighten the static load and thereby make children: a) sit more comfortable and b) keep the children in the same position for a longer period of time.

From the comfort result it is clear that only adding thicker foam will not necessarily improve the comfort level. If the foam is not soft enough the children will still perceived the belt-positioning booster as too hard and uncomfortable. The combination of foam thickness, foam hardness and shape are main factors for affecting the perceived comfort. In the result it is not possible to validate if the foam thickness increase the time children are in position. Although, since comfort and motion are correlated it seems reasonable to assume that also the time in position would be affected to the right combination of shape, foam thickness and foam hardness.

**CH2:** Foot support will relief load on thighs and calves and thereby: a) Make children in wider age span sit more comfortable b) Decrease movement.

It is not possible to identify if the foot support improved the comfort for the prototype, mainly because no question according the foot support was included in the user tests. Since only two children in the on road study needed a foot support it is not possible to validate weather the foot support decreased the movement neither. Although both TPs using the foot support moved less on the prototype than on the IBC. This indicates that the foot support can have been a part of the decreased movement, but it can also have been because of other reasons such as the added bolsters.

**CH3:** Headrest with the right size on side supports will allow children to: a) Look out through the front and side window without leaning forward, b) Sleep and rest their head in a comfortable position, c) Sleep and rest in position

Since it of safety reasons were not possible to include the prototype headrest in the on road study, it is not possible to say if the children would be able to look out through the windows in position while driving nor of they can sleep and rest in position. Although, observations during the static study indicated that the side supports should be small enough to enable the child to look out while in position. The answers from the static study show that the size of prototype side supports would make it easier for the children to sleep in a comfortable position. The results thereby shows tendencies of the CH3 can be
confirmed with the prototype headrest, but further testing needs to be done to get it validated.

**CH4:** *Soft bolsters with the right size will: a) Improve the impression of good comfort since children feel embraced, b) Give support but still give the perception of free movement, c) Prevent children from extreme positions, d) Improve support for children during dynamic impacts as turning.*

Since the bolsters on the prototype were not perceived as soft CH4 is difficult to fully validate. Although, user study one shows that the initial comfort around the back was very dependent on how much space the TP perceived it had for arms and back. If not enough space was perceived the TP considered it as uncomfortable, which shows tendencies of that children, at least for initial comfort, not necessarily enjoy feeling embraced. Even though, the result from user study two shows that none of the children experienced that they slide when the car turned, two stressed that the backrest gave them support and the observation showed a better total time in an acceptable position compared to the IBC. In addition to this, none of the children stated that they felt restrained by the bolsters. Thereby, promising indications for fulfilling CH4b-d have been shown if softer bolsters would have been tested.

**CH5:** *A flexible solution can allow several children a good comfort while a fixed solution can allow perfect comfort for a few children*

During the workshop and the two user studies it was foremost the fixed features that were considered as uncomfortable. For example was the high-back booster with small bolster not involved in the two user studies after too many of the children expressed that the fixed headrest side supports were placed too far down during the workshop evaluation activity. Furthermore, the dimensions of the seat cushions and the distance between the backrest bolsters were often commented as too short or too narrow. The features on the belt-positioning boosters that were adjustable were not at all criticized, such as the vertically adjusted foot support and headrest. From what this thesis has been able to test, CH5 is considered validated.

### 10.3 FUTURE WORK

Further studies need to be performed in order to specify how a solution is design with an accurate comfort experience for the whole span of children in the target group. These are the aspects that need to be further explored:

- **The optimal dimensions for a backrest.** The foam hardness, foam thickness and shape need to be investigated further for initial and cruising comfort. Both a fixed solution for the target group and a solution with adjustable bolsters in height and width is of interest.

- **Evaluation of cruising comfort for a headrest with right-sized side supports.** The dimensions for the prototype headrest can be used as a starting point, but the shape and the foam hardness need be investigated further.

- **Further evaluation of a foot support’s effect on the comfort experience.** This needs to be investigated both for initial comfort and cruising comfort and should preferably be studied in a higher car like a Volvo XC60.
• Adjustable height for the booster cushion seat. It was observed during the study that some children were seated too low in the car to be able to look out through the side windows while seated in position.

• The comfort aspects identified in the workshop. Children express wishes for adjustable angle on the backrest, temperature regulation and a massage system.

Furthermore, some aspects of the arrangement and methodology for comfort evaluation on an on road study needs to be investigated further. These are the aspects that need to be further explored:

• Which activities to include during an on road study. The activities need to counteract that the child get bored or restless during the duration of the study. The included activities need to be adapted to the study’s focus to not affect the result; thus the comfort/discomfort experience and the time duration.

• A subjective evaluation method containing fewer steps. The evaluation as well as how to include it better during the ride need to be investigated further. This in order to better identify comfort/discomfort aspects that occurs during the ride.

• A suitable objective method to better validate the subjective.

From the workshop with primary users other user wishes than the one regarding comfort were collected. If designing a new belt-positioning booster these are also aspect that should be considered and further investigated:

• Children think that common belt-positioning boosters have boring colors. The style of a developed belt-positioning booster can be further investigated and perhaps different designs on replaceable covers could suit the whole target group.

• Availability to eat and store snacks when seated in the car. Children propose solutions such as removable tables similar to the ones that can be seen in airplanes or trains.

• Place to charge and store devices, such as mobile phones and tablets.

Even if secondary users are not the one affected by the comfort, several features on a belt-positioning booster affect them as well. Since the parents often are the purchaser it is important that these aspects are fulfilled as well to assure they buy the right belt-positioning booster. Aspects important for the secondary users are:

• Ease to mount and dismount
• Flexible to transport and store
• Fit together with to more belt-positioning boosters in the rear seat
• Work even if the parent has its own car, car pools etc.
• Neural color to make it easy to resell
11 CONCLUSIONS

This chapter presents the final conclusion by answering the two research questions for the thesis.

**RQ1:** How can a belt-positioning booster support a child to sit comfortable and safe positioned in the rear seat of a car?

To make children sit comfortable and safe positioning in the car they should be seated in a belt-positioning booster with a headrest, backrest, seat cushion and a foot support. Furthermore, to make the child perceive the ride as comfortable the belt-positioning booster’s supporting parts need to be perceived as soft around head, back and under the buttock. It is also of great importance that the child feel that they fit inside the belt-positioning booster why all parts need to be dimensioned for all children in the target group. Thereby, the size of the belt-positioning booster and the combination foam thickness, foam hardness and shape are the main factors for affecting the perceived seating comfort for children. Furthermore, children wish for a solution that include an adjustable backrest, temperature regulation and a massage system to improve the comfort for the belt-positioning boosters.

**RQ2:** Which methods are suitable when collecting data with children as the target group?

Initially in the process children are preferably invited as design partners to collect their needs and user wishes and parents can in this stage be invited as secondary users. For that purpose suitable methods are focus groups, brainstorming or interviews with both parents and children.

To develop prototypes is a good way to collect information about what children think about different comfort aspects. During a development process static comfort evaluation, and if possible cruising comfort evaluations, should be done repeatedly with primary users from the target group. This to verify measurements, shape and foam hardness. For height and length dimension studies can be performed with anthropometric devices, such as glock test dummies, as references.

If a prototype is manufactured it should be included in a larger static evaluation with primary users in the target group, preferably with existing belt-positioning boosters as references. The number of users should enable conclusions to be drawn between body measurements and comfort/discomfort experience. At this stage a dynamic study need to be included in order to verify the cruising comfort. A moderator shall preferably be present in the car during the ride in order to observe and interact with the child to be able to identify reasons for the user’s behavior.
**RQ3:** Which methods are suitable when evaluating seating comfort with children as the target group?

When evaluating seating comfort with children subjective data shall be collected during comfort evaluations, both quantitative and qualitative. The quantitative data can be collected through rating scales, marking discomfort on illustrations and opposite statements. The rating scales should only be included if the children are older than 6-7 years old. Qualitative data can be collected by general questions regarding comfort/discomfort experience. Both quantitative and qualitative evaluation can be gathered from both for overall comfort experience as well for specific body areas. Quantitative data makes it easier to identify linkages regarding the experience while the qualitative data verify and complete the quantitative data.

Video observations can be used to identify how the children are positioned during rides and together with subjective data the reasons for repositioning can be identified. In order to evaluate the video observations time for different positions can be timed.
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Appendix A – Questions for semi-structured interviews

Interview questions for semi-structured interview with Isabelle Stockman

- Hur la ni upp studierna med barn?
  o Vilka åldrar var barnen i studierna?
  o Hur stora var skillnaderna i åldersspannet?
  o Vad är bra att ha i åtanke under studierna?
  o Hur reagerade barn med/utan föräldrar? Någon av alternativen som är att föredra?
  o Fick barnen något för att de ställde upp?
  o Vilken metodik låg i grunden till studierna?

- Vilken var den vanligaste orsaken till att barn kom ur position?
  o Kunde ni se vilka utgångspositioner som var farligast?
  o Vad var de största skillnaderna mellan små och stora barn?
  o Vilken position ledde till att barnen klarade manövrarna bäst?
  o Såg ni några betydande skillnader mellan stol och kudde?
  o Användes IBK:n i någon studie?
  o Vilka är dina åsikter om kuddar/stolar och stöd (fotstöd mm)

- Vid vilken ålder/längd anser du barn bör sitta på kudde stol?
  o Vilket spann bör vi inkludera i studien?

Interview questions for semi-structured interview with Katarina Bohman

- Vad är det bästa en bilkudde/stol kan tillföra?
  o Vad vill man uppnå?
  o Hur kan en riktigt dålig bilkudde vara utformad?

- Vilka tidigare studier anser du skulle vara bäst att studera?

- Kan du rekommendera några metoder?

- Vad har du kommit fram till angående real life safety kopplat till komfort?

- Hur jobbar man med komfort vid utveckling av säkerhetssystem för barn?

(Ta med frågor intervju med Isabelle Stockman om det känns relevant under intervjun)
Appendix B – Scored identified risks

The risks refers to the risks that were identified during the creation of hypotheses and the specification of requirements.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaning forward</td>
<td>3</td>
</tr>
<tr>
<td>Lateral movement</td>
<td>3</td>
</tr>
<tr>
<td>Rotate</td>
<td>3</td>
</tr>
<tr>
<td>Slouching</td>
<td>3</td>
</tr>
<tr>
<td>Feet outside CRS</td>
<td>3</td>
</tr>
<tr>
<td>Not properly restrained</td>
<td>3</td>
</tr>
<tr>
<td>Move seat belt away from safe route</td>
<td>3</td>
</tr>
<tr>
<td>Negative attitude toward CRS</td>
<td>3</td>
</tr>
<tr>
<td>Hit hard edges</td>
<td>3</td>
</tr>
<tr>
<td>Tilt head</td>
<td>2</td>
</tr>
<tr>
<td>Misuse</td>
<td>2</td>
</tr>
<tr>
<td>Stop using CRS too early</td>
<td>2</td>
</tr>
<tr>
<td>Travel without CRS</td>
<td>2</td>
</tr>
<tr>
<td>Frustration</td>
<td>2</td>
</tr>
<tr>
<td>Does not look comfortable</td>
<td>2</td>
</tr>
<tr>
<td>Skewing</td>
<td>2</td>
</tr>
<tr>
<td>Prefer the type of CRS they are used to</td>
<td>1</td>
</tr>
<tr>
<td>Arms outside CRS</td>
<td>1</td>
</tr>
<tr>
<td>Seat belt not straightened enough</td>
<td>1</td>
</tr>
<tr>
<td>Do not buy the most comfortable alternative</td>
<td>1</td>
</tr>
</tbody>
</table>
## Appendix C – The hypotheses table

<table>
<thead>
<tr>
<th>Reformulated customer needs</th>
<th>Design parameters</th>
<th>Hypotheses</th>
</tr>
</thead>
</table>
| Children search for a comfortable position | • Soft seat cushion  
• Soft backrest  
• Foot support  
• Support for thighs and/or calves  
• Head support  
• Bolster | • Thicker foam in seating and backrest will lighten the static load and thereby make children sit more comfortable  
• Padding around critical areas for calves and thighs will make children in wider age span sit in a more comfortable position  
• Foot support will lighten load on thighs and calves and thereby make children sit more comfortable  
• Head support will allow children to sleep and rest their head in a more comfortable position  
• Smaller, soft bolsters embrace the child and thereby improve the impression of good comfort | |
| Children will change positions inside the CRS | • Bolsters  
• Soft seat cushion  
• Soft backrest  
• Foot support | • Bolsters will prevent children from extreme positions  
• Thicker foam in seating and backrest will lighten the static load and thereby keep children in the same position for a longer period of time  
• Foot support will lighten load on thighs and calves and thereby increase movement  
• Smaller, soft bolsters embrace the child and thereby give some support but still gives the perception of free movement | |
| Children perform activities during the ride | • Bolsters  
• Elbow/arm support  
• Head support | • Bolsters will prevent children from extreme positions  
• Elbow/arm support will help children play with a device in a straighter neck position  
• Head support will allow children to sleep and rest in position | |
| Children grow, both physically and physically  
• Affect size and flexibility of CRS  
• Affect attitude towards CRS | • Flexible width  
• Flexible height  
• Flexible length  
• Overall design | • A flexible solution can allow several children a good comfort while a static solution can allow perfect comfort for a few children  
• The preferred design of a booster changes over the years | |
| The CRS is placed in a dynamic environment | • Bolsters | • Bolsters on backrest and seat cushion will allow better support for children during dynamic impacts as turning | |
| Children want to buckle themselves up | • Bolsters  
• Height of booster | • Smaller seat bolsters make it possible for children to reach the buckle by themselves  
• The possibility to lean over bolsters affect the possibility for children to buckle themselves up  
• A lower booster makes it easier for children to buckle themselves up | |
| Children should be able to look around/out | • Bolsters  
• Headrest | • Small bolsters will give children support while looking through window without blocking the view  
• A headrest with smaller side supports will allow children to look out throw the front and side window without leaning forward | |
Appendix D – Enlarged customer needs table

<table>
<thead>
<tr>
<th>Customer statement</th>
<th>Customer need</th>
<th>Reason for reposition</th>
<th>Risks</th>
<th>Improvement areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS do not allow comfortable positions for children</td>
<td>The belt-positioning booster enables children to sit comfortable</td>
<td>Search for a more comfortable position</td>
<td>*Leaning forward *Lateral movement *Rotate *Skewing *Slouching *Position feet on front seat/seat cushion *Not properly restrained *Frustration</td>
<td>See below aspects</td>
</tr>
<tr>
<td>Backrest is too hard</td>
<td>The backrest is comfortable</td>
<td>Perceived stiffness and discomfort</td>
<td>*Leaning forward or rotate</td>
<td>*Softer backrest</td>
</tr>
<tr>
<td>Cushion is too hard</td>
<td>The cushion is comfortable</td>
<td>Perceived stiffness and discomfort</td>
<td>*Lateral movement *Searching for feet support *Rotate</td>
<td>*Softer cushion</td>
</tr>
<tr>
<td>The cushion’s length is not adjusted for child’s leg length</td>
<td>The cushion’s length is adjusted for child’s leg length</td>
<td>Cushion length on booster is for many children too short, while seat cushion is too long. The combination results in load on calves and/or thighs.</td>
<td>*Leaning forward or rotate *Stop using CRS too early</td>
<td>*Foot support *Flexible support for thighs and/or calves</td>
</tr>
<tr>
<td>Children outgrow the belt-positioning booster too early</td>
<td>There is belt-positioning boosters big enough for all children</td>
<td>Bigger children do not fit shoulders between bolsters and the cushion is perceived too small.</td>
<td>*Leaning forward or rotate</td>
<td>*Enough space for hips *Enough space for shoulders and arms *Right length for back and head support</td>
</tr>
<tr>
<td>Older children think belt-positioning booster is uncool</td>
<td>The perception of the belt-positioning booster is positive or neutral for all ages</td>
<td></td>
<td>*Stop using CRS too early</td>
<td>*Change the perception of the CRS</td>
</tr>
<tr>
<td>Children want to see surrounding</td>
<td>The belt-positioning booster allows children to look around or/and out</td>
<td></td>
<td>*Bolster limits the child’s field of vision. *Children look out through front window</td>
<td>*Remove/redesign factors that limit field of vision</td>
</tr>
</tbody>
</table>

References
| Children want to perform activities in the car | The belt-positioning booster enable children to perform activities comfortably | Performing activities | *Leaning forward  
*Laterally movement  
*Tilt head forward  
*Rotate  
*Arms outside CRS | *Allow better support  
*Prevent children from performing extreme positions |
|-----------------------------------------------|--------------------------------------------------------------------------------|--------------------|---------------------------------|---------------------------------|
| Children grow fast | The belt-positioning booster allows children in different sizes | *Child is too small for the CRS  
*Child is too big for the CRS | *Slouching  
*Not properly restrained  
*Leaning forward or rotate  
*Stop using CRS too early | *Flexible height (cushion and backrest)  
*Flexible width (cushion and backrest) |
| Children have relatively bigger and heavier heads than adults | The belt-positioning booster gives support for the head | Searching for/lack of head support, commonly while sleeping. | *Lateral movement  
*Tilt head forward | *Head support |
| Bad angle on high-back booster back | The belt-positioning booster has an ergonomic angle on the backrest | Uncomfortable posture | *Leaning forward  
*Skewing | *Angle of backrest |
| The children get influenced by subjective opinions | The belt-positioning booster is costumed to subjective perception of comfort | – | *Children prefer the type of CRS they are used to independently of the perceived comfort of a new one  
*If a CRS does not look comfortable it is not perceived as comfortable | *A comfortable impression |
| Big bolsters lead to a locked-in feeling | The belt-positioning booster gives the perception of free movement | Children want to escape the boosters | *Leaning forward  
*Skewing | *Bolster design |
| Difficult for children to buckle themselves | It is easy for children to handle the belt and buckle by themselves | – | *Misuse  
*Not properly restrained  
*Frustration | *Allow easy assessment to seat belt buckle  
*Make it easier for children to route the seat belt correctly |
| Misplacement of seat belt when buckle | It should not be possible to misplace the seat belt | *Escaping the seat belt  
*Rub against neck | *Unbuckle themselves  
*Move seat belt away from safe position  
*Seat belt not straightened enough | *Make it easier to route the seat belt correctly  
*Improved seat belt geometry |
### Children tend to have a lot of energy and move often

The belt-positioning booster allows the child to change positions safely

*Static load*
*Impatience*
*A lot of energy*

*Leaning forward*
*Lateral movement*
*Rotate*
*Skewing*
*Slouching*
*Position feet on front seat*
*Not properly restrained*
*Frustration*

*Allow better support*
*Prevent children from performing extreme positions*

### Child and high-back booster move while turning and/or braking

The belt-positioning booster has the same movement as the car in dynamic environment

*Turning*
*Braking*

*Negative attitude toward CRS*
*Lateral movement*
*Hit hard edges*

*Keep the child in position during the dynamic elements*
*Movement of high-back booster*

### Parents prioritise other aspects over child comfort

Comfort is prioritized

*Do not buy the most comfortable alternative*
*Travel without CRS*

*Size*
*Weight*
*Portability*
*Mounting*
*Effect on adults comfort*

### Different priorities for long and short journeys

The belt-positioning booster is adapted for both long and short journeys

*Performing activities*
*Searching for head support while sleeping*
*Static load*
*Impatience*
*A lot of energy*

*Not properly restrained*
*Travel without CRS*
*Tilt head forward*
*Leaning forward*
*Lateral movement*
*Tilt head forward*
*Rotate*

*Suitable for long and short journey*
# Appendix E – Weighted enlarged customer needs table

<table>
<thead>
<tr>
<th>Total risk score</th>
<th>Customer statement</th>
<th>Leaning forward</th>
<th>Lateral movement</th>
<th>Rotate</th>
<th>Skewing</th>
<th>Slouching</th>
<th>Feet outside</th>
<th>Arms outside</th>
<th>Tilt head</th>
<th>Not properly restrained</th>
<th>Misuse</th>
<th>Stop using CRS too early</th>
<th>CRS</th>
<th>Travel without safe position</th>
<th>Move seat belt away from CRS</th>
<th>Seat belt not straightened enough</th>
<th>Frustration</th>
<th>Prefer the type of CRS they are used to</th>
<th>Negative attitude</th>
<th>Hit hard edges</th>
<th>Most comfortable alternative</th>
<th>Do not buy the CRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>CRS do not allow comfortable positions for children</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
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<td>1</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>23</td>
<td>Children tend to have a lot of energy and move often</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Children outgrow the belt-positioning booster too early</td>
<td>1</td>
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<td>15</td>
<td>Cushion is too hard</td>
<td>1</td>
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<td>15</td>
<td>Children want to perform activities in the car</td>
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<td>13</td>
<td>Different priorities for long and short journeys</td>
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<td>11</td>
<td>Children grow fast</td>
<td>1</td>
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<td>10</td>
<td>Backrest is too hard</td>
<td>1</td>
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<tr>
<td>10</td>
<td>Difficult for children to buckle themselves up</td>
<td>1</td>
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<tr>
<td>9</td>
<td>The cushion’s length is not adjusted for child’s leg length</td>
<td>1</td>
<td>1</td>
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<td>9</td>
<td>Child and high-back booster move while turning and/or braking</td>
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<td>8</td>
<td>Bad angle on high-back booster back</td>
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<td>8</td>
<td>Big bolsters lead to a locked-in feeling</td>
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<td>6</td>
<td>Children want to see surrounding</td>
<td>1</td>
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<td>6</td>
<td>Parents prioritise other aspects over child comfort</td>
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<td>5</td>
<td>Older children think belt-positioning booster is uncool</td>
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<td>5</td>
<td>Children have relatively bigger and heavier heads than adults</td>
<td>1</td>
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<td>4</td>
<td>Misplacement of seat belt when buckle</td>
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<td>3</td>
<td>The children get influenced by subjective opinions</td>
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**Child Comfort in Rear Seats of Cars**
Appendix F – Setup for workshop session one and two

Setup for workshop session one:

INFO

Hej och välkomna hit! Vi hoppas fikat smakade bra. Era namnlappar ser jättefina ut!
Jag heter Tove/Sofia och vi har bjudit in er idag för att vi behöver experter som kan hjälpa oss med en uppgift vi jobbar med. Vi ska hjälpa Volvo med att komma på idéer på nya bilstolar och bilkuddar. Alltså sådana här [visa exempelbilder]. Så vi vill ha hjälp från er att veta vad ni tycker om era bilstolar eller bilkuddar och hur de kan bli bättre. För ni vet ju massa mer om det här än vad vi vet.

Vi kommer att prata en ganska mycket i grupp idag och göra saker tillsammans. Som ni ser är vi ganska många och ni är lite olika gamla. Så det är jätteviktigt att vi lyssnar på varandra och låter en prata i taget. Vi hjälps är så att alla som vill prata ska få prata och är snälla emot varandra. Idag har ni bara rätt vad ni än säger, så passa på!

Det viktigaste idag är att vi ska ha roligt tillsammans. Skulle ni tycka att det är tråkigt så går det bra att avsluta när ni vill. Då säger ni bara till mamma eller pappa eller någon av oss. Det är viktigt att ni är med för att ni vill och tycker att det är roligt.

[Visa mikrofonen].

- År det någon som vet vad det här skulle kunna vara?

Det är en inspelningsapparat (alternativt säg att det är rätt).

- Vad tror ni vi vill ha den till?


Det är ni som bestämmer om vi får spela in era röster idag, om ni inte vill det är det helt okej. Hur känner ni inför att vi spelar in det ni säger idag?
LÄRA KÄNNA VARADNRA-LEK

Så, nu är det slut på informationsprat. Nu skulle vi vilja veta lite mer om er så vi kan lära känna varandra bättre och lära oss lite namn. Så vi ska gå ett varv och så ska alla få säga sitt namn och sitt favoritgodis. Så jag börjar: Jag heter ....

[Låter barnen presentera sig själva]
(Här borde klockan vara ca. 16.35 enligt schema)

BILSTOLSPROVNING (20 min)

Så, nu är det ju faktiskt ni som är expeterna. Så vi tänkte säga åt era föräldrar att ställa sig i föräldrarhörnan där borta. För de pratar så mycket annars och det vill vi ju inte. Känns det bättre att mamma eller pappa är med så går det bra, men då får ni hålla koll på dem så att de är tysta.

Här inne ska vi testa lite olika bilstolar. Så vi skulle vilja börja med att ni ställer er bakom:

- Den stol eller kudde som är mest lik den ni åker på hemma. (om någon åker på flera, välj den som du tycker bäst om).
- Den stol eller kudde som ni tycker är snyggast


- Stolen eller kudden är skön att sitta på
- Den här vill jag åka på i min bil

(Här borde klockan vara ca. 16.55 enligt schema)

SCENARIOÖVNING (20 min)

Då börjar vi med att be föräldrarna att sätta sig i den nya föräldrarhörnan igen. Det är fortfarande okej att mamma eller pappa sitter med, men kom ihåg att hålla koll på dem så att de är tysta.

[Två stora rutor ritade på white boarden]

Nu ska vi hjälpa de här två barnen att köpa en ny bilstol. [ritar två könsneutrala gubbar på tavlan i ruta 1].

- Vad heter dem?
- Vad har de för färg på kläderna?
- Vad tycker person 1 om att göra på fritiden?
- Vad tycker person 2 om att göra fritiden?

Person 1 är 7 år och Person 2 är 10 år.

114
Person 1 & 2 är på väg in i affären. [Ritar ett hus bredvid gubbarna].

- Vad finns utanför affären?
- Vad är det för färg på affären?

Nu är person 1 & 2 är inne i affären och ska de hitta sin favoritbilstol. Vi skulle vilja att ni hjälper till att rita hur ni tycker att Person 1 & 2:s bilstol skulle ska se ut. Ni får välja om ni vill rita till en av dem eller båda [Papper och pennor finns på bordet]. Färglägg, ändra formen eller lägg till delar. Fundera på hur ni tycker bilstolen ska se ut för att passa Person 1 & 2.

Frågor att eventuellt hjälpa till med:

- Vad tror du Person 1&2 vill kunna göra när de åker bil?
- Vilka är deras favoritfärger?
- Vad tror du de tycker är coolt/snyggt?

Så nu har ni fått fundera lite. Nu ska vi se hur Person 1:s stol kommer se ut. [Be barn presentera olika delar av sin design för person 1 och rita en sammanställning på white boarden i ruta 2.]

- **Avrundning och avslutning**
  
  o Vad tyckte ni var roligast? Var något tråkigt?
  o Tacka för att de kom
INFO

Hej och välkomna hit! Vi hoppas fikat smakade bra. Era namnlappar ser jättefina ut!
Jag heter Tove/Sofia och vi har bjudit in er idag för att vi behöver experter som kan hjälpa oss med en uppgift vi jobbar med. Vi ska hjälpa Volvo med att komma på idéer på nya bilstolar och bilkuddar. Alltså sådana här [visa exempelbilder]. Så vi vill ha hjälp från er att veta vad ni tycker om era bilstolar eller bilkuddar och hur de kan bli bättre. För ni vet ju massan om det här än vad vi vet.

Vi kommer att prata en ganska mycket i grupp idag och göra saker tillsammans. Som ni ser är vi ganska många och ni är lite olika gamla. Så det är jätteviktigt att vi lyssnar på varandra och låter en prata i taget. Vi hjälper år så att alla som vill prata ska få prata och är snälla emot varandra. Idag har ni bara rätt vad ni än säger, så passa på!

Det viktigaste idag är att vi ska ha roligt tillsammans. Skulle ni tycka att det är tråkigt så går det bra att avsluta när ni vill. Då säger ni bara till mamma eller pappa eller någon av oss. Det är viktigt att ni är med för att ni vill och tycker att det är roligt.

[Visa mikrofonen].


Det är ni som bestämmer om vi får spela in era röster idag, om ni inte vill det är det helt okej. Hur känner ni inför att vi spelar in det ni säger idag?

LÄRA KÄNNA VARADNRA-LEK

Så, nu är det slut på informationsprat. Nu skulle vi vilja veta lite mer om er så vi kan lära känna varandra bättre och lära oss lite namn. Så vi ska gå ett varv och så ska alla få säga sitt namn och sitt favoritgodis. Så jag börjar: Jag heter ....

[Låter barnen presentera sig själva]

(Här borde klockan vara ca. 16.35 enligt schema)
BILSTOLSPROVNING (20 min)

Så, nu är det ju faktiskt ni som är expeterna. Så vi tänkte säga åt era föräldrar att ställa sig i föräldrarhörnan där borta. För de pratar så mycket annars och det vill vi ju inte. Känns det bättre att mamma eller pappa är med så går det bra, men då får ni hålla koll på dem så att de är tysta.

Här inne ska vi testa lite olika bilstolar. Så vi skulle vilja börja med att ni ställer er bakom:

- Den stol eller kudde som är mest lik den ni åker på hemma. (om någon åker på flera, välj den som du tycker bäst om).
- Den stol eller kudde som ni tycker är snyggast
- Den stol eller kudde som ni tycker är fulast

Fråga barnen lite varför de tycker som de tycker för varje fråga.


- Stolen eller kudden är skön att sitta på
- Den här vill jag åka på i min bil

[Be barnen ställa framför stolarna igen]. Så nu ska ni få ställa er bakom den stolen som ni:

- Helst skulle vilja åka i hemma.
- Den stolen som ni tyckte var skönast
- Den stolen som var minst skön

Fråga barnen lite varför de tycker som de tycker för varje fråga.

(Här borde klockan vara ca. 16.55 enligt schema)

SCENARIOÖVNING (20 min)

Då börjar vi med att be föräldrarna att sätta sig i den nya föräldrarhörnan igen. Det är fortfarande okej att mamma eller pappa sitter med, men kom ihåg att hålla koll på dem så att de är tysta.

[Två stora rutor ritade på white boarden]

Nu ska vi hjälpa de här två barnen att köpa en ny bilstol. [ritar två könsneutrala gubbar på tavlan i ruta 1].

- Vad heter dem?
- Vad har de för färg på kläderna?
- Vad tycker person 1 om att göra på fritiden?
- Vad tycker person 2 om att göra fritiden?
- Vad vill person 1 och 2 kunna göra i bilen?
Person 1 är 7 år och Person 2 är 10 år.

Person 1 & 2 är på väg in i affären. [Ritar ett hus bredvid gubbarna].

- Vad finns utanför affären?
- Vad är det för färger på affären?

Nu är person 1 & 2 är inne i affären och ska de hitta sin favoritbilstol. Vi skulle vilja att ni hjälper till att rita hur ni tycker att Person 1 & 2:s bilstol skulle ska se ut. Ni får välja om ni vill rita till en av dem eller båda [Papper och pennor finns på bordet]. Färglägg, ändra formen eller lägg till delar. Fundera på hur ni tycker bilstolen ska se ut för att passa Person 1 & 2.

Frågor att eventuellt hjälpa till med:
- Vad tror du Person 1 & 2 vill kunna göra när de åker bil?
- Vilka är deras favoritfärger?
- Vad tror du de tycker är coolt/snyggt?

Så nu har ni fått fundera lite. Nu ska vi se hur Person 1 & 2:s stolar kommer se ut. [Be barn presentera olika delar av sin design för person 1 och rita en sammanställning på white boarden i ruta 2.]

Fråga barnen varför vissa egenskaper är viktigt för stolen i bilen. Exempel:
- Varför är det så bra att ha en popcorn-maskin i bilen?

Avrundning och avslutning

- Vad tyckte ni var roligast? Var något tråkigt?
- Tacka för att de kom
Volvo Personvagnar AB
Assar Gabrielssons Väg
405 31 GÖTEBORG
tel. 031-59 00 00
org.nr.: 556074-3089


Vi kommer att ha den här workshopen för att förstå vad barn i er ålder tycker om era barnstolar och barnkuddar. Vi vill också få reda på hur ni skulle önska att barnstolar och barnkuddar ser ut om ni själva får bestämma. Vi kommer att använda informationen vi får från er för att föreslå hur nya barnstolar och barnkuddar skulle kunna se ut i framtiden och hur man kan göra de mer bekväma.

Om du vill vara med i workshopen vill vi att du lämnar en del information om dig själv (personuppgifter) till Volvo Personvagnar AB. Vi vill veta ditt namn, din ålder och att vi får skriva upp att du varit med i workshopen. Vi kommer också att ta bilder under workshopen och spela in det ni säger. Vi kommer också vilja spara era teckningar.

Det är frivilligt att vara med i workshopen och du berättar själv om du vill lämna några uppgifter till oss. Uppgifterna kommer bara att användas av oss som jobbar på företaget och kommer att raderas innan sommaren (juli 2017). Vissa bilder på er och vissa teckningar kan komma att vara med i vår rapport och presentation (examensarbetsrapport och framläggningspresentation) och kommer då att visas för personer utanför företaget. I så fall kommer inga ansikten vara med på bilderna och det kommer inte att stå vem som har gjort teckningarna.


Om du vill vara med i workshopen, vänligen skriv under med ditt namn på baksidan.
Jag deltar frivilligt i provningen och samtycker till att Volvo Personvagnar AB behandlar personuppgifter om mig i enlighet med det ovanstående.

______________________________

Ort och datum

______________________________

Namn (om omyndig krävs båda vårdnadshavares samtycke)

______________________________

Namnförtydligande

______________________________

Namn = samtycke ifrån vårdnadshavare 1         Namn = samtycke ifrån vårdnadshavare 2

______________________________

Namnförtydligande vårdnadshavare 1         Namnförtydligande vårdnadshavare 2
Appendix H – Dimensions for test dummies P10 TNO and H3

Test dummies’ dimensions. All dimensions are compared to corresponding age for a 50%ile of the Dutch population*

<table>
<thead>
<tr>
<th></th>
<th>P10 TNO dummy (10 yrs. old)</th>
<th>H3 dummy (6 yrs. old)</th>
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<tr>
<td></td>
<td>Body dimensions [cm]</td>
<td>Corresponding 50%ile age* [yrs.]</td>
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<tr>
<td>Stature standing</td>
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<td>8-9</td>
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<td>Shoulder breadth</td>
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<td>Standing</td>
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<td>Breadth across elbows</td>
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<td>Hip breadth seated</td>
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<td>length, seated</td>
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<td>Buttock-knee length</td>
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<td>Popliteal height</td>
<td>46</td>
<td>&gt;12</td>
</tr>
<tr>
<td>seated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*50%ile of Dutch population according to (Steenbekkers, 1993).
Appendix I - Sketch for the initial design plan for prototype headrest
Appendix J – Final sketch for the prototype footrest
Appendix K - Agreement for participation in user study one

SAMTYCKE TILL DELTAGANDE I statisk studie om barnstolskomfort

Volvo Personvagnar AB
Assar Gabrielssons Väg
405 31 GÖTEBORG
tel. 031-59 00 00
org.nr.: 556074-3089


Vi kommer att ha den här studien för att förstå hur sköna ni tycker olika barnstolar och barnkuddar är. Vi vill också få reda på hur bra ni ser ut genom fönstret och om något är i vägen om ni spelar spel på er mobil eller läsplatta. Vi kommer att använda informationen vi får från er för att föreslå hur nya barnstolar och barnkuddar skulle kunna se ut i framtiden och hur man kan göra dem skönare.

Om du vill vara med i studien vill vi att du lämnar en del information om dig själv (personuppgifter) till Volvo Personvagnar AB. Vi vill veta ditt namn, din ålder, ett antal kroppsmått och din vikt. Kroppsmåten kommer vi mäta när vi ses. Vi kommer också att ta bilder under studien.


Om du vill vara med i vår statiska studie, vänligen skriv under med ditt namn på baksidan.
Jag deltar frivilligt i provningen och samtycker till att Volvo Personvagnar AB behandlar personuppgifter om mig i enlighet med det ovanstående.

Ort och datum

Namn (om omyndig krävs båda vårdnadshavares samtycke)

Namnförtydligande

Namn = samtycke ifrån vårdnadshavare 1  Namn = samtycke ifrån vårdnadshavare 2

Namnförtydligande vårdnadshavare 1  Namnförtydligande vårdnadshavare 2
Appendix L - Agreement for participation in user study one

SAMTYCKE TILL DELTAGANDE I KÖRSTUDIE OM BARNSTOLS Komfort

Volvo Personvagnar AB
Assar Gabrielssons Väg
405 31 GÖTEBOG
Tel. 031-59 00 00
Org.nr.: 556074-3089


Vi kommer att ha den här studien för att förstå hur sköna ni tycker olika barnstolar och barnkuddar är. Vi vill också få reda på hur ni rör er i stolarna. Vi kommer att använda informationen vi får från er för att föreslå hur nya barnstolar och barnkuddar skulle kunna se ut i framtiden och hur man kan göra dem skönare.

Om du vill vara med i studien vill vi att du lämnar en del information om dig själv (personuppgifter) till Volvo Personvagnar AB. Vi vill veta ditt namn, din ålder, ett antal kroppsmått och din vikt. Kroppsmätten kommer vi mäta när vi ses. Vi kommer också att filma dig när du åker i bilen.


Om du vill vara med i vår statiska studie, vänligen skriv under med ditt namn på baksidan.
Jag deltar frivilligt i provningen och samtycker till att Volvo Personvagnar AB behandlar personuppgifter om mig i enlighet med det ovanstående.

______________________________

Ört och datum

______________________________

Namn (om omyndig krävs båda vårdnadshavares samtycke)

______________________________

Namnförtydligande

______________________________

Namn = samtycke ifrån vårdnadshavare 1

______________________________

Namn = samtycke ifrån vårdnadshavare 2

______________________________

Namnförtydligande vårdnadshavare 1

______________________________

Namnförtydligande vårdnadshavare 2
Appendix M – Comfort hypotheses, test hypotheses and comfort goals for user study one

User study one - Static test

Comfort hypotheses **buttock support**

**CH1**: Thicker foam in seating and backrest will lighten the static load and thereby make children:

1. c) Sit more comfortable
2. d) Keep children in the same position for a longer period of time

Test hypotheses **buttock support**

**TCH1**: The foam thickness and hardness on cushion matter for perceived comfort

- Subjective: Let children evaluate 3 different foam hardnesses and thicknesses combinations on a cushion

Goal for test **buttock support**

**GCH1**: Find out what children think about different foam thicknesses and hardnesses on the cushion

Comfort hypotheses **foot support**

**CH2**: Foot support will lighten load on thighs and calves and thereby:

1. a) Make children in wider age span sit more comfortable
2. b) Decrease movement

Test hypotheses **foot support**

**TCH2**: Find out how a foot support would affect the perceived comfort

- Subjective: Identify if children will evaluate the prototype as more comfortable compared to the integrated booster cushion

Goal for test **foot support**

**GCH2**: Foot support will make children sit more comfortable with less foam

Comfort hypotheses **head support**
**CH3:** Headrest with the right size on side supports will allow children to:

- d) Look out through the front and side window without leaning forward
- e) Sleep and rest their head in a comfortable position
- f) Sleep and rest in position

**Test hypotheses head support**

**TCH3:** The headrest will allow children to rest their head in a comfortable position

- Subjective: Ask the children about comfort experience around head and neck

**Goal for test head support**

**GCH3 a)** Find out what the general opinion of the headrest is

**GCH3 b)** Find out if the headrest affect the ability to perform actives in the car

**Comfort hypotheses back support**

**CH4:** Soft bolsters with the right size will:

- a) Improve the impression of good comfort since children feel embraced
- b) Give support but still give the perception of free movement
- c) Prevent children from extreme positions
- d) Improve support for children during dynamic impacts as turning
- e) Make it possible for children to reach the buckle by themselves

**Test hypotheses back support**

**TCH4 a):** The children will appreciate the comfort for the prototype over the old solutions

- Objective: Take a picture of each child in the different CRS to see how they fit
  - Subjective: Let children evaluate 3 existing solutions and the prototype

**TCH4 b):** The bolsters might be in the way when children play on a device

- Objective: Observation form and picture
  - Subjective: Ask the child if bothered when playing

**TCH4 c):** The bolsters might be in the way when children buckle up themselves

- Objective: Observation form when child buckle themselves up

**Goal for test back support**

**GCH4 a)** Find out if it affects the ability to perform actives in the car

**GCH4 b)** Find out if the children prefer the prototype backrest or other existing solutions
**ANVÄNDARTEST – STATISK STUDIE**

Namn expert: ____________________________  
Datum: ______________________________

<table>
<thead>
<tr>
<th>Mått</th>
</tr>
</thead>
<tbody>
<tr>
<td>Längd stående</td>
</tr>
<tr>
<td>Axelbredd stående</td>
</tr>
<tr>
<td>Armbågsbredd stående</td>
</tr>
<tr>
<td>Höftbredd sittande</td>
</tr>
<tr>
<td>Sitthöjd</td>
</tr>
<tr>
<td>Axelhöjd sittande</td>
</tr>
<tr>
<td>Armbåghöjd sittande</td>
</tr>
<tr>
<td>Rumpa till knäveck sittande</td>
</tr>
<tr>
<td>Knäveckshöjd sittande</td>
</tr>
<tr>
<td>Vikt</td>
</tr>
</tbody>
</table>
TESTA BARNSTOLAR (NRX: ________________)

Vid första stolen förklara först de olika skalorna och vad barnet kommer få svara på. Jätteviktigt att alltid ge samma respons på alla svar oavsett vad de svarar.

- Låt barnet sätta sig själv i sätena och spänna fast sig.
- Låt barnet känna in sig och sätta sig bekvämt i sätet, ge dem 2-3 min om nödvändigt.
- Inled med att ta ett foto av barnet rakt framifrån när hen sitter i bilstolen.
- Ställ sedan frågorna:

  Hur känns det när du sitter i den här stolen/på den här kudden?

  [Be barnet märka ut på sin skala] Smiley: ____________________________

  Varför?

  __________________________________________

  __________________________________________

  __________________________________________

  Hur känns det:

  Runt nacke och huvud? Varför?

  __________________________________________

  __________________________________________

  __________________________________________

  Runt axlar och rygg? Varför?

  __________________________________________

  __________________________________________

  __________________________________________

  Under rumpan? Varför?

  __________________________________________

  __________________________________________

  __________________________________________
Vet du vad ordet bekvämt betyder? JA NEJ

**BERÄTTA:** Jag kommer nu att läsa upp två ord i taget som beskriver två olika känslor. Du kommer få välja det ord som du tycker är mest likt din känsla när du sitter i den här bilstolen. Känns det:

- Trångt eller gott om plats?
  - TRÅNGT
  - GOTT OM PLATS
- Skönt eller ont?
  - SKÖNT
  - ONT
- Mjukt eller hårt?
  - MJUKT
  - HÅRT
- Bekvämt eller obekvämt
  - BEKVÄMT
  - OBEKVÄMT

Kommentarer:

____________________________________________________________________________________________________

____________________________________________________________________________________________________

____________________________________________________________________________________________________

BERÄTTA: Tänk att det är du på den här bilden. Kan du måla med den röda pennan var det gör ont eller skaver någonstans?

FRÅGA: Hur tror du det hade känts att sova i den här stolen?

____________________________________________________________________________________________________

____________________________________________________________________________________________________

____________________________________________________________________________________________________

FRÅGA: Tänk på det vi har pratat om nu. Kan du ge stolen en poäng mellan 1-10 där tio är så skönt det bara kan bli och 1 betyder att det gör mycket ont?
VAD ÄR VIKTIGT FÖR DIG FÖR ATT DET SKA VARA SKÖNT ATT ÅKA BIL?

______________________________________________________________

______________________________________________________________

______________________________________________________________

VILKEN VAR DIN FAVORITSTOL?

______________________________________________________________

______________________________________________________________

______________________________________________________________
TESTA SKUMKUDDAR NRX

- Förklara vad ”känna bordet genom kudden” innebär
- Låt barnet sätta sig själva på kuddarna
- Be de sätta sig så skönt det går utan ryggstöd
- **Ställ sedan frågorna:**

**Vad tycker du om kudden? Varför?**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Känns den mjuk eller hård? Varför?**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**Kan du känna bordet/stolen genom kudden?**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
SPELA SPEL OCH TESTA SYNFÄLT

- Låt barnet sätta sig själv i prototypen och spänna fast sig.
- Presentera spel för dem på Ipad (alternativt att de får spela något eget)
- Låt dem spela 5-10 min (en omgång av spelet) observera samtidigt och fyll i formulär.

Kommentarer:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

**FRÅGA:** Tänkte du något på stolen när du spelade? Vad?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

**FRÅGA:** Var det något som störde dig när du spelade? Vad?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Appendix O – Questionnaire for user study one and two

ANVÄNDARTEST – STATISK STUDIE

Namn expert: _____________________________ Datum: _____________________________

TESTA BARNSTOLAR NRX

Hur känns det när du sitter i den här stolen/på den här kudden?

Tänk att det är du på den här bilden. Kan du måla med den röda pennan var det gör ont eller skaver någonstans?

Tänk på det vi har pratat om nu. Kan du ge stolen en poäng mellan 1-10 där tio är så skönt det bara kan bli och 1 betyder att det gör mycket ont?

Mycket ont

1 2 3 4 5 6 7 8 9 10
Appendix P – Test person dimensions for user study one and two

### Dimensions for user study one

<table>
<thead>
<tr>
<th></th>
<th>TP1</th>
<th>TP2</th>
<th>TP3</th>
<th>TP4</th>
<th>TP5</th>
<th>TP6</th>
<th>TP7</th>
<th>TP8</th>
<th>TP9</th>
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<td>54</td>
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### Dimensions for user study two

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<td>36,5</td>
<td>31,8</td>
<td>32,5</td>
<td></td>
</tr>
<tr>
<td>Höftbredd sittande</td>
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<td>21,7</td>
<td>31,2</td>
<td>27,5</td>
<td>31,1</td>
<td>27,5</td>
<td>26,8</td>
<td></td>
</tr>
<tr>
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<td>75,5</td>
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<td>69</td>
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<td>77</td>
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Appendix Q – Full result for user study one

Result from scales and opposite words exercise

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<th>Booster Cushion – scale and opposite words result</th>
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<td>TP 1</td>
</tr>
<tr>
<td>TP 2</td>
</tr>
<tr>
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<td>TP 4</td>
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<tr>
<td>TP 9</td>
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<td></td>
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High-back booster – scale and opposite words result

<table>
<thead>
<tr>
<th>Trångt = 1, Gott om plats = 2, Mitten = 3</th>
<th>Skönt = 1, Ont = 2, Mitten = 3</th>
<th>Mjukt = 1, Hårt = 2, Mitten = 3</th>
<th>Bekväm = 1, Obekväm = 2, Mitten = 3</th>
<th>Smile</th>
<th>Poäng</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP 1</td>
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<td>1</td>
<td>3</td>
</tr>
<tr>
<td>TP 2</td>
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<td>1</td>
<td>4</td>
</tr>
<tr>
<td>TP 3</td>
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<td>1 (lite)</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>4</td>
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<td></td>
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<td>3,1</td>
</tr>
</tbody>
</table>
# Integrated Booster Cushion – scale and opposite words result

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<th>Skönt = 1, Ont = 2, Mitten = 3</th>
<th>Mjukt = 1, Hårt = 2, Mitten = 3</th>
<th>Bekväm = 1, Obekväm = 2, Mitten = 3</th>
<th>Smile</th>
<th>Poäng</th>
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<tr>
<td>TP 1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
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<td>2</td>
<td>1</td>
<td>3</td>
<td>8</td>
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<tr>
<td>TP 3</td>
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<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>10</td>
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<tr>
<td>TP 4</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>2</td>
<td>1</td>
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</tr>
<tr>
<td>TP 6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>TP 7</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>TP 8</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>TP 9</td>
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<td>1</td>
<td>1</td>
<td>4</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>3,3</td>
<td>8,1</td>
</tr>
</tbody>
</table>

# Prototype – scale and opposite words result

<table>
<thead>
<tr>
<th></th>
<th>Trångt = 1, Gott om plats = 2, Mitten = 3</th>
<th>Skönt = 1, Ont = 2, Mitten = 3</th>
<th>Mjukt = 1, Hårt = 2, Mitten = 3</th>
<th>Bekväm = 1, Obekväm = 2, Mitten = 3</th>
<th>Smile</th>
<th>Poäng</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP 1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>TP 2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
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<td>TP 3</td>
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</tr>
<tr>
<td>TP 4</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>TP 5</td>
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<td>1</td>
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<td>TP 6</td>
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<td>2</td>
<td>3</td>
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<td>1</td>
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<td>7</td>
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<tr>
<td>TP 8</td>
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<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
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<tr>
<td>TP 9</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,0</td>
<td>6,1875</td>
</tr>
</tbody>
</table>
Comments from general questions.
The answer from the overall question is sorted to the area the comment regarded.

<table>
<thead>
<tr>
<th>Booster cushion – general questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>TP 1</td>
</tr>
<tr>
<td>TP 2</td>
</tr>
<tr>
<td>TP 3</td>
</tr>
<tr>
<td>TP 4</td>
</tr>
<tr>
<td>TP 5</td>
</tr>
<tr>
<td>TP 6</td>
</tr>
<tr>
<td>TP 7</td>
</tr>
<tr>
<td>TP 8</td>
</tr>
<tr>
<td>TP 9</td>
</tr>
<tr>
<td>TP 1</td>
</tr>
<tr>
<td>TP 2</td>
</tr>
<tr>
<td>TP 3</td>
</tr>
<tr>
<td>TP 4</td>
</tr>
<tr>
<td>TP 5</td>
</tr>
<tr>
<td>TP 6</td>
</tr>
<tr>
<td>TP 7</td>
</tr>
<tr>
<td>TP 8</td>
</tr>
<tr>
<td>TP 9</td>
</tr>
</tbody>
</table>
## Integrated Booster Cushion – general questions

<table>
<thead>
<tr>
<th>TP 1</th>
<th>Konstig vinkel på huvudstöd, lite hårt</th>
<th>Bra att armar får plats nära kroppen. Lite skålform som gör att armarna får plats. Lite hårt bakom rygg/bakre del av rumpan</th>
<th>Inte hårt och inte så mjukt så att man åker ner</th>
<th>Rätt bekvämt men lite hårt att luta huvudet</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP 2</td>
<td>Skönt, lite mjukare</td>
<td>Skönt, går att röra på axlar och armar</td>
<td>Lite hårt över hela (mest vid laren). Hård vid vaderna</td>
<td>Inte så skönt</td>
<td>Hårt vid vaderna</td>
</tr>
<tr>
<td>TP 3</td>
<td>Jätteskönt, mjukt och bekvämt</td>
<td>Toppen den är mjuk</td>
<td>Mjukt och skönt</td>
<td>Bra</td>
<td>Övrigt</td>
</tr>
<tr>
<td>TP 4</td>
<td>Bra men hamnar i skarven</td>
<td>Bra, gott om utrymme och inget som klämmer</td>
<td>Mjukt men kanten skarver mot vaden.</td>
<td>Bra, mjukt</td>
<td>Kant skarver mot vaden</td>
</tr>
<tr>
<td>TP 5</td>
<td>Bra känns bekvämt</td>
<td>Bra</td>
<td>Inte bra, den är hård</td>
<td>Bra lutar huvudet mot bältet</td>
<td>Övrigt</td>
</tr>
<tr>
<td>TP 7</td>
<td>Ok men kommer emot skarv på huvudstöd</td>
<td>Bra, mycket utrymme</td>
<td>Ganska bra men den är liten. Kan ramla av</td>
<td>Går inte, måste ta stöd mot hård dörrkarm</td>
<td>Övrigt</td>
</tr>
<tr>
<td>TP 8</td>
<td>Bra men når inte upp till huvudstöd, hamnar i hålrum och det gör lite ont</td>
<td>Skönt men bolster hamnar lite i vägen för armbägar</td>
<td>Lite hårt längst bak (hålrum) Annars bra. är däremot en kant mot vaden</td>
<td>Bättre när det finns sidostöd för huvudet.</td>
<td>Övrigt</td>
</tr>
<tr>
<td>TP 9</td>
<td>Skönt, inte hårt</td>
<td>Ganska skönt inte hårt</td>
<td>Ganska skönt, inte hårt</td>
<td>Ganska skönt</td>
<td>Övrigt</td>
</tr>
</tbody>
</table>
## Prototype – general questions

<table>
<thead>
<tr>
<th>TP 1</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hårt bakom huvudet, sidorna också hårdt. Bra längs på sidostöden</td>
<td>Bolster puttar fram armar, känns konstigt. Trångt under axlar och skaver bakom ryggen</td>
<td>Känner en skarv vid ryggen, känns lite konstigt. Annars bra</td>
<td>Bra men hårt att luta huvudet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 2</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganska hård huvudstöd och hårt bakom huvudet</td>
<td>Trångt över axlarna och ganska hårt</td>
<td>Hårt, den är inte så mjuk</td>
<td>Inte skönt</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 3</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bra, bekvämt med huvudstöd</td>
<td>Ganska bra, får inte plats helt men ganska skönt</td>
<td>Skönt samma som IBK:N</td>
<td>Det är nog skönare att sova med sidostöd vid huvudet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 4</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bra men lite hård, stöden ger inte efter.</td>
<td>Kläms lite på sidan av ryggen</td>
<td>Bra men vill ha längre kudde under låren</td>
<td>Vet inte, lite hårt vid nacke och rygg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 5</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bra, mjukt</td>
<td>Bra, mycket mellanrum</td>
<td>Bra, mjukt</td>
<td>Bra, vet inte varför men lutar huvudet mot nackstödet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 6</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jättebekvämt men nackstödet hade kunnat vara lite längre fram till.</td>
<td>Lite tight vid midjan, under skuldrorna. Sidobolstrena är ganska obekväma</td>
<td>Bekvämt om dynan hade varit längre. Alldeles för lite plats fram till</td>
<td>Hade gått med längre sitts och längre sidostöd för huvudet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 7</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>cropped Bra med stöd. Vill att huvudstöd ska gå längre fram</td>
<td>cropped Bra förutom att bolster trycker mot armen och vis skuldran</td>
<td>Känns bra men tycker att den känns kort</td>
<td>Kan nog det</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 8</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skönt, väldigt mjukt</td>
<td>cropped Trångt vid bolster, hårt och får ej plats med armar och ryggen</td>
<td>Lite hårt längst fram på kudden, under låren</td>
<td>Skönt för huvudet med stöd men svårt att luta sig pga bolster</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TP 9</th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpa</th>
<th>Sova</th>
<th>Övrigt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skönt, bra utrymme om man vill sova</td>
<td>Lite obekvämt med sidobolster vid axlarna, skönare att ha armarna längst sidan</td>
<td>Skönt, inte hårt</td>
<td>Skönt att luta huvudet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Answers on overall general questions and observations

<table>
<thead>
<tr>
<th>Viktigt för att det ska vara skönt att åka bil</th>
<th>Favorit</th>
<th>Spela Ipad</th>
</tr>
</thead>
<tbody>
<tr>
<td>inte hårt, vill kunna se ut (ej stora bolster vid huvudet)</td>
<td>IBK</td>
<td>Padda i knät, kommer ej emot prototypen.</td>
</tr>
<tr>
<td>Varmt och mjukt man ska kunna sova skönt.</td>
<td>Den vanliga kudden, brukar åka på den</td>
<td>Lite framåtlutad, rör hela kroppen. Struntade in prototypen</td>
</tr>
<tr>
<td>Huvudkudde och att det ska vara skönt att ta på sig säkerhetsbältet.</td>
<td>IBK:n</td>
<td>Satt framåtlutad men tänkte inte på prototypen</td>
</tr>
<tr>
<td>Inte göra ont eller vara hårt, bra med utrymme. Stöd som man kan luta sig emot och sova</td>
<td>Britax</td>
<td>Framåtlutad med padda i knät. Tänkte inte på prototypen när hon spelade.</td>
</tr>
<tr>
<td>Sova eller spela Ipad för då känner jag inget. Viktigt att det är mjukt, inte hårt och inte trångt.</td>
<td>IBK</td>
<td>Framåtlutad, tänkte inte på prototypen</td>
</tr>
<tr>
<td>Att kunna sova i den och att den är skön</td>
<td>Britax</td>
<td>Hade varit skönare om det gick att sitta i skräddare. Lutar sig framåt</td>
</tr>
<tr>
<td>Mjukt och mycket plats för att kunna sova bra.</td>
<td>Britax</td>
<td>Sitter framåtlutad och tyckte att det gjorde ont under lären samt att det var svårt att röra på överkroppen.</td>
</tr>
<tr>
<td>Skönt att sova, mjukt speciellt där man ska lägga huvudet</td>
<td>IBK:n - brukar åka på den. Går att lägga huvudet skönt</td>
<td>Satt framåtlutad men tänkte inte på prototypen hon satt i</td>
</tr>
</tbody>
</table>
Appendix R - Comfort hypotheses, test hypotheses and goals for user study two

User study two – on road study:

Comfort hypotheses buttock support
CH1: Thicker foam in seating and backrest will lighten the static load and thereby make children:
   e) Sit more comfortable
   f) Keep children in the same position for a longer period of time

Test hypotheses buttock support
   TCH1: The foam thickness and hardness on cushion matter for perceived comfort
      o Subjective: Let children evaluate the difference in perceived comfort/discomfort when standing still and cruising

Goal for test buttock support
   GCH1: Find out if the children perceive differences in perceived comfort/discomfort regarding initial comfort and cruising comfort.

Overall hypotheses foot support
CH2: Foot support will lighten load on thighs and calves and thereby:
   a) Make children in wider age span sit more comfortable
   b) Decrease movement

Test hypotheses foot support
   TCH2 a) Foot support will lighten load on thighs and calves and thereby make children sit more comfortable
      o Objective: Look after positions that indicates discomfort (are listed in advance)
      o Objective: Look if foot support is used during test ride
      o Objective: Look so children don't use other foot support during the ride
      o Subjective: Ask the children about the foot support (in a clever way)
   TCH2 b) Extra support or padding around thighs and calves is not necessary when using foot support
      o Objective: Look after positions that indicates discomfort (are listed in advance)
      o Subjective: Ask the children about overall bothering areas (in a clever way)
   TCH2 c) A foot support will not make the overall position or overall comfort worse
Goal for test foot support

GCH2 a) Find out if a foot support is used when offered
GCH2 b) Find out if the foot support improve the overall comfort for the children
GCH2 c) Find out if the bolsters keep the children in a better position during a ride (or “affect the children’s position”)

Overall hypotheses back support

CH4: Soft bolsters with the right size will:
 a) Improve the impression of good comfort since children feel embraced
 b) Give support but still give the perception of free movement
 c) Prevent children from extreme positions
 d) Improve support for children during dynamic impacts as turning
 e) Make it possible for children to reach the buckle by themselves

Test hypotheses back support

TCH4 a) The shape and support of added foam on backrest make children sit more comfortable
 o Objective: Look after positions that indicates discomfort (are listed in advance)
 o Objective: Look after signs of that the shape or the foam bother the child
 o Subjective: Ask the children about the back support (in a clever way)
 o Subjective: Ask the children about overall bothering areas (in a clever way)

TCH4 b) The backrest will increase amount of acceptable positions and the overall comfort
 o Objective: Compare chosen positions between the prototype with the reference
 o Objective: Look if amount of unacceptable positions are fewer for prototype than reference
 o Subjective: Ask if enjoyed the comfort from the backrest support

Goal for test back support

GH4 a) Find out if the backrest's shape improve the overall comfort for the children
GH4 b) Find out if the bolsters improve the child’s position and/or comfort when turning (dynamic environment)
GH4 c) Find out if the children perceive the shape of the back as improved support for their back
GH4 e) Find out if the children feel limited in their movement because of the shape of the backrest
GH4 f) Find out if the bolsters keep the children in a better position during a ride (or “affect the children’s position”)
GH4 g) Find out if the foam is too hard to affect the comfort in a positive way

Overall hypotheses head support

CH3: Headrest with the right size on side supports will allow children to:
   a) Look out through the front and side window without leaning forward
   b) Sleep and rest their head in a comfortable position
   c) Sleep and rest in position

Test hypotheses head support

TCH3 a) Children will use side support to rest their head even if not sleeping
   o Objective: Look if children use head side support during test ride
   o Subjective: Ask the children about the head support (in a clever way)
TCH3 b) An adjustable head rest will not make the head position or comfort worse
   o Objective: Compare chosen positions between the prototype with the reference
   o Subjective: Was not bothered by the head rest during the ride
   o Subjective: Ask if enjoyed the comfort from back head rest support

Goal for test head support

GCH3 a) Find out whether children use the headrest when they are awake
GCH3 b) Find out if our design of headrest limits the children’s view when looking through window
Appendix S – Interview form for user study two

ANVÄNDARTEST – KÖRSTUDIE

Namn expert: ___________________________  Datum: ______________________

<table>
<thead>
<tr>
<th>Mått</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Längd stående</td>
<td></td>
</tr>
<tr>
<td>Axelbredd stående</td>
<td></td>
</tr>
<tr>
<td>Armbågsbredd stående</td>
<td></td>
</tr>
<tr>
<td>Höftbredd sittande</td>
<td></td>
</tr>
<tr>
<td>Sitthöjd</td>
<td></td>
</tr>
<tr>
<td>Axelhöjd sittande</td>
<td></td>
</tr>
<tr>
<td>Armbågshöjd sittande</td>
<td></td>
</tr>
<tr>
<td>Rumpa till knäveck sittande</td>
<td></td>
</tr>
<tr>
<td>Knäveckshöjd sittande</td>
<td></td>
</tr>
<tr>
<td>Vikt</td>
<td></td>
</tr>
</tbody>
</table>
INNAN AVFÄRD NRX________________________

Vid första stolen förklara först de olika skalorna och vad barnet kommer få svara på. Jätteviktigt att alltid ge samma respons på alla svar oavsett vad de svarar.

- Låt barnet sätta sig själv i sätet och spänna fast sig. (Dubbelkolla att det ser bra ut)
- Sätt dig i baksätet och låt föräldern köra iväg med bilen.
- Ställ sedan frågorna:

Hur känns det när du sitter i den här stolen/på den här kudden?

[Be barnet märka ut på sin skala] Smiley: ____________________________

Varför?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Hur känns det:

Runt nacke och huvud? Varför?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Runt axlar och rygg? Varför?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Under rumpan? Varför?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Vet du vad ordet bekvämt betyder? JA NEJ

**BERÄTTA:** Jag kommer nu att läsa upp två ord i taget som beskriver två olika känslor. Du kommer få välja det ord som du tycker är mest likt din känsla när du sitter i den här bilstolen. Känns det:

<table>
<thead>
<tr>
<th>Trångt eller gott om plats?</th>
<th>TRÅNGT</th>
<th>GOTT OM PLATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skönt eller ont?</td>
<td>SKÖNT</td>
<td>ONT</td>
</tr>
<tr>
<td>Mjukt eller hårt?</td>
<td>MJUKT</td>
<td>HÅRT</td>
</tr>
<tr>
<td>Bekvämt eller obekvämt</td>
<td>BEKVÄMT</td>
<td>OBEKVÄMT</td>
</tr>
</tbody>
</table>

**Kommentarer:**

BERÄTTA: Tänk att det är du på den här bilden. Kan du måla med den röda pennan var det gör ont eller skaver någonstans?

**FRÅGA:** Hur tror du det hade känts att sova i den här stolen?

FRÅGA: Tänk på det vi har pratat om nu. Kan du ge stolen en poäng mellan 1-10 där tio är så skönt det bara kan bli och 1 betyder att det gör mycket ont?

- Sätt dig i passagerarsätet och låt barnet åka ifred
EFTER RUTT (NRX:___________________)

Jätteviktigt att alltid ge samma respons på alla svar oavsett vad de svarar.

- Stanna bilen och hoppa bak till baksätet igen och låt föräldern fortsätta köra.
- Ställ sedan frågorna:

Hur känns det när du sitter i den här stolen/på den här kudden?

[Be barnet märka ut på sin skala] Smiley: _________________________________

Varför?

----------------------------------------------------------------------------------

----------------------------------------------------------------------------------

----------------------------------------------------------------------------------

Hur känns det:

Runt nacke och huvud? Varför?

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----------------------------------------------------------------------------------

----------------------------------------------------------------------------------

Runt axlar och rygg? Varför?

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----------------------------------------------------------------------------------

Under rumpan? Varför?

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----------------------------------------------------------------------------------

----------------------------------------------------------------------------------
BERÄTTA: Jag kommer nu att läsa upp två ord i taget som beskriver två olika känslor. Du kommer få välja det ord som du tycker är mest likt din känsla när du sitter i den här bilstolen. Känns det:

<table>
<thead>
<tr>
<th>Trångt eller gott om plats?</th>
<th>TRÅNGT</th>
<th>GOTT OM PLATS</th>
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</thead>
<tbody>
<tr>
<td>Skönt eller ont?</td>
<td>SKÖNT</td>
<td>ONT</td>
</tr>
<tr>
<td>Mjukt eller hårt?</td>
<td>MJUKT</td>
<td>HÅRT</td>
</tr>
<tr>
<td>Bekvämt eller obekvämt?</td>
<td>BEKVÄMT</td>
<td>OBEKVÄMT</td>
</tr>
</tbody>
</table>

Kommentarer:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

BERÄTTA: Tänk att det är du på den här bilden. Kan du måla med den röda pennan var det gör ont eller skaver någonstans?

FRÅGA: Hur kändes det när bilen svängde?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

FRÅGA: Var det något du störde dig på när du åkte?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

FRÅGA: Tänk på det vi har pratat om nu. Kan du ge stolen en poäng mellan 1-10 där tio är så skönt det bara kan bli och 1 betyder att det gör mycket ont?
VAD ÄR VIKTIGT FÖR DIG FÖR ATT DET SKA VARA SKÖNT ATT ÅKA BIL?


VILKEN VAR DIN FAVORITSTOL?


**Appendix T – Full result for user study two**

<table>
<thead>
<tr>
<th>TP</th>
<th>Initial</th>
<th>Final</th>
<th>Initial</th>
<th>Final</th>
<th>Initial</th>
<th>Final</th>
<th>Initial</th>
<th>Final</th>
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</thead>
<tbody>
<tr>
<td>TP1</td>
<td>Skön under rumpan och men mot vad</td>
<td>Bra, mjukt</td>
<td>Inte skönt med benere, hård kant. Benen sommar när man har dem uppe</td>
<td>Sådär, har huvudet i skarv</td>
<td>Bra gott om utrymme</td>
<td>Bra, inte för hårt eller mjukt</td>
<td>Bra, mjukt - inte hårt, inte skön</td>
<td>Bra, mjukt och skön</td>
<td>Bra, obekvämt mot vad - ont när man vaknar</td>
<td>kant vid vad</td>
<td>Bra, det är lite bolster som stoppar så att man inte åker runt</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>TP2</td>
<td>Bra</td>
<td>Vet inte</td>
<td>Bra</td>
<td>Bra</td>
<td>Skönt</td>
<td>Åkte runt rätt mycket och ratschade mot armbågen</td>
<td>Bra, skönt</td>
<td>Bra, skönt</td>
<td>Skönt</td>
<td>nej</td>
<td>bra men gled lite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP3</td>
<td>Jätteskönt, skaver inget</td>
<td>Jätteskönt, bra</td>
<td>Lite hårt precis bakom huvudet (skarv)</td>
<td>Bra mjukt, bättre än vanliga barnstolar som är hårdar</td>
<td>Bra, kändes skönt när jag åkte</td>
<td>Skönt, mjukt och fluffigt</td>
<td>Fortfarande jätteskönt</td>
<td>skönt, mjukt och bekvämt</td>
<td>nej</td>
<td>bra</td>
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</tr>
<tr>
<td>TP4</td>
<td>Mjuk och skön</td>
<td>Fortfarande bra och skön</td>
<td>lite hårt och obekvämt (skarv)</td>
<td>bra</td>
<td>Bra, Lite hårt vid axlarna</td>
<td>mjukare än förut</td>
<td>mjukt, bra</td>
<td>Vill ha den bredare och längre</td>
<td>Lite obekvämt, inte så bra vid huvudet</td>
<td>nej</td>
<td>Gled åt sidan lite</td>
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</tr>
<tr>
<td>TP5</td>
<td>Skönt, mycket utrymme</td>
<td>Skakigt, TP upplevde att hon skakade</td>
<td>skönt</td>
<td>skönt, mjukt, mycket utrymme</td>
<td>skönt, skakade inte</td>
<td>mjukt, varmt</td>
<td>mjukt, varmt</td>
<td>mjukt, varmt</td>
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<td>skönt, vet inte</td>
<td>nej</td>
<td>Bra, kände inte att det svängde</td>
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### Integrated Booster Cushion – scale and opposite words result

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<td></td>
<td><strong>Skönt = 1, Ont = 2, Mitten = 3</strong></td>
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<td><strong>Bekväm = 1, Obekväm = 2, Mitten = 3</strong></td>
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## Prototype – General questions

<table>
<thead>
<tr>
<th></th>
<th>Nacke &amp; Huvud</th>
<th>Axlar &amp; Rygg</th>
<th>Under rumpan</th>
<th>Sova</th>
<th>något som störde</th>
<th>svängar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Före</td>
<td>Efter</td>
<td>Före</td>
<td>Efter</td>
<td>Före</td>
<td>Efter</td>
<td>Efter</td>
</tr>
<tr>
<td><strong>TP1</strong></td>
<td>Skön, mjuk</td>
<td>bra, inte ont</td>
<td>Bra, skönt om man kan sova</td>
<td>Går inåt, skulderblad trycks ut. Lite trångt och obekväma sidor</td>
<td>Lite klämmande, som innan. Inte helt plats för ryggen</td>
<td>Bra, mjukt. Vill kunna ta stöd mot sidobolstrena vid rumpan</td>
</tr>
<tr>
<td><strong>TP2</strong></td>
<td>Hårdare än IBK</td>
<td>Så långt att åka, gillar inte att åka långt. Ofta kan det bli hårt när man sitter länge. Stolen var ganska bra</td>
<td>Bra</td>
<td>Lite rivigt (t-shirt)</td>
<td>tänkte inte på det men gillar ryggstöd</td>
<td>Bra</td>
</tr>
<tr>
<td><strong>TP3</strong></td>
<td>Skön, bekväm, fluffig</td>
<td>Sön och kul att åka på</td>
<td>Jätteskönt</td>
<td>Bra, var mjukt</td>
<td>Skönt, bekväm, gott om plats</td>
<td>Bra, får mer utrymme med armar</td>
</tr>
<tr>
<td><strong>TP4</strong></td>
<td>Mjuk, kan luta huvudet bakåt</td>
<td>Den är, mjuk. Skönt vid huvudet och ländryggen</td>
<td>bra, mjukare vid huvudet än IBK</td>
<td>Lite trångt mellan sidobolstrena, vill ha de längre ut</td>
<td>Lite obekvämt vid axlarna, kläms lite</td>
<td>Bra, vill ha längre sitts</td>
</tr>
<tr>
<td><strong>TP5</strong></td>
<td>Mjukt, inte så mycket plats, hårt vid huvudet</td>
<td>Skönt, lite trångt, mjukt under rumpa</td>
<td>hårt</td>
<td>inte så bra, hårt</td>
<td>hårt vid armbägen, emot bolster</td>
<td>hårt</td>
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</tbody>
</table>
**TP6**

<table>
<thead>
<tr>
<th>vet inte</th>
<th>Sköna svängar, mjuka sidor. Bra att det går att vinkla fotstöd</th>
<th>Ganska mjukt</th>
<th>Skönt, mjukt</th>
<th>Ganska skönt, mjukt</th>
<th>Skönt, mjukt</th>
<th>skönt, mjukt</th>
<th>mjukt</th>
<th>Ganska skönt, mjukt</th>
<th>nej</th>
<th>skönt</th>
</tr>
</thead>
</table>

**TP7**

| Bra, skönt | Bra, skönt och varmt | Gott om plats | Bra, skönt och varmt | skönt och varmt | skönt och mjukt och varmt | mjukt och stöd vid rumpan | Bra | nej | Bra, tänkte inte på att det svängde |

---

**Prototype – scale and opposite words result**

<table>
<thead>
<tr>
<th>Smile</th>
<th>poäng</th>
<th>Trångt = 1, Gott om plats = 2, Mitten = 3</th>
<th>Skönt = 1, Ont = 2, Mitten = 3</th>
<th>Mjukt = 1, Hårt = 2, Mitten = 3</th>
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<tr>
<td>Före</td>
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References