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Seating Position and Comfort for Autonomous Drive

An experimental study investigating chosen seat position and perceived comfort in the driver's seat of an autonomous car

Master's thesis in Product Development

PONTUS ANDRÉN & JOSEFINE RYSJÖ

Department of Industrial and Material Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

MASTER'S THESIS 2018

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Printed by Chalmers Reproservice
Gothenburg, Sweden 2018

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Abstract

Autonomous cars are becoming more familiar and will eventually change the way we think of transportation. In terms of autonomous driving, the car will be handling all or some tasks for controlling the car, allowing the driver to do other activities which leads to the seat of the car being used in different ways. In order to satisfy and bring value to customers, new requirements regarding the seat and seating position need to be considered and designed for.

The aim for the master thesis is therefore to identify important parameters, such as functions of the seat, and evaluate which parameters affect the seating comfort and position in a positive way and to add customer value. Additionally the aim is also to identify which seat position potential customers choose when traveling in an autonomous car.

The master thesis is divided into three different sections; Identification of scenarios and parameters, Preparation for evaluation of parameters and Evaluation of parameters. In the first section, scenarios for autonomous driving are identified from literature using for example other types of traveling solutions as reference. Important parameters of the seat for each scenario are also identified using the literature. For the second section, a prototype seat with new parameters integrated is developed to enable evaluation of the identified parameters specified for each scenario. In the third section three user tests are performed to evaluate how potential customers experience the seat when performing activities related different scenarios. Furthermore the aim of the user tests is to investigate if newly added parameters contributes to a better position and better comfort when traveling in an autonomous car.

The result displays that integration of additional parameters in the seat improves the comfort and position when performing other activities than manually driving the car. Furthermore, it is found that some aspects of the seating position are dependent on the activity carried out by the user, whilst others are not. Some aspects of the seating position and comfort are also dependent on the body height of the person.

It is recommended to integrate an articulation in the back support, an adjustable head support and adjustable arm supports in the seat of an autonomous car. Additionally more space for the legs and feet are needed when traveling in AD mode.

Preface

The master thesis was conducted by two Master of Science students from two different universities, Josefine Rysjö from Linköping University and Pontus Andrén from Chalmers University of Technology, for Volvo Car Group in Gothenburg, Sweden. The work has been carried out together by both students and the master thesis will be published at both Linköping University and Chalmers University of Technology.

We wish to thank the employees at the Ergonomics department at Volvo Car Group for their support and help during our work. We would furthermore like to express gratitude to our supervisors at the ergonomics department, Tommy Apell and Pernilla Nurbo for their commitment, inputs and advice during the different stages of the process. Another person we would like to acknowledge is Krister Hedlund at the Ergonomics department for his assistant and support.

From the two Universities we also would like to express gratitude to our examiners, Professor Johan Malmqvist at Chalmers University of Technology and Senior Lecturer Kerstin Johansen at Linköping University as well as supervisor PhD Fredrik Henriksson at Linköping University for all the advice, feedback and support given throughout the process of the master thesis. Lastly, we like to thank our opponents Jakob Hamilton, Alejandro Robles Diez and Maik Schockenhoff for their valuable opinions and input to our work.

Gothenburg, June 2018

Josefine Rysjö

Pontus Andrén

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Definitions and abbreviations

AD – Autonomous drive

VCC – Volvo Car Corporation

VCG – Volvo Car Group

TP – Test Person

1 INTRODUCTION

Volvo Cars have been manufacturing cars in the premium segment since 1927 including sedans, wagons, sport wagons, cross country cars and sport utility vehicles (Volvo Car Corporation, 2018). The company is keen to make people's life easier, safer and better, facts that goes well with the company's three core values: safety, quality and care for the environment. Moving towards the future and autonomous drive technology, Volvo now face new challenges and possibilities within the area and think there is a lot to look forward to (Volvo Car Corporation, 2018).

Unsupervised autonomous cars are becoming more common and will dramatically change the way we know transportation. A car driving in unsupervised autonomous mode performs all the driving where passengers of the vehicle are not expected to have control of the car (Volvo Car Corporation, 2018). Removing the human factor from driving will potentially increase fuel efficiency, reduce total travel time and lower the number of car accidents (Fagnant & Kockelman, 2015). According to Volvo Cars, "Unsupervised autonomous cars will revolutionize society, boost global economies and transform the way we manage our time", and the company aims for their first unsupervised autonomous car to be on the market by the year of 2021 (Volvo Car Corporation, 2018).

What makes Volvo's approach to autonomous driving unique is the focus on people and not just the technology (Volvo Car Corporation, 2018). With a future of autonomous driving in sight, Volvo wants to explore new needs and possibilities for the interior of the car. Volvo's seats have been considered one of the best seats in the automotive world for years (Volvo Car Corporation, 2018) and now Volvo wants to evaluate how design parameters of today's driver's seat, such as back support gradient, vertical and horizontal position and the head support, performs in scenarios within autonomous driving and see how these parameters will affect seating comfort and customer value for future cars.

1.1 Aims

The aim of the master thesis is to identify critical parameters affecting perceived comfort and seating position and how critical parameters can be taken into account when traveling in the driver's seat of an autonomous car based on customer needs and values. Additionally the aim is also to identify which seat position potential customers choose when traveling in an autonomous car.

1.2 Goals

The goal of the master thesis is to identify and evaluate critical parameters as well as provide recommendations for future design of a driver's seat in an autonomous car in order to add customer value.

1.3 Deliverables

- List of critical parameters affecting seating position and comfort of the driver's seat.
- Plan for planning and execution of an experimental study investigating comfort and seat positioning for a driver's seat.
- Documented experience of critical parameters in the driver's seat.
- Data regarding seat positioning of the driver's seat for defined scenarios.
- Recommendations for design of a driver's seat and comfort support systems for autonomous cars.

1.4 Research questions

RQ1. What critical parameters affect seating comfort and position when traveling in AD mode?

RQ2. How can integration of new parameters in the seat affect the ability to find a good position and increase comfort compared with today's seat when traveling in AD mode?

RQ3. How should different comfort support systems for the driver's seat be designed to add customer value when traveling in AD mode?

1.5 Delimitations

The delimitations of the master thesis are:

- The focus of the research will be limited to the driver's seat.
- The steering wheel and the pedals are the only interior components that will be kept and taken in consideration when developing recommendations.
- The result will be based and presented only for certain defined scenarios.
- User tests will be conducted in Swedish in Sweden.
- Some laws and legislations concerning vehicles will not be taken into consideration to not limit the development.
- The issue of trust and motion sickness in an autonomous car will not be investigated.
- The test environment is limited to using a Volvo XC90.

1.6 Disposition of report

This chapter describes the content of the different chapters in the report.

After chapter one with introduction, the report starts with chapter two, *Background*, which includes theory about autonomous drive and information about driver's seats of today. The following chapter, *Theoretical framework*, includes theory regarding comfort and discomfort, common activities when traveling and chosen seating postures when traveling in a seat. In chapter four, *Research approach*, the different methods used in the study are explained. Chapter five, *Phase one - Identification of scenarios and parameters*, includes execution and result from the process of identifying scenarios and identifying parameters using different methods. The process of finding scenarios and parameters forms hypotheses also presented in the chapter. The chapter also includes discussion and conclusions from phase one. Chapter six, *Phase two - Preparation for evaluation of parameters*, concerns the design and construction of the prototype seat in order to enable future testing of identified parameters. Chapter seven, *Phase three - Evaluation of parameters*, includes development, execution, result and analysis from three different user tests. There is also a discussion about the result and conclusions from phase three. The final result for different parameters and recommendations regarding the design of a seat for an autonomous cars are displayed in chapter eight, *Result*. Chapter nine, *Discussion*, includes discussions about the final result, discussion of the methods used in the study and recommendations for future work. The final conclusions of the project will be presented in chapter nine, *Conclusions*. Furthermore, additional appendix is placed at the end of the report. The different chapters can be seen in Figure 1.

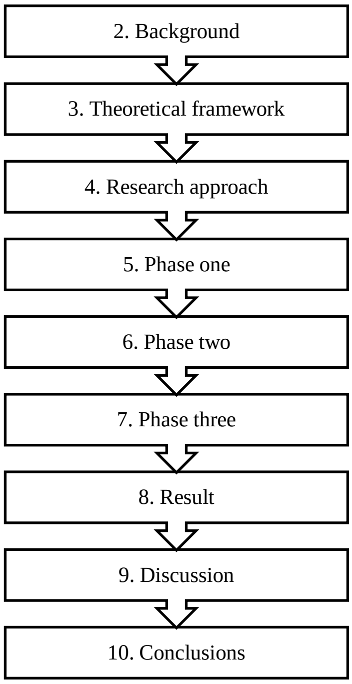


Figure 1 The different chapters in the report.

2 BACKGROUND

This chapter describes autonomous driving and how it affects the driving experience. It also presents the aspects of a driver's seat in today's cars.

2.1 Autonomous drive

When discussing autonomous cars it refers to those, who without input from the driver, is performing some aspects of safety-critical control functions e.g. steering, throttling or braking (National Highway Traffic Safety Administration, 2013). The motor vehicle is performing some or all of the dynamic driving tasks as well as the real-time operational and tactical functions required to operate a vehicle in on-road traffic (SAE International, 2016). These new systems enables drivers to have less control over the car, where the amount of control needed is dependent on the automation system.

2.1.1 Levels of autonomous drive

Autonomous driving is divided into different categories dependent of the level of automation (SAE International, 2016) (National Highway Traffic Safety Administration, 2013). SAE International (2016) categorizes autonomous driving in six levels, where level 0 is no driving automation and level 5 is the highest possible level of automation where the driver is not a part of the system at all. The National Highway Traffic Safety Administration (NHTSA) (2013) is likewise categorizing autonomous driving in different levels but use five levels, level 0- No automation to level 4- Full self-driving automation. The levels are developed in relations to the role played by the driver (human), the autonomous system and other vehicle systems when performing the dynamic driving tasks (SAE International, 2016).

SAE International (2016) categorizes according to Table 1. Execution of steering and acceleration or deceleration are referring to who is performing the longitudinal and/or lateral motions of the car consequently the steering and/or the acceleration or deceleration of the car. The second category, Monitoring of Driving Environment, refers to who is responsible for detecting and reacting to objects and events during the drive. The Fallback Performance of Dynamic Driving Task describes who is in charge of taking over the control if the system would fail and System Capability (Driving modes) describes if there is regulations of where the car is able to use the system. In level 4 the system is in control of the driving task, the environment around the car and is still in control of the system if it would fail but it is limited to where the car is able to use the system. To further understand how the autonomous system behaves in terms of driving and what is expected from the driver and the system in each level, see Table 1.

Table 1Interpretation of table explaining different levels of autonomous driving (SAE International, 2016)

Level	**Name**	**Execution of steering and acceleration or deceleration**	**Monitoring of driving environment**	**Fallback performance of dynamic driving task**	**System capability (Driving modes)**
Human driver controls all driving activities					
0	No Automation	Human Driver	Human Driver	Human Driver	No driving modes
1	Driver Assistance	Human Driver and System	Human Driver	Human Driver	Some driving modes
2	Partial Automation	System	Human Driver	Human Driver	Some driving Modes
3	Conditional Automation	System	System	Human Driver	Some driving Modes
4	High Automation	System	System	System	Some driving Modes
5	Full Automation	System	System	System	All Driving Modes
The autonomous system controls all driving activities					

2.2 Driver's seat

A driver's seat placed in a car is different depending on brand and car model. Different seats have different adjustment possibilities and characteristics. In order to increase comfort it is important to consider seat shape, upholstery characteristics, (firmness, contour etc.) and covering material of the seat (Harrison, et al., 2000). Furthermore the adjustment possibilities of the seat is an important aspect.

2.2.1 Driver's seat in cars of today

The driver's seat of today in a Volvo comes in different variants with different functions that can be operated manually or electronic, depending on the model. An electrically operated standard front seat of a Volvo XC90, see Figure 2, produced in 2017 has four individual adjustable parameters: moving the seat back and forth, moving the seat up and down, adjusting the gradient of the back and adjusting the gradient of the seat cushion (Volvo, 2016). The seat is also available in other car models from Volvo Cars. The movement of the adjustable parameters can be seen in Figure 3. Volvo also have a multifunctional seat with additional adjustable parameters such as adjustable seat cushion extension, adjustable side bolster, adjustable lumbar support and massage settings, Figure 2 (Volvo, 2016).

Figure 2 Multifunctional driver's seat of a Volvo XC90. (Volvo, 2018)

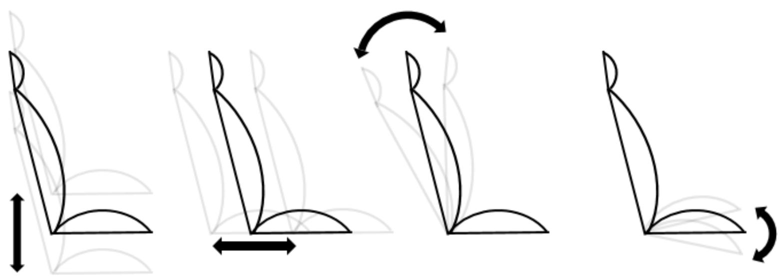


Figure 3 Adjustment possibilities of an electrically operated standard seat in a 2017 Volvo XC90: seat height position, seat length position, back support gradient, seat cushion tilt (Volvo Car Corporation , 2016).

2.2.2 Driver's seat comfort in cars

According to Donald D. Harrison (2000), the optimal driver's seat for a car is recommended to be designed with a certain set of features and parameters to support an optimal spinal position of the driver and prevent low-back pain. The optimal driver's seat would include an adjustable seat back support gradient, adjustable height, adjustable linear front-back positioning, adjustable head support, adjustable arm supports, adjustable lumbar support, adjustable depth of seat bottom, seat shock absorbers and firm, dense foam in the seat bottom. To further support the comfort of a driver's seat, Gokila & Suresh (2014) argue that additional parameters should be taken into account, such as vibration, pressure distribution and thermal comfortness.

3 THEORETICAL FRAMEWORK

This chapter presents the theoretical framework for the master thesis.

3.1 Comfort and discomfort

Comfort and discomfort are important aspects to understand when evaluating the concept of seating comfort. Zhang, et al., (1996) associates discomfort with biomechanical factors such as joint angles, pressure distribution and muscle contractions producing feelings of pain, soreness, numbness, stiffness etc. Zhang, et al., (1996) further states that discomfort can be reduced by removing physical constraints, but that the procedure does not necessarily produce comfort.

In a study defining comfort and discomfort, Helander, (2003), defines it as "Discomfort is based on poor biomechanics and fatigue. Comfort is based on aesthetics and plushness of chair design and a sense of relaxation and relief". Since discomfort is different from comfort, the two terms should be measured using separate scales (Helander, 2003). Investigating the relation between discomfort and comfort, Helander also found that low level of either comfort or discomfort does not entail high level of the opposite, but high level of either discomfort or comfort could be related to low levels of the opposite, see Figure 4.

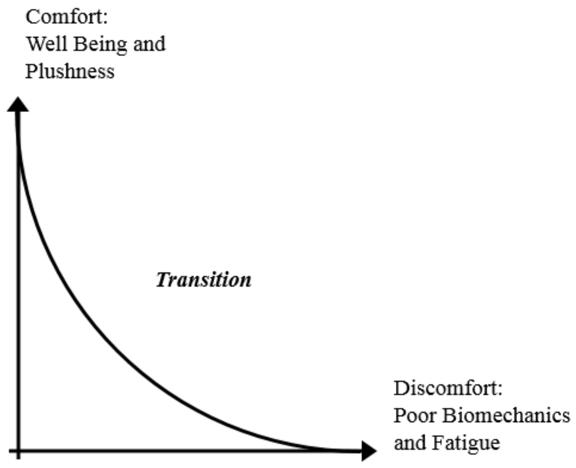


Figure 4 Interpretation of the conceptual model for seating comfort and discomfort according to Helander (2003). Displaying the coupling between discomfort and discomfort.

According to Hägg et al., (2015) there is a difference between instantaneous comfort and comfort during a longer time. Hägg et al., (2015) states that experience of instantaneous comfort does not necessary exclude discomfort later on. Furthermore comfort and discomfort are not a static feeling and can vary over time. A well-known model for seating comfort and discomfort is the comfort model by De Looze, et al., (2003) seen in Figure 5. Divided into two different sides, the left side examines the aspects of physical features affecting the user leading to discomfort and the right side examines the physical features as well as emotions and aesthetics leading to comfort. For the left side, using an office chair as an example, De Looze, et al., (2003) defines physical features to be for example form and softness, and context features as for example table height. Together with a task, these factors expose the user for loading factors that eventually could create force and pressure on the body. External loads on the body could eventually lead to perception of discomfort through provoking further physiological and biomechanical responses such as soreness, numbness and stiffness. For the right side, De Looze, et al., (2003) defines comfort with feelings of well-being and relaxation. Using the same example of an office chair, features related to context are also affected by psychosocial factors like social support and job satisfaction. The seat level not only consider physical but also aesthetic aspects of the chair. Finally on the human level, individual aspects and expectation can lead to individual emotions and feelings.

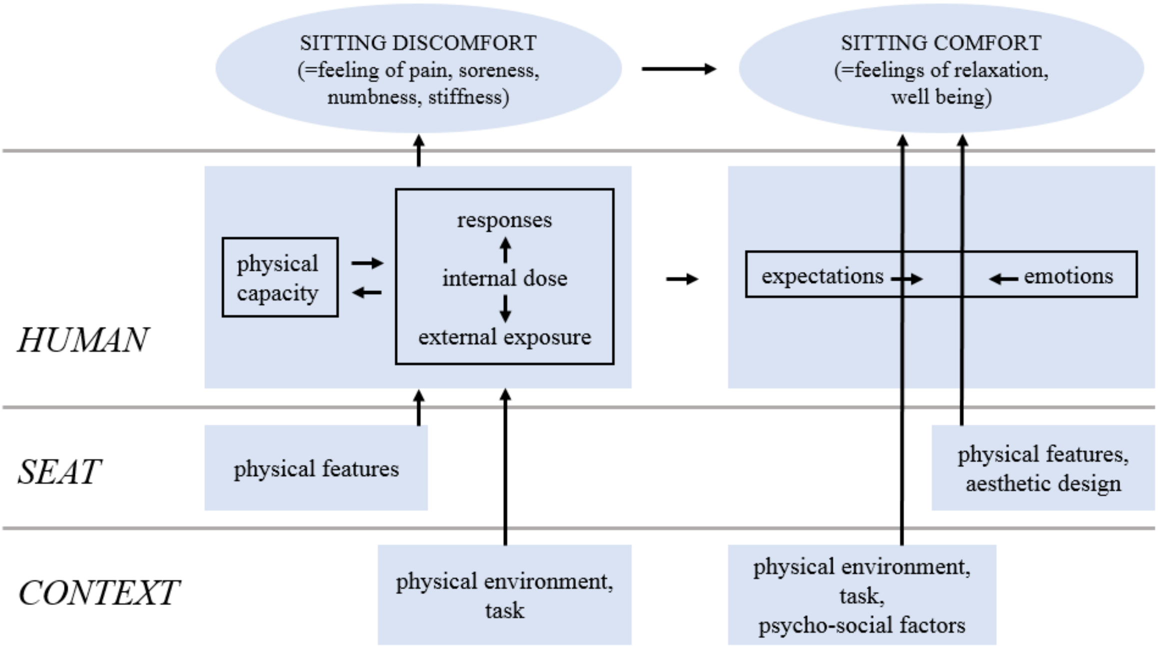


Figure 5 Theoretical model for comfort and discomfort (De Looze, et al., 2003)

3.2 Automotive usage

The number of persons usually travelling in a car is one of many aspects in terms of automotive usage. In a study measuring car occupancy rates in Norway 2007, Vågene (2009), found the average occupancy rate for cars in Norway to be below 2 passenger per car. More specific was the ratio 1.7 passenger per trip and 1.54 passenger per kilometer. The study also pin pointed a lower average for commuting, with an average of 1.14 passengers per car per trip. The average occupancy rate of less than 2 passengers per car is supported by data from the European Environment Agency (2010), where research between 2004 and 2008 displays an average occupancy rate of 1.54 for Western Europe countries (Austria, Denmark, Norway, Germany, Italy, Spain, UK). More recent statistics reviewing occupancy rates in cars have been done by the statistical company Statista (2015), where the average occupancy in cars and vans in England between 2002 and 2015 ranges from 1.57 to 1.59 passengers per car. Further statistics are presented by NUANCE (2017) through an online survey with 400 drivers from UK and US where 58 percent of the drivers expect to spend most time alone in an autonomous car.

3.3 Occupation when traveling

In this section, occupation when traveling in different types of transportations e.g. cars or trains are displayed. Furthermore desired activities when traveling in an autonomous car are presented.

3.3.1 Activities in cars

When driving a car today the driver can engage in non-driving activities, secondary tasks that not include in the primary task of driving (Ferdinand & Menachemi, 2014). Furthermore Ferdinand & Menachemi (2014) presents examples of such activities including mobile phone usage, cigarette smoking, eating, listening to music, talking to passengers and interacting with in-vehicle information systems. Sullman (2012) has asked drivers to identify secondary tasks and in 86% of the cases the driver is just focusing on driving the car and not engaged in any activities. But when eventually engaged in an activity, activities such as mobile phone usage, eating or drinking, smoking, talking to passengers and adjusting controls was performed. AA Motor Insurance (2011) support some of the activities and have recognised that eat food or drink a non-alcoholic drink are the most common secondary task, followed by using a handheld mobile phone and sending a text message. Other activities performed when driving are reading a book or newspaper (O'Neill, 2011). National Safety Administration (2012) have also identified drinking and eating as an activity regularly performed in a moving car, done by 86% of US citizens (Botterill, 2017). According to LeasPlan (2016) presented at Åkeri Entrepenad (2016), interviews performed in Sweden review activities, performed during a period spanning over a month, that almost 90% had been calling when driving, around 50% had been drinking or eating and 1/3 of the participants had been texting while driving. Observations of young adults driving performed by Fross et al. (2013) displays that using electronic devices, adjusting controls, grooming, and eating or drinking was secondary tasks that was most common. What people tend to eat in their cars is supported a study by Sandelman & Associated, presented by Chapman (2008), where the most frequent meal to buy at a drive-thru is a hamburger, a sandwich or other smaller food such as strips and nuggets.

3.3.2 Activities in other types of transport

There are other types of transportation systems were the user is traveling without the need for focusing on driving, e.g. trains and busses. Several observation studies have been conducted identifying activities performed when traveling in trains (Gripsrud & Hjorthol, 2012; Groenesteijn, et al., 2014; Kamp, et al., 2011; Russell, et al., 2011). The most observed activities according to Rusell et al., (2011) and Gripsrud & Hjorthol (2012) are looking out the window and watching other passengers on the train. These activities have also been observed by Kamp et al., (2011) but not as the most frequently performed activity. Groenesteijn et al., (2011) has observed staring and sleeping and identified it as the second most performed activity on the train ride. Sleeping and relaxing are activities that also has been frequently observed by Rusell et al., (2011), Gripsrud & Hjorthol (2012) and Kamp et al., (2011). Talking and discussing are also activities common on trains (Gripsrud & Hjorthol, 2012; Russell, et al., 2011; Groenesteijn, et al., 2014), even the most common according to Kamp et al., (2011). Gripsrud & Hjorthol (2012) have investigating both commuting and business travellers and in both groups working is the second most performed activity including working or studying, calling or texting for work purposes and using the phone in other ways related to work. Groenesteijn et al., (2011) likewise recognise working using a laptop as one of the four most commonly occuring activities, Rusell et al. (2011) has also observed working on the laptop on trains.

In addition to working, reading is also recognised on trains (Gripsrud & Hjorthol, 2012; Groenesteijn, et al., 2014; Kamp, et al., 2011; Russell, et al., 2011).

Russell, et al., (2011) has in addition to activities on trains also identified activities on busses. In more than half of the observations the passengers was looking ahead or out the window, which is more common on busses than on trains. Activities as reading, using a laptop, sleeping (eyes closed), writing and handling their wallet or belonging, was observed on the bus. Even though these activities are performed on busses the passengers are significantly more likely to perform these activities on trains (Russell, et al., 2011). Etteman, et al., (2012) have presented that various forms of relaxing occurs more often on busses than on metro and trains. Furthermore it is stated that activities such as working, talking or using communication technologies are more common on trains. According to Etterman et al., (2012), this is dependent on the conditions for work and use of communication technologies e.g. stability of the ride, and the duration of the journey. Lyons, et al., (2007) in Russell, et al., (2011) state that the difference regarding passenger activities on busses and trains can be dependent of the frequency of the service, the nature of the vehicle or the length of the journey.

The duration of the activities working on laptop, staring or sleeping, reading and talking is acknowledged by Groenesteijn et al., (2014). The average train journey in thirty observations was 1 h and 11 min. Groenesteijn et al., (2014) reviews that working on laptop had the longest average duration time, followed by staring or sleeping, reading and the shortest duration time being talking.

3.3.3 Activities in autonomous cars

In an unsupervised autonomous vehicle the driver will no longer need to focus on the driving task and can therefore be occupied with other things when traveling in the car. In a study performed by Jorlöv et al. (2017) test persons were asked what activities they would like to perform in the car, both during short journeys alone and longer journeys together with family. During longer journeys traveling together with others, activities such as play board games, watch movies and socialize with other occupants in the car are desired. During shorter journeys when travelling alone, activities such as looking out the window, surf the internet and sleep were the ones preferred by the user (Jorlöv, et al., 2017). Schoettle and Sivak (2014) also argue that the driver would “watch the road even though they would not be driving”, it is even the most common desire. Other desired activities differs depending on country, although in general text or talk with friends or family, work, sleep, read and watch TV or movies are mentioned. Pettersson and Karlsson (2015) have like Jorlöv et al., (2017) and Schoettle and Sivak (2014) acknowledged sleeping, relaxing, reading, socialising, video entertainment, games and using social media as preferred activities. In addition other activities as eating, tending to children and drinking alcohol are mentioned.

3.3.4 Seating positons when traveling

Different studies have been performed evaluating the way people want to be positioned when traveling in AD mode (Jorlöv, et al., 2017) (Pettersson & Karlsson, 2015). Other studies have identified how people are positioned when performing different activities e.g. sleeping, working on trains (Kamp, et al., 2011) (Groenesteijn, et al., 2014). Both Kamp, et al., (2011) and Groenesteijn, et al., (2014) also identifies what parts of the seat that are being used when performing the specific activity. Furthermore Groenesteijn, et al., (2014) has identified what parts of the seat the user would like to adjust during different activities and positions.

Identifications of positions when using a laptop in different situations has also been conducted (Hiemstra-van Mastrigt, 2015) (Gold, et al., 2012) (Asundi, et al., 2010).

3.3.5 Posture and position in a car environment

In a user test conducted in the U.S, participants were asked to imagine being in an autonomous car (Page Ive, et al., 2015). The test was conducted in a right-hand car but the test persons were seated on the left side, since this is the driver's seat of a car in the US. The components possible to adjust were the back support gradient, the head support height, the seat length position, and the seatbelt height. The most common positions identified when asked to be a passenger in a non-autonomous car or a driver in an autonomous car was upright, sprawled outwards and compact position where the legs are hunched toward the torso. The upright position was pointed out to be associated with alertness. When in compact position the seat is generally moved forward on the seating track and the body thereby confined. In the sprawled outward position the seat is generally moved backwards on the seat track and the back support gradient is increased backwards in the car. The preferred gradient of the back support in an autonomous car of level 4 has been investigated and the study displays that a back support gradient over 30 degrees is preferred by passengers and drivers when relaxing and sleeping in the seat (Hagberg & Jodlovsky, 2017). Hayashi &ABE (2008) has also identified preferred back support gradient when taking a short nap and taking a long nap in a car seat. Findings show that average of preferred back support gradient for taking a short nap is 38.7 degrees and for the long nap 63.3 degrees. Furthermore, Page Ive et al., (2015) has investigated how people would like to be oriented in relation to other occupants in the car. The result was that six out of ten wants to face forward and only turn their head to look at another occupant and four out of ten had a desire to be able to swivel the seat to face other passengers.

In an observation study done by Heimstra-van Mastright (2015) the effect on seating posture in the backseat of a BMW 7-series depending on different activities is evaluated. Participants were told to read a book, use a tablet pc and work on a laptop during a period of 30 minutes as the seating posture was observed and documented. The body posture observed when using different devices can be seen in Table 2.

Table 2 Coding system for body posture observation (Hiemstra-van Mastrigt, 2015)

Task	**Arms**	**Upper body**	**Head**	**Legs**
Laptop	Both arms along body	Upright, in seat	Upright	Straight together
Tablet	One arm supported	Leaning (left), in seat	Bent forward	Apart
Read	Both arms supported	Leaning (right), in seat	Bent forward strongly	Other

Result from the study done by Heimstra-van Mastright (2015), show a significant increase of the neck angle where the head is tilted forward when using a tablet or reading a book. These two use cases also review that participants often use one hand to hold the device or book where the other hand is used to control the tablet or simply placed in the lap when reading. The hand used for holding the device or book is always supported by an arm support depending on which side the participant lean towards. When using the tablet, using both hands for holding the device, using the thumbs to control the tablet is also observed.

Heimstra-van Mastright further presents possible design improvements to support this type of behaviour when travelling in a car. To support the use of a tablet or when reading a book, an arm support could be used to prevent the increased neck angle. Furthermore the result when using a laptop demonstrates one dominant posture where the laptop is placed on the participants lap in an upright position with arms alongside the body and legs placed straight together. This position implied an increased neck angle but also the aspect of vibrations as disturbing. To support the use of a laptop while traveling in a car, Heimstra-van Mastright suggest a proper laptop support for reducing vibrations and prevent shifting.

Asundi, et al., (2009) has further investigated different seating scenarios for working on a laptop. The scenarios are: sitting by a desk using a laptop, sitting with a laptop positioned on the lap and sitting with a laptop positioned on the lap using a commercial product acting as a support between the lap and the laptop to higher its position, consequently not performed in a car. Results from this study shows that, by using the commercial product for additional support to higher the position of the laptop, the neck angle could be decreased but also implied a higher wrist angle since the study did not have any arm support.

3.3.6 Posture and position on trains

When traveling in other transport solutions, such as trains, postures in relation to activities have been observed (Kamp, et al., 2011) (Groenesteijn, et al., 2014). When relaxing or sleeping in a train seat there is a desire for body support in the seat regarding the back support, seat cushion, arm support, table and head support (Hiemstra-van Mastrigt, 2015). Moreover, according to Heimstra-van Mastrigt (2015), the desires are; Backrest -*fully reclined*, Seat cushion-*upwards to prevent sliding*, Arm support- *long to support full arm*, Table- *not used* and Head support-*Side support, neck support.* Kamp et al., (2011) has also investigated trains and recognised common postures when relaxing and sleeping, see Figure 6. The association between activity, sleeping or relaxing, and the positions of the head, trunk and arms are the strongest. The most observed postures are important to consider in a new car interior to design for usability and comfort, but further research is necessary to analyse specific details of car interiors (Kamp, et al., 2011). Groenesteijn et al., (2014) have conducted a similar study and in addition to Kamp et al., (2011) that also identifies turning the head in seating positions, postures can be seen in Figure 6. Seats suitable for sleeping are one of the parameters identified as important for workers with long commuting time (Das, et al., 2017).

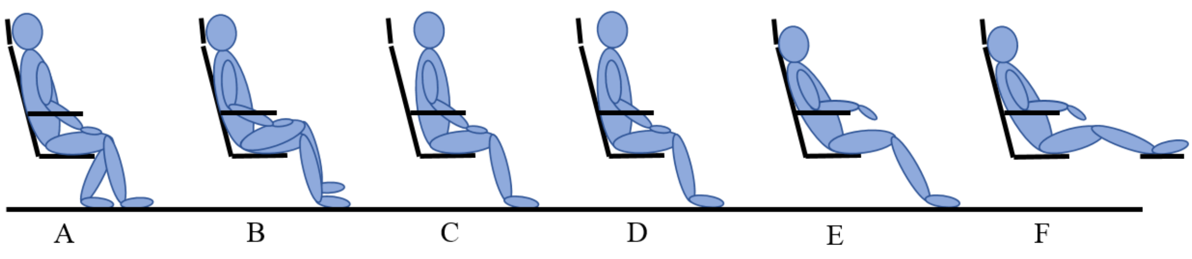


Figure 6 Significant postures for watching (A, B and C), talking (C), eating (C), relaxing (E) and sleeping (E and F) (Kamp, et al., 2011)

Furthermore, Kamp, et al., (2011) identifies the most common seating posture for what is defined as "High-level activities", which is using small or large electronic devices. Common for the top three postures of high-level activities is that the head is free from the head support, see Figure 7.

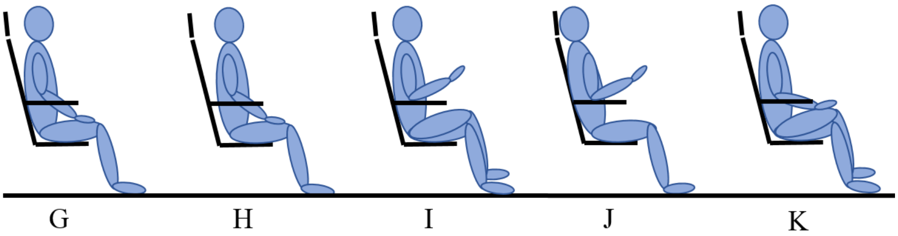


Figure 7 Most frequent seating postures in High-Level Activities: G (63.3%), H (43.5%), I (21.7%), J (15.9%) and K (11.4%) (Kamp, et al., 2011)

When talking to other passengers on the train, postures with head and trunk rotated have been observed, see Figure 8 (Groenesteijn, et al., 2014). Kamp, et al., (2011) has likewise looked at postures for talking and discussing and have in addition categorized this with the activities reading and eating & drinking, see Figure 6.

Activity	**Posture and comfort notes**							
Reading	8	7	7		7			
Staring/sleeping	6	8		6.5			6	
Talking	6.5			8		5.5		7
Working on laptop	7	7	7.5		7			

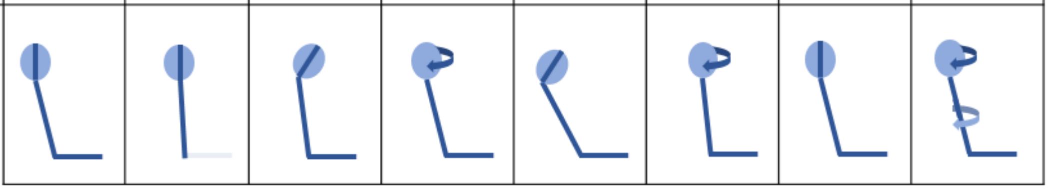


Figure 8 Activities, postures and comfort scores. Scale 1-10: not comfortable at all - very comfortable. (Groenesteijn, et al., 2014)

The ability to adjust parts of the train seat, (head support, seat, pan, backrest table) and when performing activities have been investigated (Groenesteijn, et al., 2014). When sleeping, the two parameters that most people (66 %) wanted to adjust was head support and back support. Almost half of the people (48%) also wanted to adjust the seat cushion and the table. When investigating the activity of using a laptop, the result displays a table as the option with the highest percentage of preferred adjustability (79%), followed by back support position (77%), head support position (71%) and seat cushion position (62%). Furthermore when asked what parameters the test person would like to be adjustable when talking to other travellers the most common answer was the head support. The second parameter was adjustability of the table and after that, the ability to adjust the back support. The seat cushion was the least requested adjustments

3.3.7 Seat orientation in an autonomous car

In a study by Jorlöv, et al., (2017), two scenarios for driving in an autonomous car were investigated, a longer travel with the family and a shorter drive for example driving to work. Test persons were asked to enter a minimalistic setting consisting of four chairs and afterwards asked to redesign how they would like to sit in an autonomous vehicle. The result is displayed in Figure 9. The most common desired position for the longer drive scenario is rotating the front seats 180 degrees (C), rotating the seats in 135 degrees facing inwards in the car (E) and the seats rotated 90 degrees (D) (Jorlöv, et al., 2017). Furthermore, seats positioned as today and the front seats rotated inwards in the car was identified (A & B). The relation between the answer can be seen in Table 3. During the short scenario when driving on their own, almost all participants desired to be seated forward-facing (Jorlöv, et al., 2017).

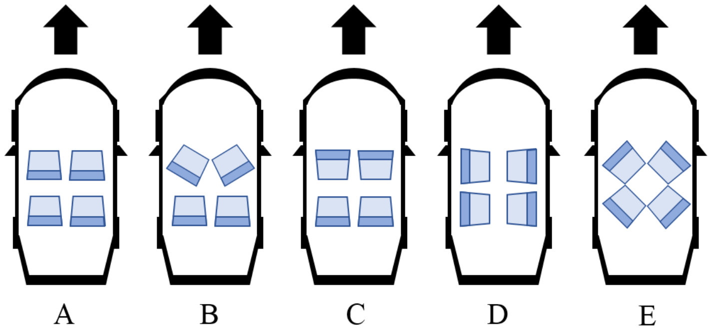


Figure 9 Possible seating positions in an autonomous car (Jorlöv, et al., 2017)

Table 3 Number of specific answers (Jorlöv, et al., 2017)

Seat position	Frequency of participating votes
A	4
B	1
C	12
D	5
E	6

In a similar study performed in a parking lot in Gothenburg, people were asked to arrange 4 chairs in car drawn on the ground how they expected the interior to look in an autonomous car (Pettersson & Karlsson, 2015). The result displays that participant expected to turn into a space more adapted to comfort, social activities and relaxation. In this test swivelling seats were commonly drawn which show an interest for more social opportunities in the autonomous car (Pettersson & Karlsson, 2015).

4 RESEARCH APPROACH

In order to answer the research questions, there is a need to evaluate if and how different parameters are affecting seating comfort and position in a driver's seat when traveling in an autonomous car. In this chapter, theory about the research approach is presented.

4.1 Subjective data methods

Subjective data is collected by letting the user describe their personal experience of the situation (Osvalder, et al., 2015). The user is able to, either verbal or written, explain what they think, feel or believe of the specific situation. Furthermore subject data collection is enabling an overall impression of the situation to be taken into consideration in the overall evaluation.

4.1.1 Subjective evaluation of comfort and discomfort

According to Osvalder, et al., (2015) subjective methods are important when evaluating discomfort as it is primarily personal preference that contribute to comfort experience. This can be done throughout focus groups, interviews or questionnaires including scales measuring e.g. discomfort, pain, or fatigue. Furthermore Osvalder, et al., (2015) argue that it is good to supplement subjective estimation with observations of behavioural changes e.g. change in body posture, movement or focus changes to better understand the situation.

When measuring comfort and discomfort Helander (2003) argues that it is essential to use different scales for comfort and discomfort since they are different from each other. According to Helander (2003), there are different questions related to comfort and discomfort. Questions about comfort are asked in regards to aesthetics, sense of relaxation and relief and wellbeing while questions about discomfort is asked in relations to biomechanics factors such as pain and soreness (Helander, 2003). In order to evaluate local features of a seat, a forced choice rating and a checklist can be used (Shackel, et al., 1969). When evaluating seating comfort and discomfort it is easier to capture variations preferred options that is influenced by fit, if the body size of the test persons (TP) is taken into consideration (Ziolek, 2014).

4.2 Objective data methods

Objective data collection is collected through measurements of the system (Osvalder, et al., 2015). Furthermore objective data collection can be supplemented by observations of a situation. This type of data does not consider what the user is experiencing in the situation.

4.2.1 Objective evaluation of comfort and discomfort

In order to measure comfort, objective measurements measuring angles, torque and forces can be used (Osvalder, et al., 2015). The relation between objective measurements and discomfort is according to De Looze, et al., (2003) stronger than for comfort since the relation between physical exposures has a clearer connection to discomfort than to comfort. When evaluating seating pressure a special pressure map can be placed in the seat to measure pressure of the person sitting. Although according to Osvalder, et al., (2015) it is often hard to find the connection between discomfort and the pressure reading. Furthermore Osvalder et al., (2015), presents observation as a good objective method for mapping and quantifying the motion pattern and postures in different positions of the TP. This can be conducted either by direct observation or filming of TP. In order to gain a better explanation of the objective data it is good to in addition use subjective methods.

4.3 Benchmarking

It is critical to understand the competitive product in order to position a new product on the market which can be done through a benchmarking of competitive products (Ulrich & Eppinger, 2012). Moreover, a benchmarking of competitive products can serve as an inspiration for the product being developed. Benchmarking can identify existing concepts developed to solve the problem and reveal strengths and weaknesses with these concepts. When conducting a benchmarking it is good to use external search to gather data (Ulrich & Eppinger, 2012).

4.4 Semi-structured interview

Semi-structured interviews have proven to be both versatile and flexible and is therefore a common method for data collection (Kallio, et al., 2016). Semi-structured interviews can be used when an interviewer want a deeper understanding of specific topic (Osvalder, et al., 2015). A certain level of knowledge of the topic are is required since the interview questions are based on previous knowledge (Kallio, et al., 2016). Since there is a specific topic for the semi structured interviews it is easier to analyse than an unstructured interview (Osvalder, et al., 2015). Furthermore Osvalder, et al. (2015) explains that when performing a semi-structured interview some questions are determined in advance, often open questions, but the interviewer is still able to ask follow-up questions which enables the interviewer to control the discussion. Some negative aspects of using interviews is the fact that the interviewer needs to be present during the whole time and can therefor influence the person being interviewed (Osvalder, et al., 2015). Another disadvantage is the fact that what people say they would act are not always consistent with how they actually act in a situation (Osvalder, et al., 2015).

4.5 Prototyping

The purpose of making and using a prototype is to get a better understanding for what the solution needs to be able to do and to learn from the process itself (Wikberg Nilsson, et al., 2015). A prototype is often a physical model made to test a concept or an idea leading up to what is eventually the final product. Prototyping could mean testing different variants, combinations or possibilities with the aim of better understanding the design issue, exploring innovative solutions or testing the functionality. The difference between prototyping and manufacturing is that prototyping often includes sketches, mock-ups or other cost effective solutions, while manufacturing often includes a detailed plan for production and costs (Wikberg Nilsson, et al., 2015).

The use of early prototypes or mock-ups is a good tool for understanding the human interaction with a possible solution early in the project. Mock-ups are full-scale models built to test for example function, ergonomics or the space of movement (Wikberg Nilsson, et al., 2015).

4.6 Scenarios

Scenarios is an effective strategic planning tool for planning medium to long-term under uncertain conditions and can help to understand the logic of development, clarify driving forces and also be used for evaluation purposes. The method can help to identify contextual challenges and opportunities which can be used to generate strategic options (M. Lindgren, 2003). Foster, (1993) defines a scenario as: “A description of a ‘possible future’ based on a set of mutually consistent elements, within a framework of specified assumptions, which will typically encompass both quantitative and qualitative elements.” Furthermore, Wikberg Nilsson, et al.,

(2015) describes the purpose of using scenarios as developing criterias for the user interaction to understand the behavior and impulsion of the user.

4.7 Observation

Observation is a good method when collecting information about how a human is acting in a situation (Osvalder, et al., 2015; Wikberg Nilsson, et al., 2015). It can also be useful to clarify other type of data if this is unclear (Hennik, et al., 2011). Observations will provide knowledge about what people actually do, not what they say they will do, since people is not always aware of they actually are behaving in certain situations (Osvalder, et al., 2015; Hennik, et al., 2011). Furthermore the body language of people can be observed and this can give information about behavioural norms (Hennik, et al., 2011). However observations will not provide information about the underlying reasons of the behaviour sometimes making the interpretations of the result tough (Osvalder, et al., 2015). Moreover feelings, attitude and wishes will not be provided. According to Hennik, et al., (2011) the method is also time consuming which can be seen as a limitation.

The method can be used as a stand-alone method but is often combined with other methods to provide supplementary data (Hennik, et al., 2011). When combining observations with e.g. interviews or focus group different perspectives of the problem can be identified.

4.8 User test

A user test is a method where real users interact through a number of relevant and realistic tasks with either a product, a technical equipment or a system (Osvalder, et al., 2015). The profile of the users is supposed to match the chosen target group set for the product in the best way possible in terms of background, profession, education, age and knowledge. The relevant user sometimes needs to be an expert where long-term knowledge of the product is needed, but could also be a first time user which is more suitable when testing the user's ability to use a product correctly. The duration of the test should not exceed the total time of 1 hour, including introduction, eventual interviews and ending, where the actual problem solving should not exceed the total time of 30 minutes (Osvalder, et al., 2015).

Osvalder, et al., (2015) continues to describe the user test as tool that provides a lot of useful data when evaluating a user interface, something that is useful in several different stages of the product development process, but also as something that is a very time consuming if done with a large group of users. A user test group usually consist of six to eight people, and if two results are to be compared, a test needs up around twelve people in each test group to be enough for calculating significant differences between the two. To find approximately 75-80 percent of the user problems a common guideline is to have at least five or six people participating in the study, to increase the number of participants does not entail finding more or new problems (Osvalder, et al., 2015).

A method for compiling and analysing large amount of data, such as comments from a user test, is the so called KJ method, named after the ethnologist Jiro Kawakita. The method is an effective and simple tool for communicating the result for a large amount of data (Scupin, 1997). It is based on the action of writing facts on small notes, where the notes are spread out on for example a table and paired together based on the content. When all the notes are gathered into groups, each group is given a name according to what theme.

4.9 Applied research approach

The research was divided into three phases. The first phase starts with a literature study as well as expert interviews to acknowledge basic understanding and build a theoretical framework concerning seating comfort and autonomous driving. Expert interviews were conducted with employees of Volvo Cars to find out more about Volvo's previous work within the area and to further support the very beginning of the research. In addition, a benchmark was carried out to investigate how other competitors have envisioned autonomous cars of the future. Furthermore scenarios was used to create a context for the user since this level of autonomous driving does not exist today but rather is a "possible future". Output from the first phase are scenarios, parameters and hypotheses for adding customer value for seating comfort in autonomous driving.

The second phase includes development of several prototypes to enable evaluation of parameters identified in phase one. Furthermore the test environment was determined. Output from this phase was prototypes placed in a test environment.

In the third phase user tests was designed and conducted based on identified parameters and hypotheses from phase one. During the user tests, observations were used to identify how users actually sat in the seat. Furthermore objective and subjective data was combined and compared to find the most relevant result. The work was iterated during several user tests throughout the phase. Furthermore, result from the evaluations was presented, analysed and discussed. The output from this phase was positions chosen in the different scenarios and user's perception of comfort and position for defined scenarios.

The output from phase three was used to answer hypotheses from phase one and research questions for the project in the result chapter. Further result and analysis was used to create deliverables for the project. The whole process can be seen in Figure 10.

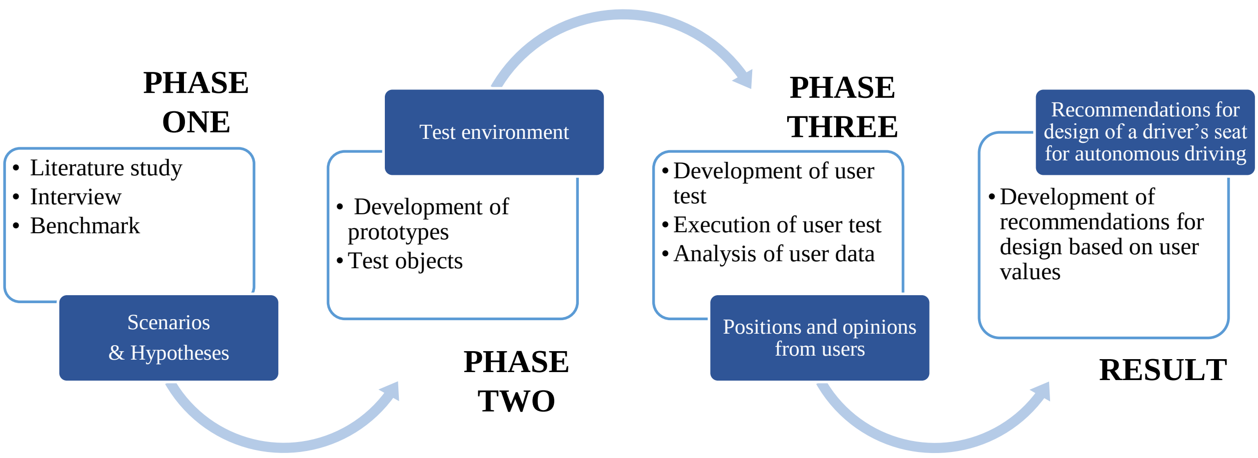


Figure 10 The three different phases of the project. The white area displays tasks that will be performed in the phase and the blue area displays output and input for the different phases.

5 PHASE ONE – IDENTIFICATION OF SCENARIOS AND PARAMETERS

The first part of the project was conducted to identify scenarios for AD when the driver no longer needs to be in control and therefore has the ability to do other things in the car. After scenarios and important parameters of the seat affecting the seating position are identified, hypotheses are formed. In this chapter different steps performed and result are presented together with a discussion and conclusion from the phase that will be brought into the next phase.

5.1 Benchmarking study

An external benchmarking was conducted with the aim to gain a better understanding for existing products as suggested by Ulrich & Eppinger (2012). It was also developed to get knowledge of interior concepts and solutions for autonomous driving as well as for car seats for autonomous driving developed by other car and seat manufactures. This benchmark was carried out by using the internet to access information.

5.1.1 Benchmarking results

Most car manufactures have developed concepts for what tomorrow's interior in cars might look like (Beecham, 2016). The external search reviewed concepts from companies like Adient, Yanfeng, Brose, Mercedes-Benz, BMW, and Volkswagen. One function identified is the possibility to swivel the seat, enabling seats to be moved around between different positions in the car, and to use the space more freely. Other functions in the seats are foot support and arm support. The seats are often of slim design and the seat belt is only present in some of the concepts, Mercedes-Benz and Tesla. One identified seat for the cars of tomorrow is developed by Brose that can rotate 180 degrees and provide arm supports and foot support (Brose, 2017), se Figure 11.

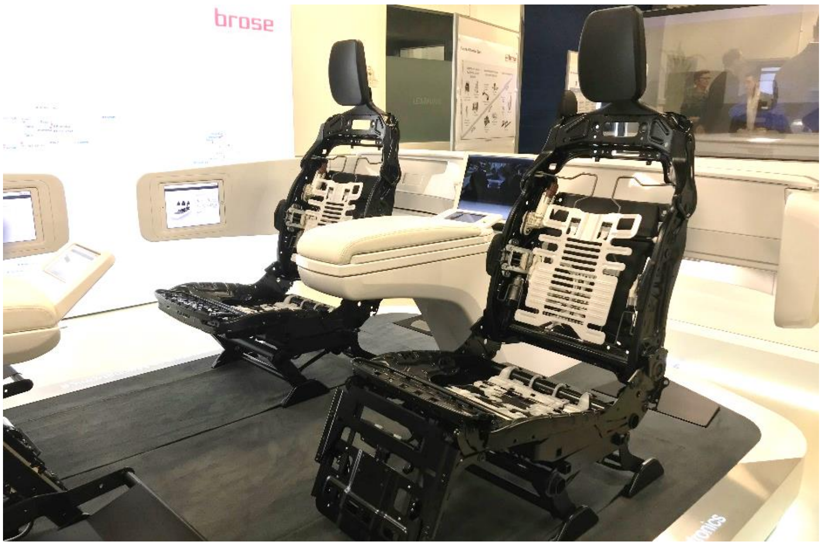


Figure 11 Seat structure developed by Brose.

5.2 Expert interviews

Semi-structured interviews with experts was carried out with employees within different departments at Volvo Cars concerning the topic of autonomous driving. Suggested by Osvalder, et al., (2015), the interviews where semi-structured since a deeper understanding of the topic was desired. The aim of the interviews was to obtain a holistic view to the concept of autonomous driving and to get additional information and aspects early in the project. The interviews were held with experts within safety and user experience at separate occasions.

5.2.1 Expert interviews result

Expert interviews gave important insights of how other departments at Volvo Cars work with the concept of autonomous driving. This chapter summarizes the most interesting findings and thoughts from the interviewees.

Interview with safety expert

The expert began to state an important aspect when talking about autonomous driving: "There is no crash-free future". An important statement implying that the future of a totally crash free future is hard to reach and still to come. Additional safety aspects were discussed during the topic of autonomous driving. The expert meant that concepts showing futuristic new ways of travelling in vehicles, for example lying down or travelling with a rotated seat orientation will set totally new requirements on belt positioning, air bags and other safety system in the car. Another safety aspect is trusting the vehicle when the driver has entered AD mode. The big change from manually driving a car to travel as a passenger, thereby trusting the car to handle by itself, is interesting. The expert thinks people will gain more trust to the concept of autonomous driving as the technology improves.

Interviews with experts within user experience

Experts within user experience at Volvo Cars agree that there is a lot of research to be done in terms of new ways of travelling when the car handles the driving. Future concepts of AD travelling concerning new positions for the driver and the seat will set new requirements for the interior and how the driver interact with different information and entertainment systems. According to the experts, this new interior aspect of autonomous driving requires a completely new development model since the driver no longer will have to drive the car and have time to perform other activities – the question is just what type of activities? Each driver is unique and will thereby behave in a unique way in an autonomous car, putting pressure on the ones who develop cars for the future.

5.3 Identifying scenarios in literature

In order to find scenarios for traveling in an autonomous car, a literature study was conducted. In this study, activities when traveling in a modern car or with other types of transport are identified together with desired activities for traveling in AD mode. To find the most frequent occupations when driving a car or travelling with other types of transport, a compilation of previously done studies in the field was conducted. The same procedure was done for desires for AD mode traveling. In this compilation the observation result from the different studies was categorized into different categories. In each study the percentage of observations connected to the activities categories was defined. The percentage result in each of the activity categories was compered between different studies in order to identify which activities are most common when traveling in cars, other types of transport and desires when traveling in AD mode. This comparison between different studies can be seen in Appendix A. To further identify scenarios the result in the three different traveling categories are compared. The compilation of occupations and activities is the foundation for creating scenarios.

5.3.1 Identified scenarios in literature

Results from compiling the most frequent activities in different types of transports form five different scenarios which upon future work will be based. The chosen scenarios are listed in the following section, regardless of meaning or importance for the project.

Relaxing

The user is travelling in autonomous driving mode and would like to relax or stare out the window during the trip.

Reading or using a handheld device

The user is travelling in autonomous driving mode and would like to read a book or use a smaller electronic device such as a mobile phone or a tablet.

Working on laptop

The user is travelling in autonomous driving mode and would like to work, reading emails or other activities on a laptop.

Eating and drinking

The user is travelling in autonomous driving mode and would like to eat or drink something during the trip.

Travelling together

The user is travelling in autonomous driving mode together with other passengers where they would like to have a conversation face to face.

5.4 Identifying parameters in literature

For different scenarios, users will have different preferences and needs based on how they are positioned. In order to identify important parameters, such as back support or arm support, and how different parameters can be paired with the right scenario, a literature study was conducted. In the literature study postures and seating comfort linked to activities connected to the different scenarios has been evaluated. Different studies have investigated seating postures in cars (Hiemstra-van Mastrigt, 2015; Page Ive, et al., 2015; Hagberg & Jodlovsky, 2017; Hayashi & ABE, 2008). Others have been focusing on evaluating postures in train seats (Kamp, et al., 2011; Groenesteijn, et al., 2014; Hiemstra-van Mastrigt, 2015) as well as desired position and posture when traveling in autonomous driving mode in a car (Jorlöv, et al., 2017; Pettersson & Karlsson, 2015; Page Ive, et al., 2015) The observations and result from the different scenarios has contributed to identifying parameters from the different scenarios. Through a compilation, see Table 4, a good overview of what is affecting the different scenarios is presented.

Table 4 Compilation of different activities affecting comfort and posture in different scenarios

Study/ Scenario	Relaxing	Reading or using handheld device	Working on laptop	Eating or drinking	Traveling together
Kamp, et al., (2011)	- *Position of:* Head, Trunk, Arms	- Back support gradient - Head support - Trunk in contact/no contact with back support	- Back recline - Head support - Trunk contact/no contact with back support	- Upright position - Head support - Trunk contact/no contact with back support	
Groenesteijn, et al., (2014)	- Rotated head. - *Adjustable:* Head support, Back support		- *Adjustable*: Table, Back support, Head support, Seat cushion,		- *Adjustable:* Head support - *Rotated:* Head, Trunk
Hiemstra-van Mastrigt (2015)	- Back support - Seat cushion - Arm support - Head support.	- Head bent forward - Arm support	- Proper laptop support - Increased neck angle - Arm support - Back support gradient - Head support		
Asundi, et al., (2010)			- Product for additional support affects neck and wrist angle - Arm support		
Jorlöv, et al., (2017)					- Swivel seat
Pettersson & Karlsson (2015)					- Swivelling seats
Page Ive, et al., (2015)	- Backwards on seat track - Back support gradient increased				- Rotating head - Swivel the seat
Hagberg & Jodlovsky (2017)	- Back support gradient				
Hayashi &ABE (2008)	- Back support gradient				

5.4.1 Identified parameters in literature

Each defined scenario will affect the position of the seat according to how the posture of the user changes. Standard adjustable seating parameters as defined in the XC90 seat will all contribute to the seating posture more or less depending on the scenario. In addition to existing parameters such as back support and head support of the XC90 seat, new parameters such as laptop support and arm support are identified as interesting for further development. In Table 5, parameters of interest are listed independently and paired with the defined scenarios.

Table 5 Important parameters for the specific scenario based on the literature study.

Scenario	Identified parameters
Relaxing	Back support, head support, arm support, foot or leg support
Reading or using a handheld device	Arm support, head support, trunk support
Working on laptop	Support area (table), arm support, back support, head support
Eating or drinking	Back support, support area (table)
Travelling together	Seat orientation, head support, back support

5.5 Hypotheses

Using the result from defined scenarios, benchmarking and identified seat parameters in literature, hypotheses are formed to support further development and evaluation. Hypotheses are used as a base for what future evaluation will answer to and to summarize findings from Phase one.

Relaxing

When the car is in AD mode and the driver wants to relax, the back support gradient will be increased. Furthermore support of the whole back will contribute to increased comfort. There is also a desire to have a supported head. Additionally arm supports will increase the level of comfort when relaxing. The same will be achieved by providing foot support.

Reading or using a handheld device

When the car is in AD mode and the driver wants to read a book or use a smaller handheld electronic device, it is desirable to have arm supports. Furthermore, foot support will increase the level of comfort in the performed activity. A head support that enables support for the head in different positions will also increase the level of comfort. Moreover support of the whole back will also contribute to improved comfort when using a handheld device.

Working on laptop

When the car is in AD mode and the driver wants to work on a laptop using a laptop support placed in the car, the level of comfort will be increased by the ability to use an arm support. Furthermore support of the whole back adds additional comfort when performing the activity. A head support in different positions will also improve comfort when working on a laptop.

Eating or drinking

When the car is in AD mode and the driver wants to eat or drink, it is desirable to have areas to store the food or drink when the driver is not actively consuming the food or drink. Furthermore support of the whole back will improve comfort as well.

Travelling together

When the car is in AD mode and the driver is travelling together with others, a different seating orientation is desired to support and enable conversation. The seating orientation should provide possibilities to create an environment where one can see each other when having a conversation. Additionally support of the whole back in the different positions is desired. Support for the head in the different orientations is also desired.

5.6 Discussion of phase one

With the basic thought of autonomous driving being that you don't need to be in control when the car drives on its own, the driver could now implement activities previously only possible for the passengers. Although different traveling solutions, as presented in the thesis, have different characteristics such as a train following a train track or a buss being more dynamic and affected by the physical layout of the road. The nature of the vehicle could thereby affect the desire or will to perform certain activities in the identified scenarios. This will not be further investigated in the study but is a subject suitable for future work considering autonomous driving. How the length and type of the journey affect the defined scenario also needs to be further investigated.

The benchmarking study and process discovered many concepts for AD, but it usually not display how well tested external concepts are or how long into the development process concepts have gone. Many of the concepts, for example swivelling or rotating seats, would be hard to fit in a car with the geometrical shape of a car of today, due the limited interior space. It is also difficult to understand which level of autonomous drive external concepts are developed for. Therefore, parameters designed with inspiration from benchmarking concepts needs to be put into a more realistic environment. Furthermore postures in other type of seats, both car seats and other seats, are also investigated and the fact that not only car seats have been investigated could have an effect since different parameters may be more or less important in different types of seats.

Result from phase one concerning identified parameters only focus on what type of parameters that affect each scenario, and not how a specific parameter should be or is designed. Parameters used in each scenario is dependent on what type of activity the user performs and could be affected by how the parameter is designed for the specific subject being analysed. How parameters needs to be designed to be appreciated by the user will instead be investigated later in the project.

5.7 Conclusions of phase one

Data gathered from phase one resulted in scenarios for autonomous driving that will be used further in the study. Furthermore parameters affecting seating posture and comfort in different scenarios have been identified and hypotheses have been formed. These hypothesis will be investigated in the next phases by planning and conducting user tests.

6 PHASE TWO - PREPARATION FOR EVALUATION OF PARAMETERS

This chapter presents development and result regarding prototypes designed to make it possible to test scenarios, parameters and hypotheses from Phase one.

In preparation for evaluating identified parameters, a prototype seat with new parameters integrated in the seat was designed. The prototype was not designed to be produced in the future, instead the purpose was to enable tests where users can evaluate the parameters in a credible way. Due to the duration time of the study all identified scenarios could not be evaluated. When traveling in a car today it is more common to be less than two people (Agency, 2010; NUANCE, 2017; Vågene, 2009). Since the scenario 'traveling together' includes traveling with at least two people in the car, it was seen as less important to evaluate. Furthermore evaluation of the 'traveling together' scenario would mean that the seat would have to be placed facing a different direction than for the other scenarios, which would require a different test environment. In the scenarios of relaxing, reading using a handheld device, working on a laptop and eating and drinking, the seat faces forward as today while in the traveling together scenario the seat is rotated towards the centre of the car. To evaluate the other four scenarios, the developed prototyped will be mounded in the same way as a driver's seat is mounted in the cars today, facing forward.

6.1 Benchmarking study

Another benchmarking was conducted with the aim of getting inspiration on how to design the new parts of the seat in preparation for testing the parameters. It examined integrated arm supports attached to the seat, foot support and neck support, both from Volvo Cars and other manufactures. The benchmarking was carried out by using the internet to access the information.

6.1.1 Benchmarking result

The arm support recognised is placed on the side of the seat outside the bolster supports, being able to be folded away backwards on the side of the back support. Furthermore the area for arms on the arm support are narrow but it is often quiet long. The foot supports identified either places in the end of the seat cushion or further in front of the seat. The one that places in the seat cushion is often a flat surface able to be flipped up, supporting the calves. The one that places in front of the seat is usually applicable for the second seat row where it is placed in the back support of the front seat, it can also mean removing the entire front passenger seat and replace it with a console acting as a foot support. Some of the head supports identified have supporting wings on the side, other have an extra cushion on top of the support. Regarding the back support it was recognised that some brands have the possibility to adjust the upper part of the back.

6.2 Test object

The test was be performed in a Volvo XC90, see Figure 12. This car model was chosen since it is the biggest one of all Volvo Cars on the market and therefore its providing as much space possible. The interior space needs to be able to fit all prototypes in a good way and also enable space enough for the chosen scenarios. The choice of using a car that was representative for how a car looks today was made due the fact to make the evaluations as similar to an autonomous car as possible. The interior of the car will be intact and displayed in Figure 12.

Figure 12 The exterior (left) and the interior (right) of a Volvo XC90 (Volvo, 2018)

6.3 Additional seat features and parameters

From scenarios and parameters defined in phase one, hypotheses were formed where different occupations was paired with different parameters. With the hypotheses as a starting point, the different parts of the seat were investigated and further developed to support the evaluation of the hypothesis. In this chapter characteristics that was important when developing the different parts of the prototype are presented.

Head support

The head support is found to be connected to several of the defined scenarios, each of them demanding separate functions. A basic head support like the head support on a 2017 Volvo XC90 is flat and fixed in position. To support the best posture possible for the user, the head support needs to become more flexible. According to Harrison (2000) an adjustable head support is one of the parameters included in a good driver seat. In terms of the relaxing scenario, the hypotheses states that the user is likely to have an increased back support gradient and for example put more weight on the head support, this needs to be taken into consideration when designing the head support. Furthermore when relaxing it is seen in future concepts for autonomous driving that the head supports have elevated sides to better support the head.

Arm support

When reading or using other smaller electronic devices, arm supports can support the arm posture of the user (Hiemstra-van Mastrigt, 2015). The height of the arm support will be based on anthropometric measurement from Hanson, et al., 2009 concerning the average height, in a sitting position, from the seat cushion to the elbow for both men and women. To further elaborate the height of the arm support, an adjustable construction is needed. This is also supported by Donald D. Harrison (2000) who describes adjustable arm supports as a one of the items important for a good driver seat.

Foot and leg support

To further support a sprawled-out or lying position where the back support gradient is increased in a relaxing scenario, a foot or a leg support is desirable. A support system for the legs of the user is a common parameter when exanimating future concepts for autonomous driving, where an example is the concept seat designed by Brose, see Figure 11. A foot support is supposed to be placed on the car interior floor and give support for the feet and the leg support is supposed to give support for the whole legs.

Back support

To have support for the back is seen as an important parameter in many of the scenarios. In order to give more support for the back in different positions, more adjustment possibilities for the back is desired.

Laptop support

The scenario of working on a laptop sets new requirements on the interior regarding where the laptop can be placed, especially if not placed on the lap of the user. The laptop support needs to give the user a possibility place their laptop in a stable way to allow the user to work in the car.

6.4 Development process

This chapter presents identified parameters and how they have be designed to evaluate hypotheses and answer the research questions of the study. Additional design steps will be made continuously during phase two, with user tests evaluating size and position of new or modified parameters. In comparison with the XC90 comfort seat, (hereafter referred to as the standard seat, see Figure 3) new parameters or functions will be added and explained with the aim of adding customer value. New parameters will be added to a modified standard seat and used for upcoming user tests. The new seat will be evaluated in comparison to a standard seat to see if the functions added is providing extra comfort and possibilities for finding a good position.

The goal of the development process was to find simple solutions where the function of parameters can be tested in a good way, not to find the best solution or design possible. For the prototype seat to be done in time for testing it was not possible to integrate all the functions in the seat. Therefore ideas such as for leg support, foot support and laptop support was developed as separate parts while ideas for arm support, head support and back support adjustments were built into the prototype seat. Brainstorming was carried out in an iterative process where solutions and designs was developed throughout discussion. Areas in the car where the new parameters was supposed to be placed was measured, see Figure 13. This was due to the fact that there was limited space in the car and it was important that the prototype was able to be placed and used. In the iterative process, simple mock-ups were made in order to physically try the solutions in the car. Since the seat was able to move around in the car adjusting for example the height and length position, it was important that the integrated parameters in the seat does not prevent this. The mock-ups for the arm support placed in the car is displayed in Figure 14. Figure 15 present the mock-up for the laptop support and the leg support.

Figure 13 Measurement of the car as input to the development of prototypes

Figure 14 Testing mock-ups in different placements of the seat

Figure 15 Mock-up for the laptop support (left) and the leg support (right).

6.4.1 The prototype seat

The prototype seat can be seen in Figure 16 with the adjustable head support, the articulation in the back support and the arm supports integrated in the seat. The leg support and foot support were placed freely on the interior floor. The laptop support was not integrated into the car but was placed on the tunnel when used. The prototype seat had more adjustment possibilities than a standard seat and all the adjustment possibilities can be seen in Figure 17. Most of the parameters was adjusted using buttons on the side of the seat, see Figure 18.

Figure 16 The prototype seat mounted in a XC90

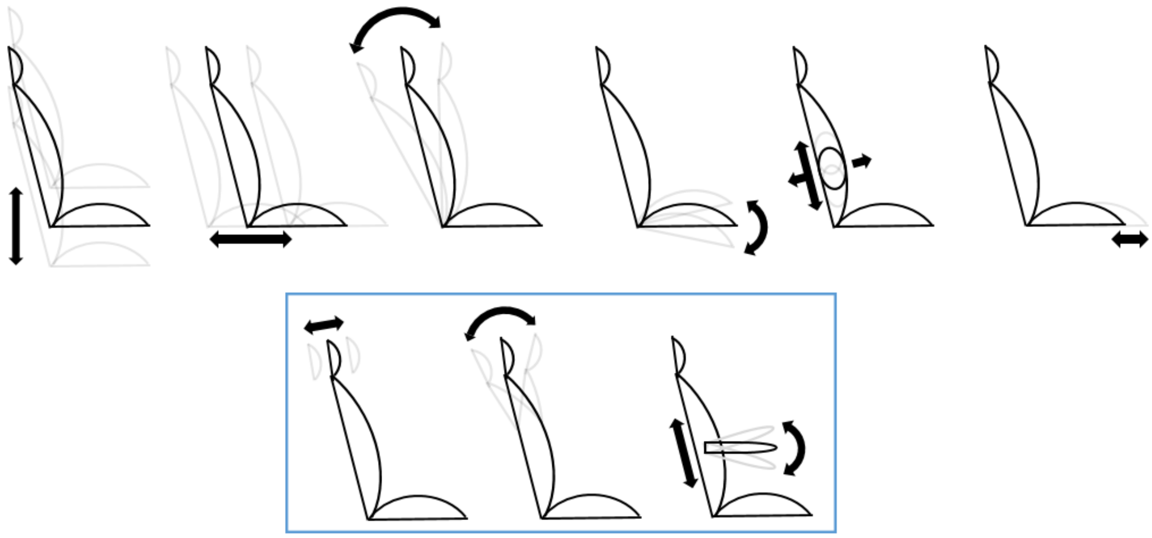


Figure 17 Existing functions the standard 2017 Volvo XC90 seat (top row) and explanation of the designed adjustment possibilities of the head support, articulation in the back support and the arm support marked by a blue square.

Figure 18 Electric adjustments of the prototype seat

Head support

To support the head position of the user, the head support will have elevated sides and the possibility to be adjusted in a motion path parallel to the back of the seat, see Figure 17. The head support is integrated into the seat and controlled by an electric motor. The position furthest back, see Figure 19, is positioned slightly further back compared to the standard seat and the position furthest front is positioned a few centimetres ahead compared to the standard seat, see Figure 19. The head support has elevated sides to give better support fort the head in different positions. The adjustable function and design of the elevated head support was designed together with a concept engineer within the ergonomics department at Volvo.

Figure 19 The head support in the position furthest back (left) and the head support in the position furthest forward (right).

Articulation in the back support

To provide the user with more adjustment possibilities for the seating position, the back support was designed to have an extra moving joint in addition to the moving joint allowing the user to adjust the gradient of the back support. The new adjustable joint would allow the user to control the shoulder section of the seat in a way similar to the already existing joint, by tilting the upper section of the seat forwards or backwards. The function is referred to as an articulation in the back support and is integrated into the seat and controlled by an electric motor. When positioned furthest back, the articulation in the back support has the same position and gradient as the seat of today, see Figure 20. It is possible to adjust the upper part of the back forward, where the position furthest forward is seen in Figure 20. The modified design of the seat was designed by a concept engineer at the ergonomics department.

Figure 20 The articulation in the back support in the position furthest back (left) and the articulation in the back support in the position furthest ahead (right).

Arm support

The arm supports were designed to provide support for the arms and to fit on both sides of the seat. The width of the arm supports was limited to the interior of the car and adjusted to the space available. The length of the arm supports were designed to give support for a large part of the under arm. The arm supports are integrated into the seat and the height can be adjusted manually. The arm supports are located horizontal to the seat and displayed in Figure 21.

Figure 21 Arm support on the left side of the seat.

Foot and leg support

The leg support was designed as an extension to the previous design of the XC90 seat. To examine the best design for the support systems, different variants were designed with different height, angle and position. The leg supports was designed using a more soft plastic foam and designed to follow the height of the seating cushion of the XC90 seat. The leg supports was designed with three different gradients: 15, 30 and 45 degree gradient (Figure 22). Three different variants of the foot support was designed in plastic foam. It was designed to be positioned on the interior carpet floor with a flat bottom and a rounded top in three different heights: 5, 10 and 15 cm (Figure 22).

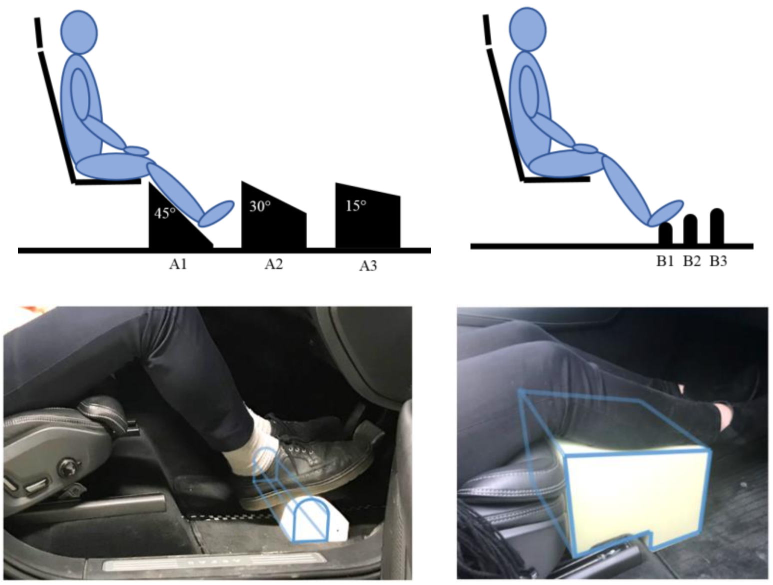


Figure 22 Different designs for the foot support and leg support.

Laptop support

Depending on safety systems, such as airbags, decision was made to try and avoid having the laptop placed straight in front of the steering wheel. A laptop support placed in the centre of the car close to the infotainment system was designed in order to evaluate the position when working on a laptop. A support area was cut out using 10mm thick plywood. A cut out for the gear shift made it possible to adjust the length positioning of the support area, see Figure 23. The support area stretches approximately 20cm from the center console in the centre of the car towards the door, creating a laptop support in front of the driver without putting weight on the user’s thighs.

Figure 23 Design and explanation of the laptop support.

7 PHASE THREE – EVALUATION OF PARAMETERS

This chapter presents development, execution, result and analysis of user tests performed in the project.

7.1 Introduction of user tests

Three user tests were conducted to evaluate how users experience the driver's seat for different AD scenarios. The focus was to evaluate if new parameters contribute to a better perceived comfort and the possibility to find a good position in different AD scenarios. Therefore, questions in the user tests focus on comfort and not discomfort. Although there was still interesting to know if parts of the seat, in a chosen position, leads to discomfort in order to provide information on how to further support the design of seats for autonomous cars. Furthermore the position of the seat was interesting to know to identify how the seat was used when having the ability do other things than driving.

Only three out of five scenarios stated in the hypotheses were evaluated in the different tests due to the time frame of the project. The scenarios evaluated were 'Relaxing', 'Reading or using a handheld device' and 'Working on a laptop', meaning that 'Eating and drinking' as well as 'Traveling together' were not evaluated. These three scenarios were chosen since they can be tested using the same test object and was believed to contribute with different types of positions.

7.2 User test one – Foot, leg & laptop support

A first user test was performed with the aim of gathering data about the newly designed foot support, leg support and laptop support regarding their physical size, shape and position. The test included ten people employed at the ergonomics department of Volvo and can be seen as a qualitative study where the number of participants, according to Osvalder, et al. (2015), is enough to identify 75-80 percent of the problems. The anthropometric body height of the participants, based on the Swedish population, spanned from a 12th percentile female (159cm) to a 99th percentile male (195cm), to gather as much relevant information about the physical shape and position of the parameters possible.

7.2.1 Planning user test one

During a period of 30 minutes, a time duration supported by Osvalder, et al. (2015) for a user test, the participant got to test different variants of a leg support, foot support and laptop support. The test was supported by the hypothesis from Phase one which the chosen parameters were connected to. The foot and leg support were tested during the relaxing scenario where the TP was instructed to lean back and relax, as well as the reading scenario where the TP was instructed to read a short text on a handheld device. The laptop support was tested during the working scenario where the TP was instructed to write a short text on a laptop placed on the laptop support. For all tests, the position of the seat was predefined, where the relaxing scenario had a position with a larger back support gradient than the reading scenario and the working scenario. The back support gradient was the only parameter of the seat changed during the different scenarios, where the rest of the seat was set in a defined position as far away from the steering wheel and instrument panel as possible. This position was set to simulate a position during autonomous driving, offering the best room and space possible based on how the interior of the car is designed today. A fixed seat position for the different scenarios made it easier to isolate the parameters tested. As suggested by Osvalder, et al. (2015) both objective and subjective data gathering was conducted. Subjective data was gathered by mixing questions where the TP was asked to rate their position on a scale from 1 to 10, where 1 represented “Very bad”, 5 represented “OK” and 10 represented “Very good”. Additionally, questions where the TP was asked to freely state good and bad experiences after each tested parameter was done. This was done to identify what was contributing to comfort and discomfort for the different test scenarios. Furthermore objective data was collected by observation during the test and pictures was taken to be able to see the position chosen after the test. Observation provided knowledge about what people actually do, something supported in literature by Osvalder, et al., (2015) and Hennik, et al., (2011). The whole interview form can be seen in Appendix B.

7.2.2 Execution of user test one

The user test was conducted at Volvo Cars headquarters in Torslanda, Sweden, using a Volvo XC90 with standard seats, having the same design as Volvo Cars multifunctional seats (Figure 2), but with less functions. The test was divided into three parts where the parameters was tested one at the time. The starting order of the three different parts was randomized for each TP. The position of the seat for the relaxing scenario was furthest down, furthest back with a back support gradient of 36 degrees. The position of the seat for the reading and working scenarios was the same as for the relaxing scenario with the only difference being a more upright position with a back support gradient of 25 degrees instead of 36. In total, including all three parts of the test, three different foot supports, two different leg supports and three different sizes of the laptop support was tested.

Foot support

The part for testing the foot support began with the medium sized foot support regardless of which of the two scenarios, relaxing or reading that was tested. Each TP got to place the medium foot support freely on the interior floor mat where the chosen position later became reference for where the small and high foot support were placed. The order of the two scenarios and the order of in which the small or the large foot support was tested after the medium foot support was random. After each foot support, TP’s got to answer how good their comfort experience was using the scale from 1 (Very Bad) to 10 (Very Good) and also if they thought anything particularly good or bad in two separate questions.

Leg support

The part for testing the leg support began with one of the two different leg supports in a random order. The leg support was placed close to the seat to simulate being an extension of the original seat cushion. After each variant of leg support, TP’s got to answer to how good their comfort experience were using the scale from 1 (Very Bad) to 10 (Very Good) and also if they thought anything particularly good or bad in two separate questions.

Laptop support

The part for testing the laptop support tested three different sizes. The plywood sheet was marked with tape creating three different areas, see Figure 24. The smallest area (blue) was meant to represent the size of the center console of today, followed by two areas with increased size (yellow and red). Before testing the support area with a laptop, TP got to adjust the length positioning of the support area by moving it further back towards the back of the car or further forward towards the instrument panel. The chosen position was then kept through the remaining test. In a random order, TP got to carry out a small task on the laptop with the laptop placed in each of the marked areas. After each area of the laptop support, TP got to answer to how good their seating comfort and position was using the scale from 1 (Very Bad) to 10 (Very Good) and also if they thought anything particularly good or bad in two separate questions. TP also got to answer to how good they thought the current support area was in terms of working on a laptop also using the scale of 1 to 10.

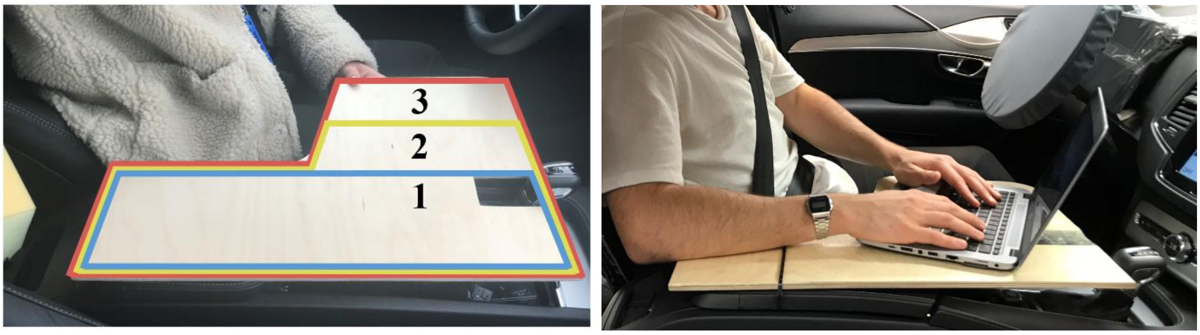


Figure 24 Different areas of the laptop support (left) and the laptop support being used (right).

7.2.3 Result from user test one

The result form user test one is displayed below for each of the tested scenarios.

Relaxing

When relaxing, the leg support with the largest gradient (more horizontal) contributes to the highest average score regarding the level of comfort in the defined position.

Regarding the foot support, the lowest one is perceived as the worst and the medium as the best, where the average score is shown in Table 6. According to comments from the test, the lowest foot support is too low and not notable at all by some TP's. Furthermore, the medium support provides a good support and has a good height. Regarding the highest support it is too high and contributes to an uncomfortable gradient for the foot when placed against it. There is also a desire to move the highest support forward towards the pedals. For distribution of grades between the TP's, see Appendix C.

Table 6 Average result from user test one regarding the seating comfort for the position when relaxing and using different variants of foot or leg supports.

RELAXING	
Foot support	**Average**
Low	5.5
Medium	7.2
High	6.8
Leg support	**Average**
Small gradient (steeper)	7.2
Large gradient (more horizontal)	7.6

Preference for the placement of the medium foot support on the interior carpet varies between different TP's. TP's with long knee height places the foot support closer to the pedals and some indicated the pedals to obstruct the positioning of the support. TP's with shorter knee height places the foot support closer to the seat but exactly where differed. Most of the TP's have their heel on the carpet and have a fairly horizontal position of the thighs when using the medium sized foot support. Some TP's place their feet on top of the foot support.

The leg support with the largest gradient (more horizontal) is the preferred one when relaxing according to the average score, see Table 6. It was not possible for all TP's to use the two variants of leg support. The leg support with a steeper gradient could not be used by six out of ten TP's. Seven of the TP's could use the leg support with a more horizontal gradient, but for the remaining three, all tall TP's, the support is seen as disturbing. For the seven people being able to use the leg support with a more horizontal gradient, all except one preferred the more horizontal leg support rather than the steeper one. Comments about the more horizontal leg support indicates that it is providing good support for the defined position but comments also indicates the support being too narrow. Furthermore, the steeper leg support is too short in the support area.

Reading using a handheld device

When reading, the support of the medium foot support contributes to the highest average score regarding the level of comfort in the defined position, see Table 7. The lowest foot support is perceived as the worst and the medium as the best, where the average score is displayed in Table 7. Comment from the test indicates that the lowest foot support does not add any value and is too low. The highest support on the other hand is too high and creates an uncomfortable wrist angle when using it. The medium one contributes to good support e.g. for the thighs but there are also indications implying the support being too narrow. For distribution of grades between the TP's see Appendix C.

Table 7 Average result from user test one regarding the seating comfort in the position when reading on a tablet and using different variants of foot or leg supports.

READING USING A HANDHELD DEVICE	
Foot support	**Average**
Low	4.8
Medium	6.9
High	5.9
Leg support	**Average**
Small gradient (steeper)	6.1
Large gradient (more horizontal)	6.3

The placement of the medium foot support on the interior carpet varies between different TP's. The TP's with tall knee height places it closer to the pedals while the TP's with shorter knee height places it closer to the seat.

The result concerning leg support displays that the support with a more horizontal gradient has the highest average score, see Table 7. However, when comparing the scores with the five TP's being able to use both the leg supports and the steeper leg support, the leg support with a steeper gradient has a higher average grade. Moreover, five out of ten TP's could not use the steeper leg support and only seven out of ten TP's could use the more horizontal leg support. The remaining three TP's, all tall participants, have problems with the support and express that the support is just being in the way and puts an undesired pressure on the calves. The more horizontal support also provides a good support but is seen as too narrow. The steeper support is likewise seen as too narrow.

Working on a laptop

The average result for the seating comfort and position when working on a laptop using different sizes of the support area is displayed Table 8. The average score for seating comfort and position when working on a laptop using the large support area is the only one having a score above 5, which is the score for being "OK". The distribution of grades is displayed in Appendix C.

Table 8 Average result from user test one regarding the seating comfort and position when working on a laptop for different sizes of support areas.

WORKING ON LAPTOP	
Support area	**Average**
Small	3
Medium	4.9
Large	6.5

The average score for how good an area is to work on indicates that the largest area is the best one, see Table 9. Observations displays that, when working on the smallest area, all of the test persons rotates the upper body and the left shoulder, whilst on the largest area, most people only rotates the left shoulder and arm towards the laptop. Furthermore, most TP's only rotate the upper part of the body. The positions observed in regards to the different sizes can be seen in Appendix C. The rotation of the torso is also frequently comment by the TP's on all of the different sizes, but the rotation gets even worse when working on the smaller areas. The placement of the laptop support in y-position varies between the TP's, see Appendix C.

Table 9 Average score on how good the different support areas are to work on with a laptop.

WORKING ON LAPTOP	
Support area	**Average**
Small	2.9
Medium	5
Large	6.2

7.2.4 Analysis of user test one

Result from the scenarios 'Reading using a handheld device' and 'Relaxing' are similar and therefore is the analysis of the two scenarios presented together. Analysis regarding the working scenario is presented by itself.

Relaxing and Reading using a handheld device

When relaxing, the average result indicates that a leg support is preferred before a foot support. The opposite is shown in the reading scenario where the average result displays that a foot support is being preferred before a leg support. However, result in both scenarios are similar and further investigation with more test persons is needed in order to validate the result. This investigation also needs to include evaluation of foot support and leg support when being used together.

Foot support

The test indicates that the low foot support is too low, it fills no function and is therefore not a good option. Furthermore, the highest foot support contributes to a bad wrist angle and the test persons wants to move it further towards the pedals where there is too little space for the foot support. Based on the average score together with the comments from TP's, the medium foot support is the best one of the three different variants of different height for both the scenarios 'Reading using a handheld device' and 'Relaxing'. However further investigation is needed regarding the placement of the foot support and if it can be fixed or if it needs to be adjustable. In order to try this, the foot support needs to be adjustable to enable future tests of the relation between height and length adjustment.

Leg support

The positioning of the leg support makes it hard for people to use it, especially tall people, applicable for both the scenarios. This is due to the fact that the edge of the leg support does not end up at the knee joint of these TP's, but further down the thigh. When this happens, the calves does not get the intended support. It is most apparent when using the support with a smaller (steeper) gradient but also applies to the support with a larger (flatter) gradient. In order for the leg support to fit more people it needs to be adjustable to enable support from the knee joint down to the calves. For the people being able to use the leg support, it provides a good support. The more horizontal leg support is the preferred one in both scenarios, which indicate that further tests with an even more horizontal gradient could be needed. Future testing also needs to investigate the space available for the feet when using the leg support. In addition there are indications of the leg support being too narrow and too short.

Working on a laptop

The test indicates that the small and the medium sized area are not good when working on a laptop in the car due to the rotation needed in the upper torso. Even if the large support area is the best one it still has quite a low score and comments from the test persons indicates that the torso rotation towards the middle is an issue. The large area is still the best one out of the three but needs to be further evaluated in this study.

There is no clear connection identified between arm length and the placement of the table. Nor can a connection between the grade on the scale and the arm length be seen in the test. However, the test indicates that there is a span for the movement of the laptop support of approximately ten centimetres towards the driver or forward towards the instrument panel, this can however depend on the specified seating position; furthest back, furthest down. Another good aspect of the laptop support is the provided arm support for the right arm when working on all the different areas although some TP's express less support when working on the large area. The height is good in relation to the specified position but further investigation in regards to height and chosen position is needed. The same applies to the length positioning of the table, when the seat is in a specific position, adjustment possibilities are needed, but if the customer is able to position the seat as preferred it might not be necessary.

7.3 User test two – Standard versus prototype seat

User test two was developed to investigate the hypotheses stated in 5.5. The aim of the test was to investigate how new parameters in the seat affected the possibility of finding a good comfort and position in the different AD scenarios. Furthermore it was also done to get the knowledge of how people position the seat in defined scenarios.

User test two was a static test evaluating initial comfort in the seat and was performed with potential customers. The participants in the test were asked to imagine a scenario where an autonomous car handled all aspects of driving the car and the TP had the possibility to do other things. The test contained three different activities; evaluation of the standard seat, evaluation of the prototype seat and evaluation of single parameters in the prototype seat. The evaluation was performed by ranking grades on a scale, giving comments on what was good and what was bad in the chosen positon and by measuring the placement of the seat.

7.3.1 Planning user test two

The goals of user test two were:

- To evaluate if additional parameters in the prototype seat contributed to increased comfort for defined scenarios compared to the standard seat.
- To evaluate how TP's positioned the seat for defined scenarios
- To evaluate how additional parameters, used one at the time, affected the comfort.

When planning user test two the hypotheses stated in 5.5 and the result from user test one were used as a starting point. To evaluate how the parameters affected the position and perceived comfort, the prototype seat with new functions was used. New parameters evaluated in user test two were the adjustable head support, the articulation in the back support and the arm supports, all integrated into a standard seat. The standard seat of an XC90 was used as a reference in the test.

In order to evaluate how people with different types of anthropometric measurements experienced the additional parameters, the participants in the test were chosen based on their body height. In order to evaluate the extremes and the middle, three groups were formed based on measurements from Hanson, et al., (2009); short: *women <20th percentile (~1616mm)*, tall: *men >80th percentile (~1850mm)* and medium group with *>20th percentile woman and <80th percentile men*. According to Osvalder et al., (2015) when comparing two groups it is good to have at least 12 participants in each group. Dependent on the length of the test, one TP was able to evaluate two of the three scenarios. Furthermore, this meant that 18 TP's in each group was necessery to achieve 12 TP results for each scenario. In total 55 people were participatig in the test. The testing time for each TP was 1 h and 15 minutes. The time was decided based on the number of questions and the number of scenarios being evaluated.

In order to evaluate the position and perceived comfort for the different seats, an interview form with a semi-structured layout was developed and used. The questions in the interview form were asked when the TP was sitting in the specific seat tested. A numeric scale from 1-10 was used where 1 represented “Very bad, 5 represented “OK” and 10 represented “Very good”. To identify what affected the score chosen, follow-up questions regarding what was good in the chosen position and what was bad in the chosen position were asked. These questions were asked on the overall perspective and specific areas or parts of the body to identify what was contributing to comfort and discomfort in the chosen position. The whole interview form can be seen in Appendix D. In addition to subjective data, objective data were documented using pictures to allow comparing data between different test persons after the test.

In order to evaluate the chosen position in each scenario, TP’s was allowed to use all the adjustment possibilities of the seat, see Figure 17. After each scenario the position of the seat was measured. The measurement made it possible to see how different adjustment possibilities were used. Furthermore to evaluate how additional parameters affected the comfort and position when used one at the time, a second part of the test was developed. In this part the chosen position in the standard seat from the first part was transferred to the prototype seat and set as a predefined position before beginning with part two. TP’s were now able to use one of the additional parameters at the time and were asked the same questions from the interview form responding to the overall comfort when only one new parameter was adjusted. This was done to evaluate how the different parameters was used when used one at the time and if it could affect the perceived overall comfort compared to the perceived overall comfort in the standard seat from part one.

7.3.2 Test enviorment for user test two

User test two was a static test where the prototype seat was mounted into a Volvo XC90. The prototype seat was mounted on the left hand side, the passenger side, in a right hand drive XC90 to prepare the setup for being tested dynamically with a driver in the future. To be able to compare the prototype seat with a standard seat, another XC90 with an unmodified standard seat was used as reference. The test was performed inside in a workshop environment. The Volvo XC90 is the biggest car model produced by Volvo Cars today and was chosen as the test environment to achieve a realistic environment with as much interior space as possible.

7.3.3 Execution of user test two

Each TP tested two out of the three scenarios and the total time for the test was 1 hours and 15 minutes. The scenario tested were relaxing, reading using a handheld device and working on a laptop, see Figure 25-27.

Figure 25 Relaxing scenario performed in the standard seat (left) and prototype seat (right).

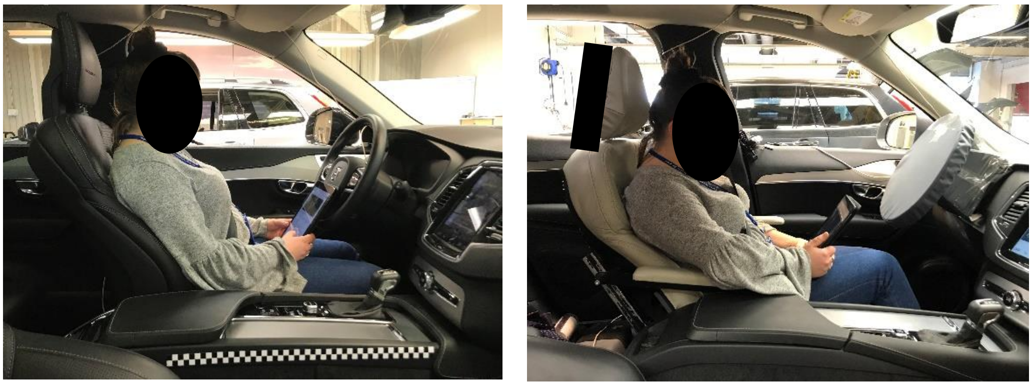


Figure 26 Reading scenario performed in the standard seat (left) and the prototype seat (right).

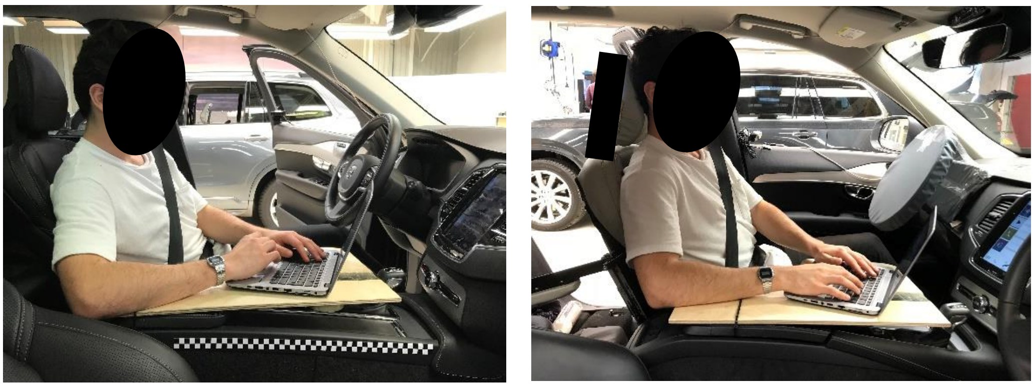


Figure 27 Working scenario performed in the standard seat (left) and the prototype seat (right).

Before starting, the TP was introduced to the concept of an AD level 4 car and was presented with the fact that in these scenarios the car was said to handle all aspects of driving on its own, and that the TP was able to perform the presented tasks without needing to think about the control of the car. The first part was an evaluation of the standard seat and the prototype seat for the defined scenarios. TP's started with sitting in one of the two seats, half of the TP's started in the standard seat and the others in the prototype seat. All different adjustment possibilities of the seat was shown on beforehand before starting the test. The TP was then presented with one of the defined scenarios and asked to use all the adjustment possibilities of the seat to find a position preferred for the specific activity in the scenario. When the optimal position was found, the moderator used the interview form (Appendix D) and asked a question regarding the overall comfort and positon where after the TP evaluated the comfort and positon using the 1-10 scale. Questions of what was perceived as good and what was perceived as bad about the comfort and position was also asked in relation to the overall score for seating positon and comfort. The result was documented as comments that were noted in an excel sheet by the moderator.

After the overall evaluation, the same questions were asked regarding different parts of the body; head, back, seat cushion, legs and feet and arms. From the chosen position in the first scenario, the TP was asked to find a new position for the second scenario and later, the third scenario. The order of scenarios were varied not to affect the result. The position of the seat was measured when all questions were asked after each scenario. The same procedure with positioning, questioning and measurement were then conducted for the second and third scenario. The same evaluation was then conducted on the other seat on both scenarios. The different between the standard seat and the prototype seat were the number of adjustment possibilities.

The second part of the test was performed using the prototype seat to evaluate the effect of one new parameter at the time. The documented position from the standard seat in part one for each defined scenario was transferred to the prototype seat to set a predefined position suited for each specific TP. The TP was then asked to adjust one of the new parameters at the time and rate the overall comfort and position using the same defined scale, where the grade from the standard seat served as reference. The questions whether anything was perceived as good or bad regarding the comfort and position were also asked. The first adjustment possibility was only adjustment of the back support articulation, secondly only the head support and lastly the possibility to adjust both of the functions at the same time. Finally the possibility of just adjusting the arm supports were done. All the other adjustment possibilities were predefined and could not be changed. Between all the tests, the seat was put back in the predefined position.

7.3.4 Result of user test two

The result from user test two is presented for each of the three scenarios.

Relaxing - Part one: possibility to adjust all parameters

The following section presents result from part one, where TP's were allowed to freely adjust all parameters of the seat for each scenario.

The difference in average score for comfort and position between the standard seat and the prototype seat is shown in Table 10, where for example "*Overall comfort and seating position +1.3*", means that the average score for the prototype seat increased by 1.3 units compared to the standard seat, based on the scale of 1 to 10. A visual explanation of the categories can be seen in Figure 28 and the distribution for the change of score can be seen in Appendix E. When comparing the two seats for the relaxing scenario, the biggest change in average score are for the overall seating comfort and position as well as for the comfort and position regarding the head, the back and the arms, see Table 10. The average score for the position and the comfort regarding the seat cushion and the legs and feet are not as affected. The highest average improvement is the score for the comfort and position regarding the head for tall people, which has an increase of 2.1. Common for all different categories are that the average score improves when comparing the two seats using the original XC90 seat as reference for all three body height groups.

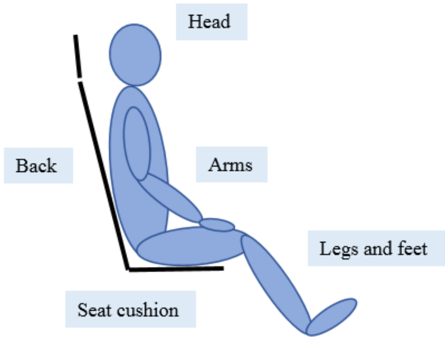


Figure 28 Explanation of the categories evaluated.

Table 10 Difference in average score for the relaxing scenario of short, medium and tall people in user test two with the standard seat as reference based on the scale of 1 to 10.

SHORT PEOPLE (<161cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.3	**+1.4**	**+0.6**	**+0.5**	**+0.3**	**+1.3**

MEDIUM PEOPLE (162cm-191cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.7	**+1.4**	**+1.0**	**+0.3**	**+0.3**	**+1.6**

TALL PEOPLE (192cm<)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.1	**+2.1**	**+1.1**	**+0.2**	**+0.0**	**+1.8**

In Figure 29, the chosen seat height and seat length position is displayed for the standard seat and in Figure 30 the corresponding measurements are displayed for the prototype seat. The red box marks the adjustment area for the seat height and length position. The figures presents a similar result for both seats regarding the length and height position. The result shows that TP's are not using the front part of the adjustment area. It also shows that more tall people sits further down and further back than the short and medium people. When comparing the back support gradient in both of the seats, it shows that a larger back gradient is more frequent for the prototype seat. The chosen back support gradient varies between around 20 to 65 degrees, where different back support gradients are seen in all three groups. In the prototype seat most people choose a back support gradient larger than 30 degrees. The chosen back support gradient in the standard seat can be seen in Figure 31 and in Figure 32 for the prototype seat. The use of the seat extension for the standard seat is displayed in Figure 33 and for the prototype seat in Figure 34. The result shows that most of the participants use the seat extension when relaxing in both seats. Furthermore almost all of the tall TP's use the seat extensions to the max, while the use of seat extension varies in the others groups, short and medium. The whole adjustment length of the seat extension is used in both seats but more people use more than 50% of the total extension.

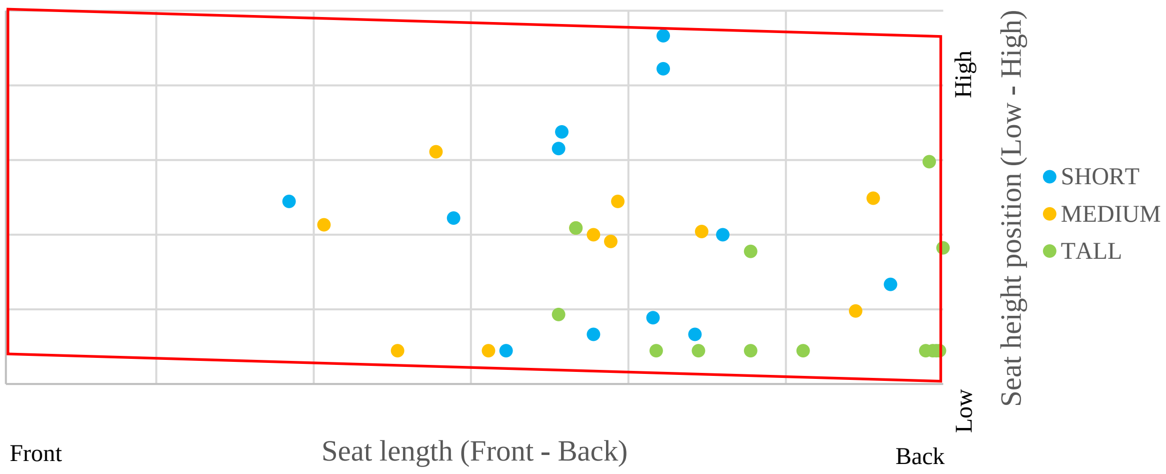


Figure 29 Seat length positon and seat height position for the relaxing scenario in user test two and the standard seat.

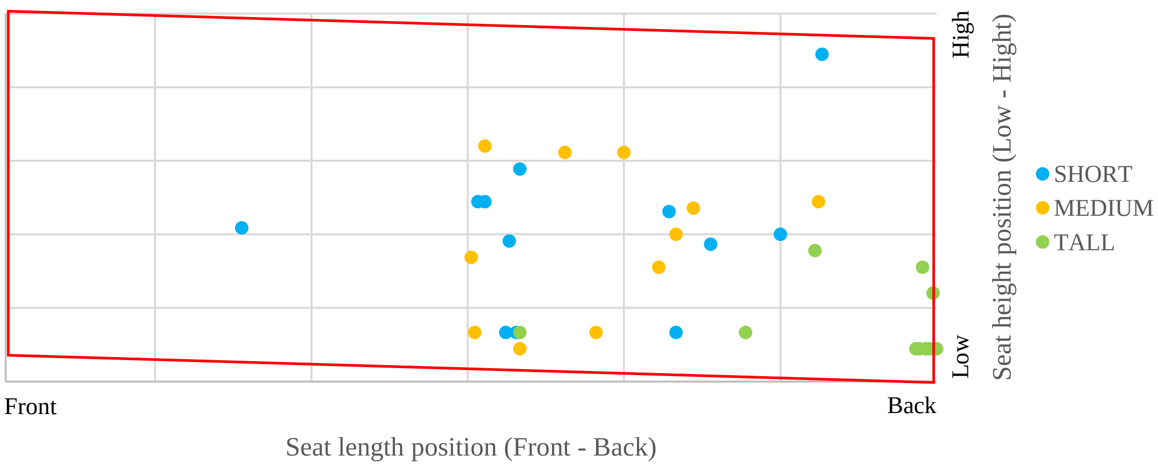


Figure 30 Seat length positon and seat height position for the relaxing scenario in user test two and the prototype seat.

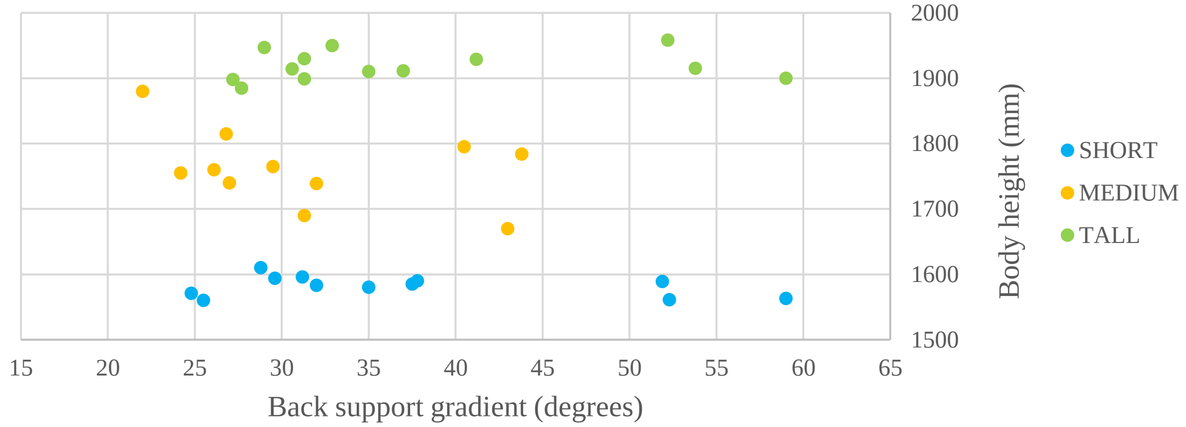


Figure 31 Back support gradient and body height of the test persons for the relaxing scenario in user test two and the standard seat.

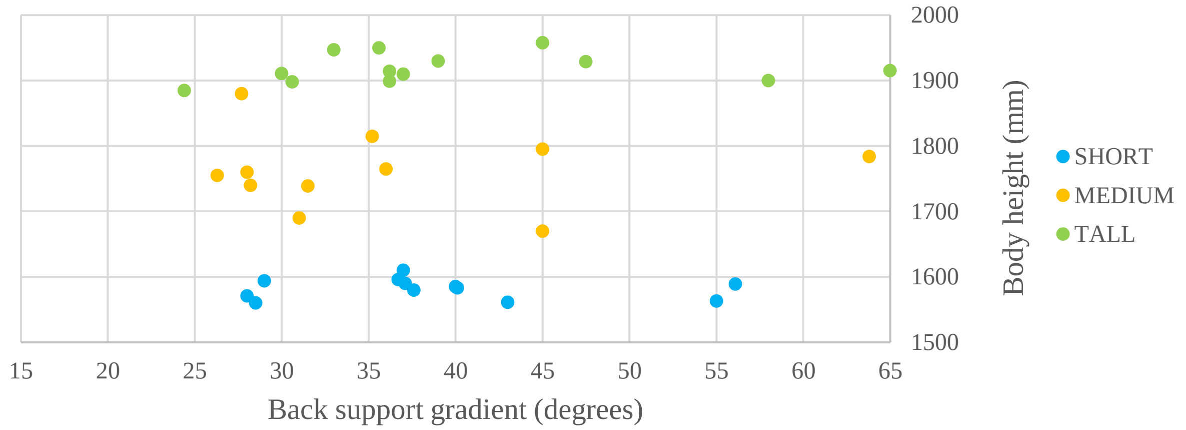


Figure 32 Back support gradient and body height of the test persons for the relaxing scenario in user test two and the prototype seat.

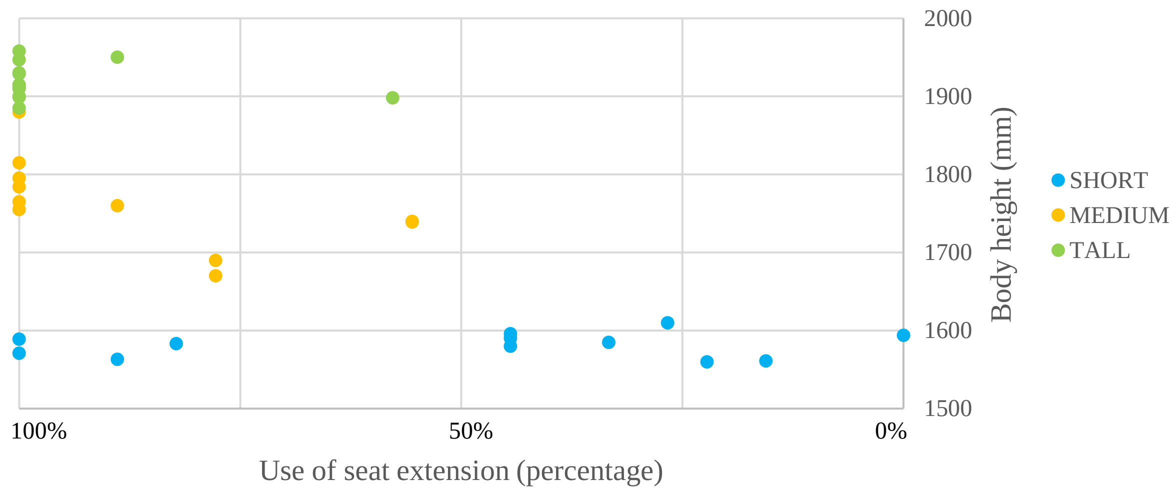


Figure 33 Use of seat extension and TP body height for the relaxing scenario in user test two and the standard seat.

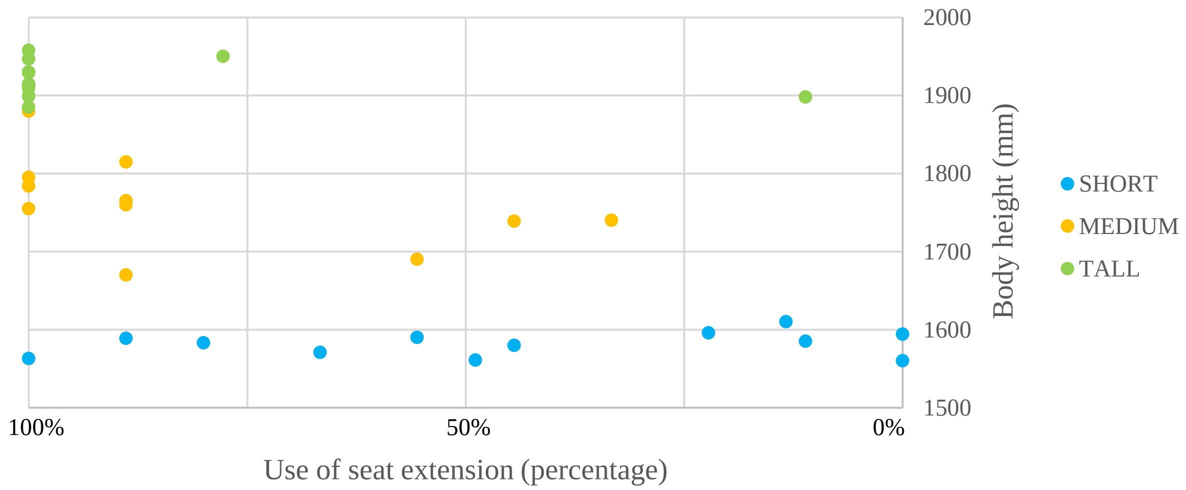


Figure 34 Use of seat extension and TP body height for the relaxing scenario in user test two and the prototype seat.

The articulation in the back support related to chosen back support gradient is displayed in Figure 35. Most of the TP's use 50% or less of the articulation when relaxing in the prototype seat. The short TP's use less articulation than the other two groups. The relation between back support gradient and the use of the adjustable head support can be seen in Figure 36. Most of the short TP's does not use the head support at all, positioning the head support as far back as possible. It is also displayed that the total adjustment area of the head support is used but most people during the test use 50% or less of the adjustment possibility. The relation between head support and articulation is presented in Figure 37. When using a large part of the adjustment area for the articulation in the back support, a smaller part of the adjustment area for the head support is used. The same relation is identified when using a large part of the adjustment area for the head support. The adjustment possibility for the head support moving the head support forward is mostly used by the tall and medium group. When relaxing most people adjust the head support and articulation in the back support but use a small part of the adjustment area for both of them.

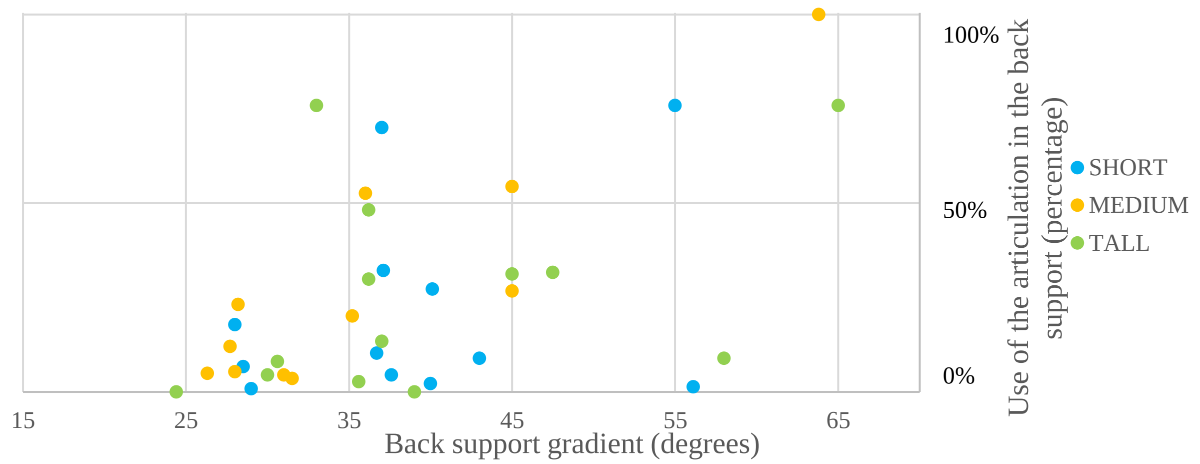


Figure 35 Back support gradient and the use of the articulation in the back support for the relaxing scenario in user test two and the prototype seat.

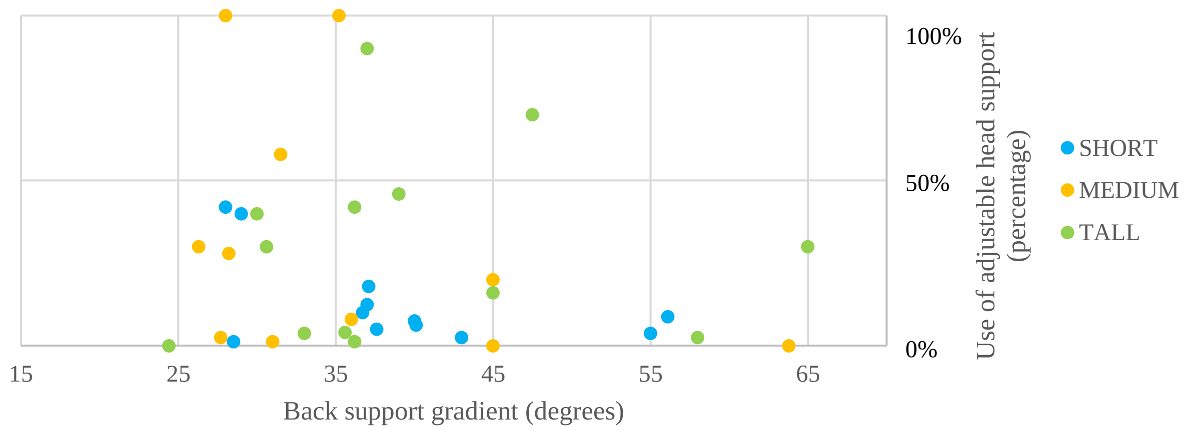


Figure 36 Back support gradient and the use of adjustable head support for the relaxing scenario in user test two and the prototype seat.

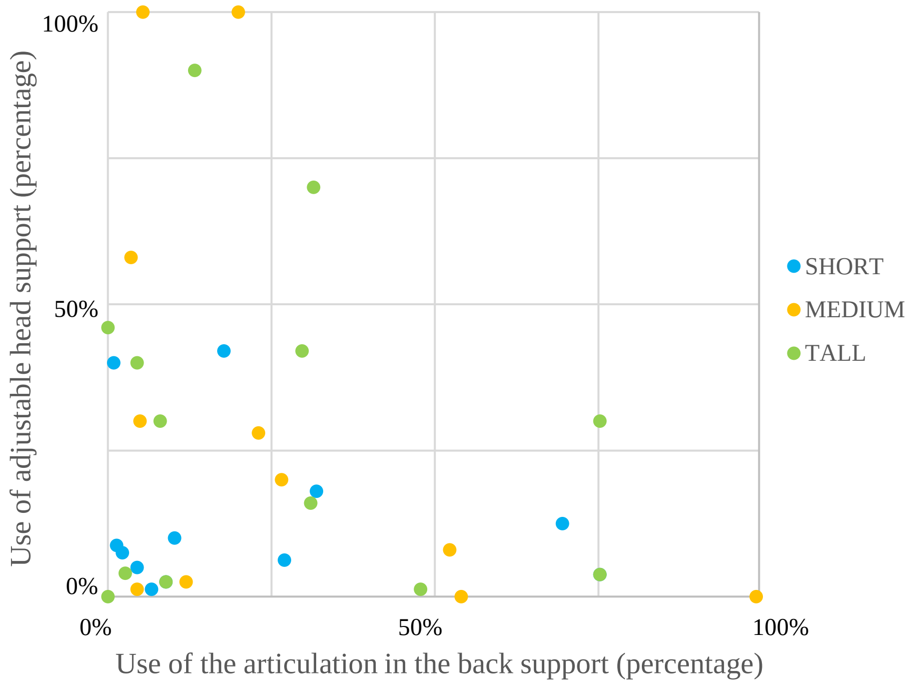


Figure 37 Use of the the articulation in the back support and the use of the adjustable head support for the relaxing scenario in user test two and the prototype seat.

The following section presents comments from part one of the scenario 'Relaxing'

Comments from user test two have been categorised using a KJ analysis where the categories have been matched with the categories of the interview form: head, back, seat cushion, legs and feet, arms and over all comments.

Opinions about the overall comfort and position comments

Comments on the overall seating comfort and position displays that all of the groups are able to find a relaxed position in both the standard seat and in the prototype seat. There are also some TP's from all of the groups experiencing problems with the seat belt in both of the seats, where the seat belt places too far from the body and thereby does not feel safe.

Opinions about the head comfort and position

Five out of twelve short TP's finds a better support for the head in the prototype seat. Five out of eleven medium and five out of twelve tall TP's finds a good neck angle when relaxing in the prototype seat. In the prototype seat, half of the short TP's experience that the head support is placed too high. Common for all the groups are that they want more support around the neck instead of a single small contact area that the head support offers today, commented by six short, four medium and six tall TP's. Five short, four medium and five tall people express a desire of more support on the sides for the head support. Five medium and three tall TP's also finds the head support too hard. Four tall TP's experience that the contact area on the head is too high.

Opinions about the back comfort and position

Five out of twelve short TP’s finds a good support for the back in the standard seat while seven out of twelve finds a good support for the whole back in the prototype seat. Five out of eleven people from the medium group finds good support for the whole back while seven out of twelve tall TP’s experience the same thing. Five TP’s from the medium group also experience that changing the articulation in the back support makes support of whole back better. Five short TP’s also finds it good to have the possibility to adjust the articulation in the back support in the prototype seat and three tall TP’s experience good support for the shoulders. Seven short, four medium and eight tall TP’s lack the lumbar support in the standard seat while five short, two medium and four tall TP’s lack the lumbar support in the prototype seat.

Opinions about the seat cushion regarding comfort and position

Six out of twelve short people finds the adjustment possibility of the seat extension good in the standard seat while five of them finds the same adjustment good in the prototype seat. Five short and six tall TP’s express a good support from the seat cushion in the standard seat, six short, two medium and three tall people express the same thing for the prototype seat. Three out of twelve tall and three out of eleven medium TP’s states that it is good having a seat extension in the standard seat. Six out of twelve tall TP’s think the seat extension is too short in both of the seats.

Opinions about the legs and feet comfort and position

Five short TP’s think that there is good space for legs and feet when relaxing in the standard seat and three of them thinks the same thing in the prototype seat. Five tall TP’s also finds the space for legs and feet good in the standard seat. The foot support on the left side of the interior floor is good when sitting in the standard seat according to five medium and six tall people. Three TP’s from the medium group also finds the support for the left foot good in the prototype seat. Three tall TP’s states that it is good to have the possibility of placing the feet behind the pedals in the car with the standard seat. Short TP’s, six in the standard seat and eight in the prototype seat, wants to have a support for the legs while relaxing. Three medium and four tall TP’s wants more space for the legs in the car with the standard seat and four tall TP’s express the same desire in the car with the prototype seat. Four medium TP’s lack a support for the right foot in both of the seats. Nine TP’s in the standard seat and eight TP’s in the prototype seat, all of them tall participants, thinks that the pedals are in the way when relaxing.

Opinions about the arm comfort and positon

Five short, six medium and six tall TP’s states that it is good to have additional arm support in the prototype seat. In addition, four short and six tall TP’s finds a good support for their arms in the prototype seat. In the standard seat seven medium and eight tall TP’s finds a good support for the right arm on the tunnel. In the standard seat seven short people lack arm support while nine medium and eight tall lack arm support on the left side. Six short TP’s express that the side bolsters affects the arm comfort in a negative way while sitting in the standard seat. Regarding the prototype seat the arm support is too narrow according to four short, five medium and four tall TP’s. For eight short TP’s the arm support is placed to wide apart.

Relaxing - Part two: possibility to adjust one parameter at the time

The following section presents result from part two, where TP's were allowed adjust only one of the new parameters at the time in the prototype seat for each scenario

When having the ability to change one new parameter at the time in the prototype seat with a predefined seating position based on part one, some TP's experience an improvement of the position and perceived comfort while others do not. Some of the TP's do not want to use the new parameters at all. The four different variants of the test included adjustment of only the back support articulation, only the adjustable head support, a combinations of the back support articulation and the adjustable head support and finally only by adjusting the arm supports. The result in relation to body height group and changed parameter can be seen in Table 11-Table 14. The result displays that the group of tall TP's is the group where most people sees an improvement of comfort and position when using the back support articulation, head support or both of them combined. More than half of the short TP's experience an improvement of comfort when able to use the arm supports. When able to adjust both the back support articulation and the head support, most people experience an improvement regardless of which body height group they belong to. The distribution of improvement in relation to the scale of 1 to 10 can be seen in Appendix F. How the different parameters have adjusted can be seen in Appendix G.

Table 11 Change of score when using the articulation in the back support in the relaxing scenario.

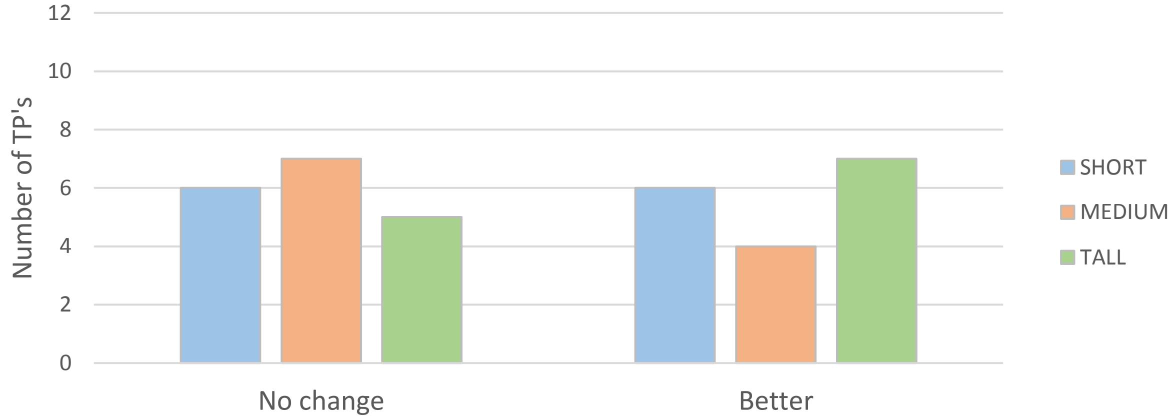


Table 12 Change of score when using the adjustable head support in the relaxing scenario.

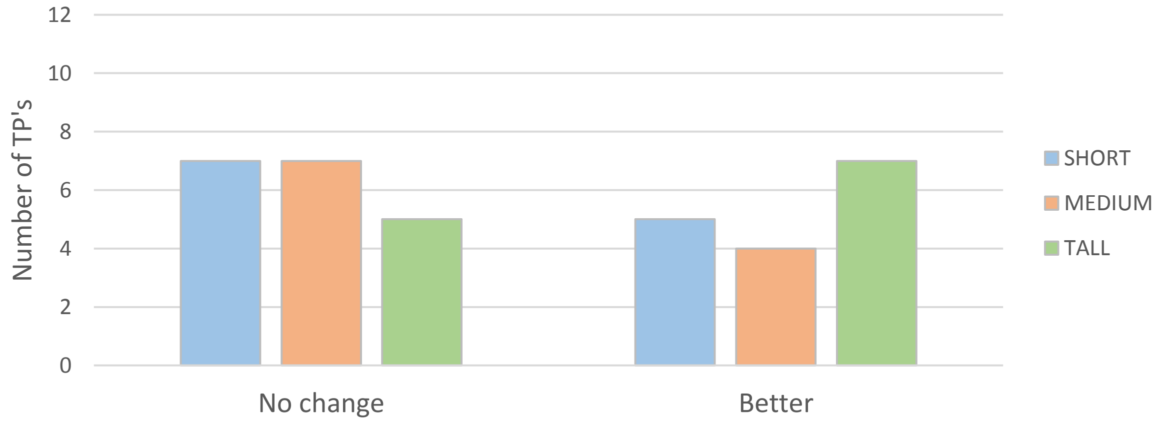


Table 13 Change of score when using the adjustable head support and the articulation in the back support in the relaxing scenario.

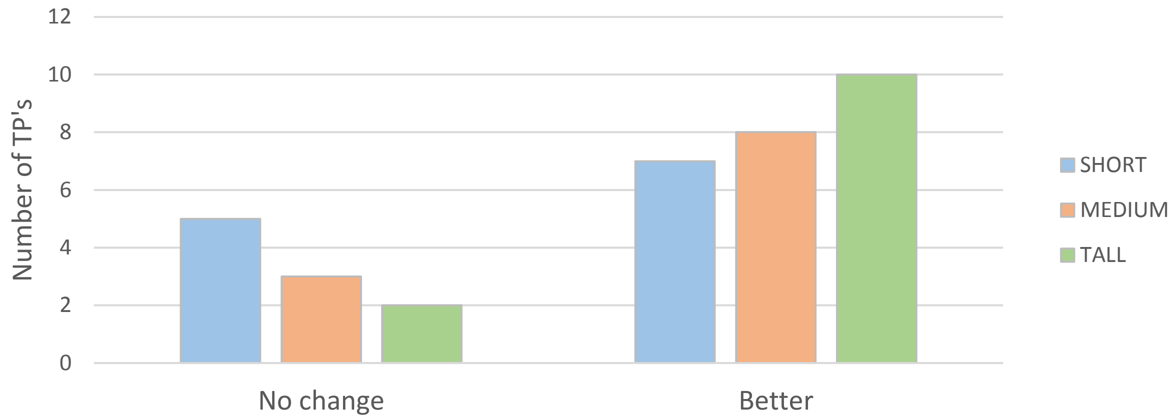
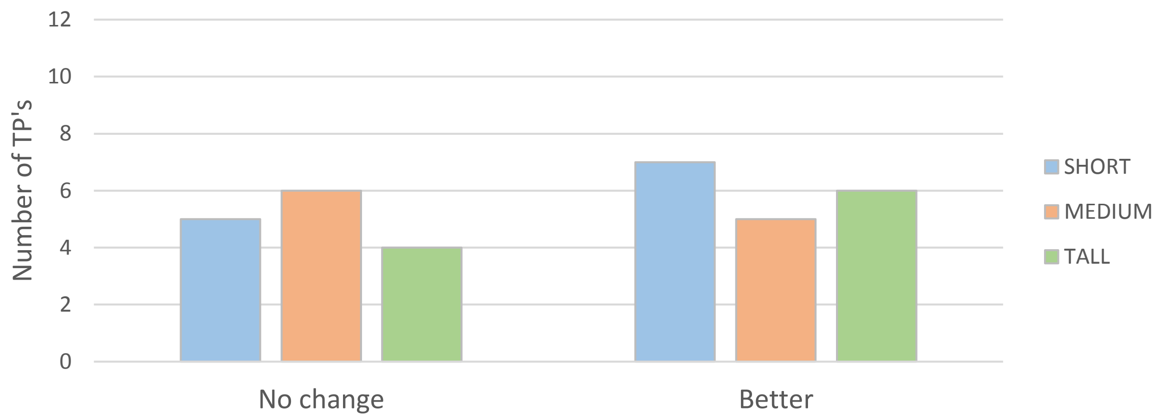


Table 14 Change of score when using the adjustable arm supports in the relaxing scenario.



The following section presents comments from part two of the scenario 'Relaxing'

Comments from this part of user test two have been categorised using a KJ analysis where the categories have been matched with the different adjustment possibility.

Opinions regarding the articulation in the back support

Four short, six medium and five tall TP's finds a better support for the upper part of the back. Four short and four tall TP's finds a better position for the head. When using the back support articulation, four short TP's desire to adjust the head support further back. Four TP's from the medium group lack arm support.

Opinions regarding the head support

Four medium, three tall and two short TP's finds a good support for the head when able to adjust the head support. Five out of twelve tall people finds a better neck angle. Four medium TP's are able to sit in a relaxed position while four other medium TP's thinks the head support contributes in a good way. The head support is, according to five short TP's, placed too high and puts pressure on a small contact point high up on the head. Furthermore three short and four tall TP's finds the adjustment of the articulation in the back support better than adjusting the head support. Three tall TP's wants more support around the neck.

Opinions when adjusting both the articulation in the back support and the head support

Four short, two medium and six tall TP's express that they just need the adjustment possibility of the back support articulation, while three tall TP's rather use only the adjustment of the head support. Three medium TP's also express that they get a good support for the back.

Opinions regarding the arm support

Three short, six medium and three tall TP's finds it good being able to use the arm supports. Three tall TP's finds it good that the arm support are positioned at the same height while five other tall TP's express that the tunnel makes the right arm support too high. Four short and two medium TP's do not want to use the arm support at all.

Reading using a handheld device - Part one: possibility to adjust all parameters

The following section presents result from part one, where TP's were allowed to freely adjust all parameters of the seat for each scenario.

The difference in average score for comfort and position between the standard seat and the prototype seat is shown in Table 15, where for example "*Overall comfort and seating position +1.3*", means that the average score for the prototype seat increased by 1.3 units compared to the standard seat, based on the scale of 1 to 10. A visual explanation of the categories can be seen in Figure 38 and the distribution for the change of score can be seen in Appendix E. When comparing the two seats, there are a significant difference in average score for some categories and for other categories the difference is close to none. Improvements for the comfort and position can be seen regarding the overall score, the head, the back and the arms for all the different body height groups. The outcome for the seat cushion and leg and feet has an average difference around zero or very close, which is also common for all three body height groups. The biggest improvement is the comfort and position regarding the head for medium people with an improvement of 2.6 units.

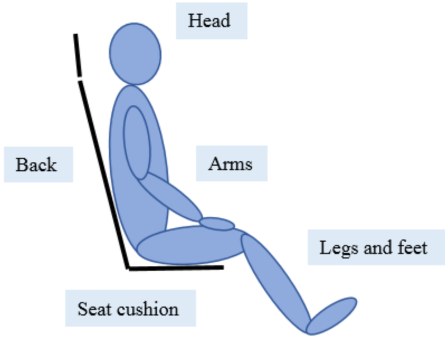


Figure 38 Explanation of the categories evaluated.

Table 15 Difference in average score for the reading scenario of short, medium and tall people in user test two with the standard seat as reference based on the scale of 1 to 10.

SHORT PEOPLE (<161cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.3	**+1.6**	**+0.8**	**+0.3**	**+0.1**	**+1.3**

MEDIUM PEOPLE (162cm-191cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.9	**+2.6**	**+1.5**	**+0.0**	**+0.2**	**+0.9**

TALL PEOPLE (192cm<)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+1.5	**+1.5**	**+1.2**	**+0.3**	**-0.1**	**+1.6**

The chosen height and length position for the standard seat is shown in Figure 39 and Figure 40 displays the same relations for the prototype seat. The position of both seats regarding height and length is similar. The short participants sits a bit further up while tall TP's is sitting further back and further down. The medium group is sitting mostly in between the other groups. The result is displaying that not the whole adjustment area has been used and TP's are not choosing to sit in the front end of the length adjustment areas. The chosen back support gradient for the scenario is displayed for the standard seat in Figure 41 and for the prototype seat in Figure 42. When comparing the back support gradient in the different seats, it displays that more people use a larger back support gradient when reading in the prototype seat. There is a wide span of chosen back support gradients and it varies for all three body height groups. The span of back support gradients varies between around 15 to 40 degrees in the standard seat and around 15 to 50 degrees in the prototype seat. Most people use a back support gradient larger than 25 degrees in the prototype seat. The adjustment of the seat extension when reading in the standard seat is shown in Figure 43 and for the prototype seat in Figure 44. Most TP's use the seat extension in both seats and the whole adjustment area is used. Most tall TP's are using the maximum seat extension possible in both seats, while the short and medium TP's are more spread out.

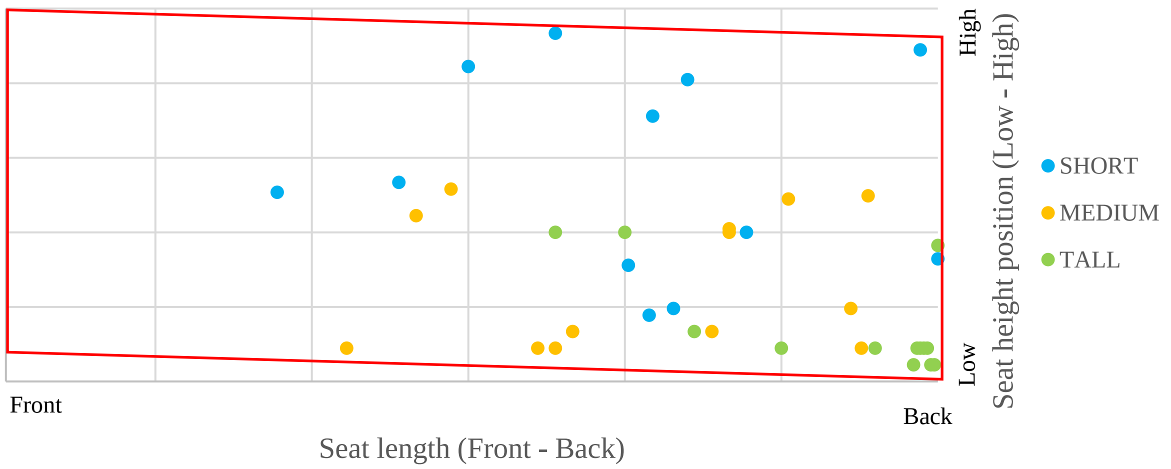


Figure 39 Seat length positon and seat height position for the reading scenario in user test two and the standard seat.

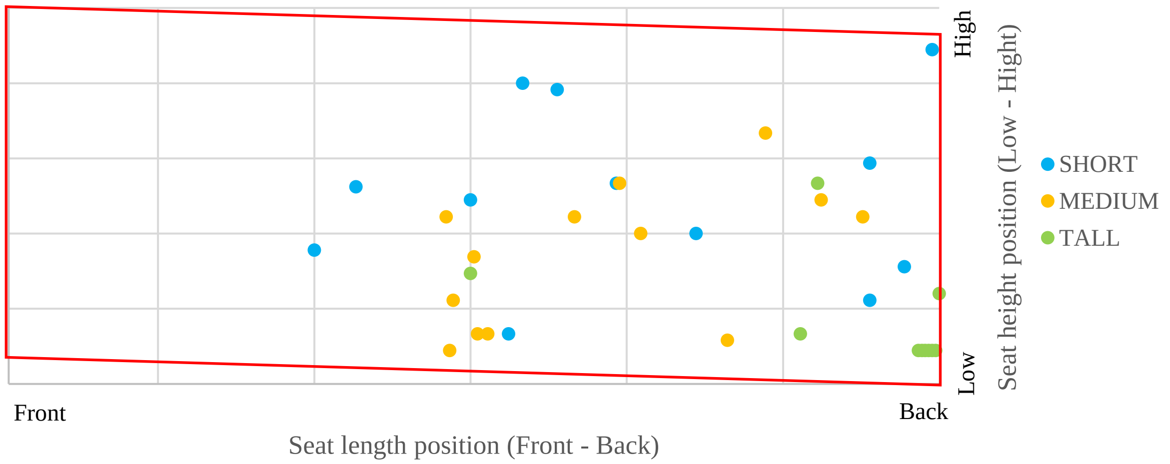


Figure 40 Seat length positon and seat height position for the reading scenario in user test two and the prototype seat.

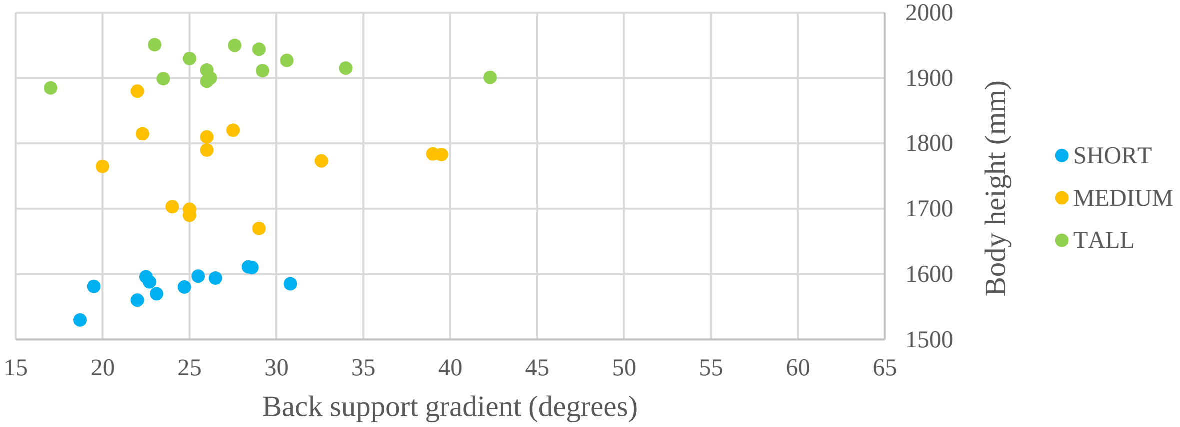


Figure 41 Back support gradient and body height of the test persons for the reading scenario in user test two and the standard seat.

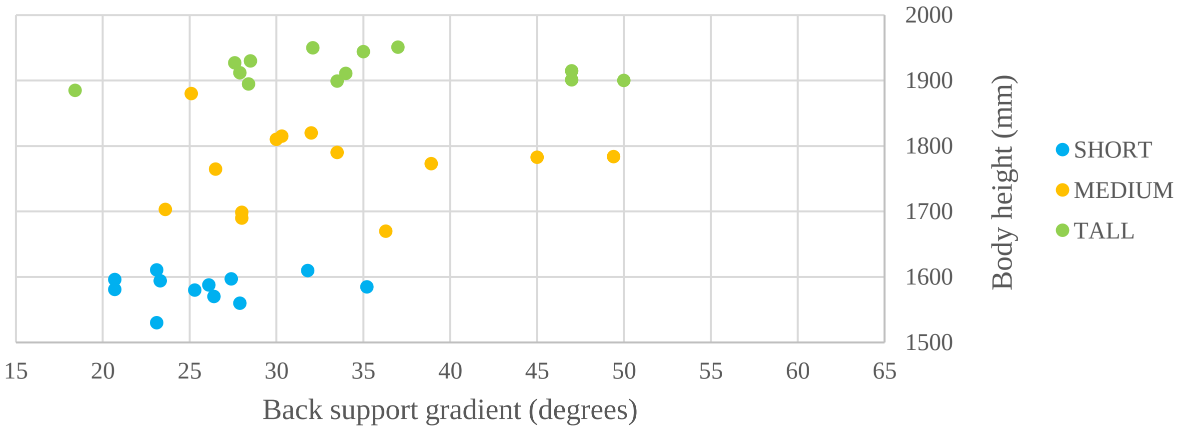


Figure 42 Back support gradient and body height of the test persons for the reading scenario in user test two and the prototype seat.

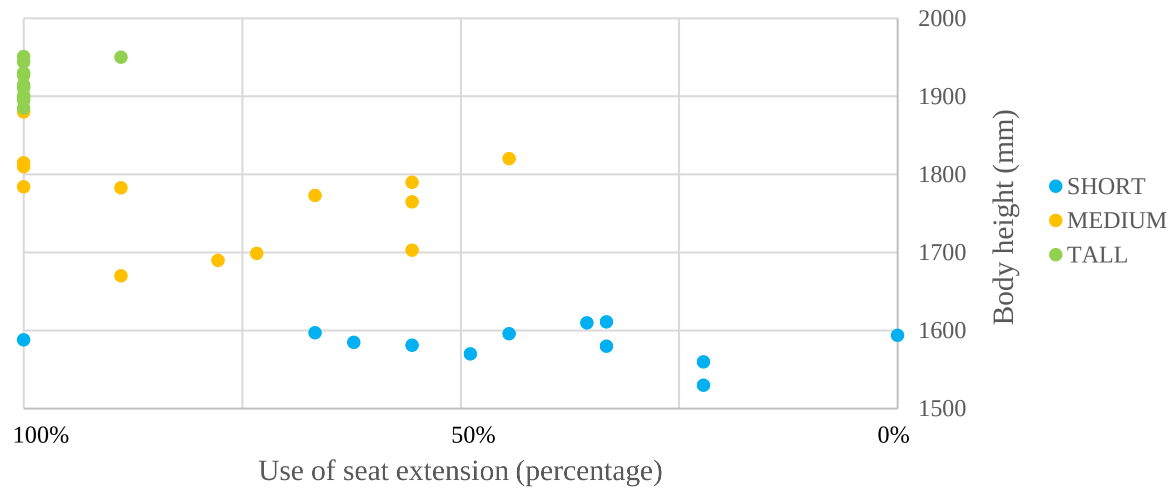


Figure 43 Use of seat extension and TP body height for the reading scenario in user test two and the standard seat.

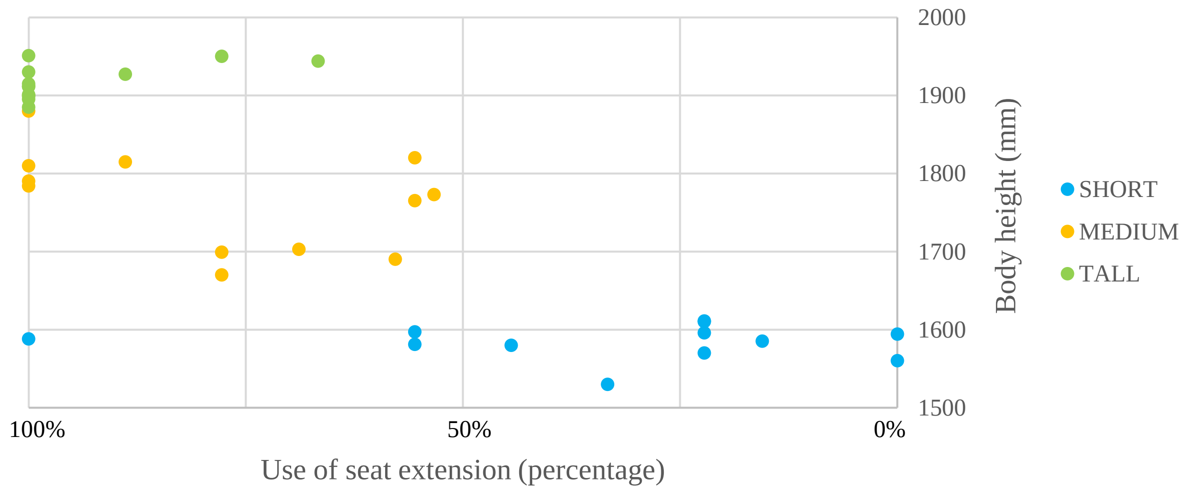


Figure 44 Use of seat extension and TP body height for the reading scenario in user test two and the prototype seat.

The relation between the back support gradient and the articulation in the back support is shown in Figure 45. Most of the short TP's use less than 50% of the adjustment area while the medium and tall group use the whole span for the adjustment area. In Figure 46 relation between the back support gradient and use of the head support when reading is displayed. The whole adjustment area of the head support is used but approximately 2/3 of all participants use less than 50 % of the adjustment, represented by mostly short people. The relation between the use of the articulation in the back support and the use of the head support can be seen in Figure 47. The result shows that participants are seldom using much of both functions simultaneously. It is also displayed that for both functions the whole adjustment area is used by only a few TP's. There are fewer TP's adjusting the head support in comparison with the number of people adjusting the articulation in the back support.

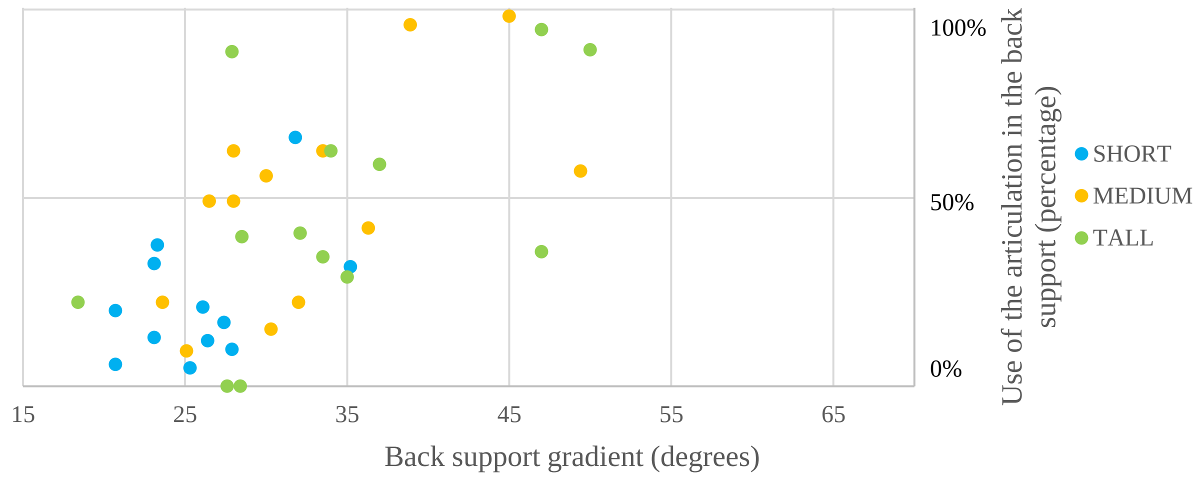


Figure 45 Back support gradient and the use of the articulation in the back support for the reading scenario in user test two and the prototype seat.

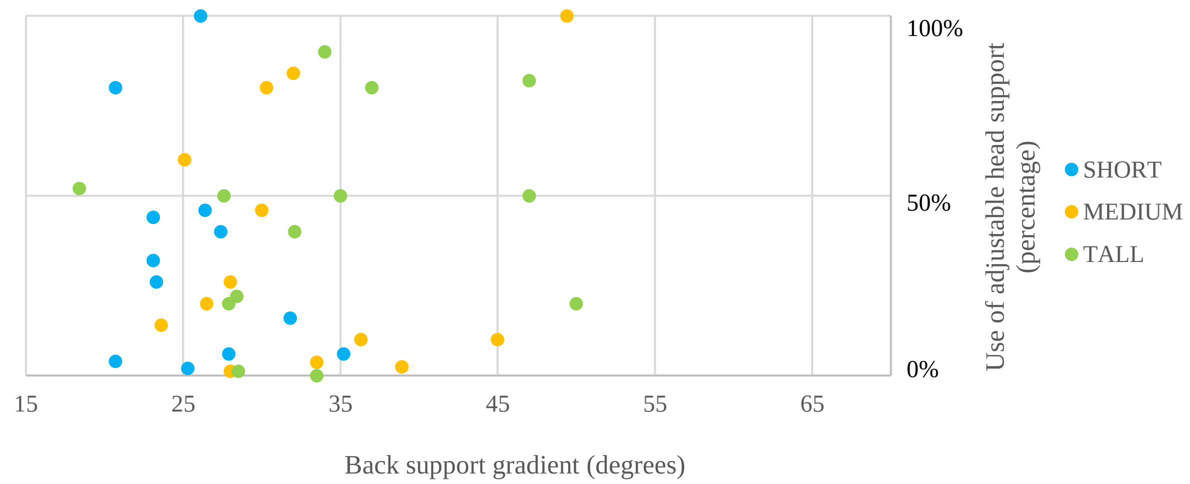


Figure 46 Back support gradient and the use of adjustable head support for the reading scenario in user test two and the prototype seat.

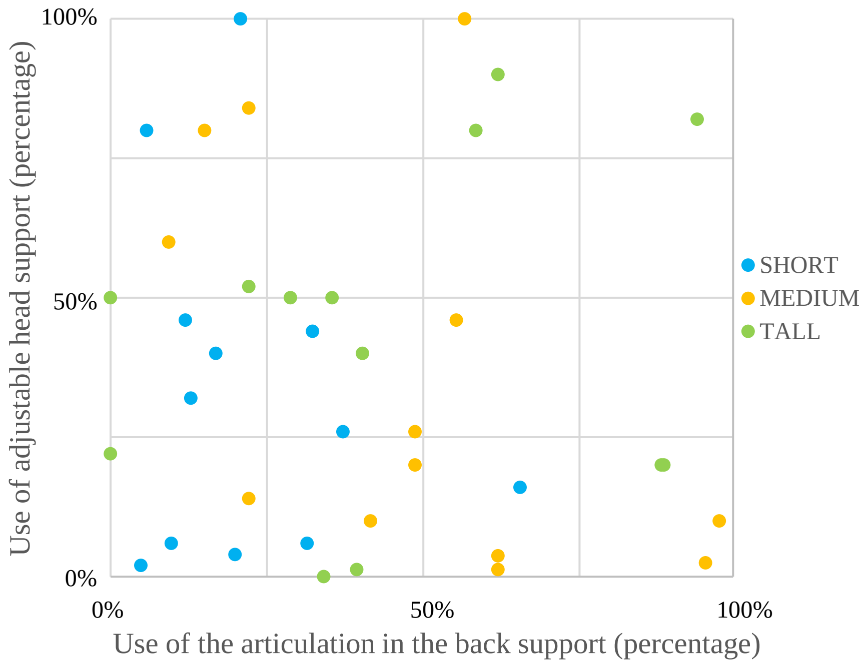


Figure 47 Use of the articulation in the back support and the use of the adjustable head support for the reading scenario in user test two and the prototype seat.

The following section presents comments from part one of the scenario 'Reading using a handheld device'

Comments from user test two have been categorised using a KJ analysis where the categories has been matched with the categories of the interview form: head, back, seat cushion, legs and feet, arms and overall comments.

Opinions about the overall comfort and position

When reading in the standard seat, three short, three medium and six tall people want to use the steering wheel as support for the tablet. Three short and three medium TP's express the same desire in the prototype seat. Furthermore five tall TP's finds a good seating posture in the standard seat. When reading, three tall TP's finds a good support for the whole body.

Opinions about the head comfort and position

In the standard seat eight short, seven medium and six tall TP's do not have support for the head and neck. In the prototype seat on the other hand, seven short, five medium and six tall TP's finds a good support for the head. In the standard seat, three medium and three tall TP's finds it good that there is space for the head and that the head can move freely. The adjustment possibility is something that four short and two medium TP's appreciate in the prototype seat. Furthermore six short people want to have the head support further down and four tall TP's want to have it higher up saying that it is pressing on the shoulders. Four medium TP's cannot use the head support in the prototype seat since the neck is bent forward to read on the tablet, the same goes for three tall people in the standard seat. Five short people lack support around the neck when reading in the prototype seat. Moreover the head support is too hard according to four tall people.

Opinions about the back comfort and position

When reading in the standard seat six short, three medium and four tall participants finds support for the whole back. In the prototype seat ten short and three tall people gets support for the whole back while eight medium and five tall people gets a good support for the upper part of the back. When reading in the prototype seat three tall people gets a good back gradient. Furthermore three short, three medium and four tall people lack the lumbar support in the standard seat and four short, two medium and three tall people lack the lumbar support in the prototype seat. The lack of support for the upper part of the back in the standard seat is mentioned by two short, fore medium and three tall TP's.

Opinions about the seat cushion regarding comfort and position

The seat cushion gives good support in the standard seat according to three short, five medium and six tall people, whereas three short, five medium and seven tall TP's express the same thing for the prototype seat. Five short TP's states that it is good to have the seat extensions in the standard seat and three participants express the same thing regarding the prototype seat. Four tall TP's also appreciate the seat extension but four tall participants want a longer extension of the seat.

Opinions about the legs and feet comfort and position

The space for legs and feet is good in the standard seat according to six short and four medium participants whereas seven short and five medium TP's express the same thing for the prototype seat. Four tall TP's express that the foot support on the left side is good when reading in the standard seat. Moreover support for the legs and feet is a desire for five short and four medium TP's in the standard seat and the same desire is stated by two short and six medium TP's in the prototype seat. Furthermore the pedals are in the way when reading in the standard seat for four medium and seven tall participants and for six tall TP's in the prototype seat. Four tall test persons in each chair lack a support for the right foot. Additionally five tall TP's cannot fit their legs properly in the prototype seat.

Opinions about the arm comfort and positon

In the standard seat four short TP's finds it good to be able to use the side bolsters as support for the arms when reading. Three short, three medium and six tall TP's finds the support for the right arm good in the standard seat. Furthermore three tall TP's express that it is enough space for the arms in the standard seat. In the prototype seat five short, seven medium and six tall TP's have good support for the arms. Four tall participants also specify that the support for the left arm is a positive aspect in the prototype seat. Furthermore in the prototype seat three short TP's finds the adjustment possibilities good. When reading in the standard seat nine of the short TP's do not have support for their arms. Four medium TP's finds the tunnel too hard in the standard seat and three TP's do not get support for the left arm. In the prototype seat seven short and four medium think that the arm support is to far apart. Furthermore six tall participants think that the arm supports are too high and dependent on the height of the centre tunnel. Three medium TP's do not want to use the arm supports.

Reading using a handheld device - Part two: possibility to adjust one parameter at the time

The following section presents result from part two, where TP's were allowed adjust only one of the new parameters at the time in the prototype seat for each scenario

When having the ability to change one new parameter at the time in the prototype seat with a predefined seating position based on part one, some TP's experience an improvement of the position and perceived comfort while others do not. Some of the TP's do not want to use the new parameters at all. The four different variants of the test included adjustment of only the back support articulation, only the adjustable head support, a combinations of the back support articulation and the adjustable head support and finally only by adjusting the arm supports. The result displays the number of TP's that do not experience any change regarding the comfort and position, as well as TP's that do express an improvement. When adjusting only the articulation in the back support, more people experience an improvement than those who are not when reading, regardless of length group, see Table 16. The result for adjusting the head support is displayed in Table 17 and shows that more short and tall participants does not experience any improvement compared to those who do. In the medium group most people experience an improvement. When having the ability to use both the head support and the articulation in the back support, most participants experience an improvement, see Table 18. The result regarding the arm supports is displayed in Table 19. Where the use of arm supports improve the arm comfort and position for more than 2/3 of the TP's, most people being tall and short participants. The distribution of improvement in relation to the used scale of 1 to 10 can be seen in Appendix F. How different parameters was adjusted can be seen in Appendix G.

Table 16 Change of score when using the articulation in the back support in the reading scenario.

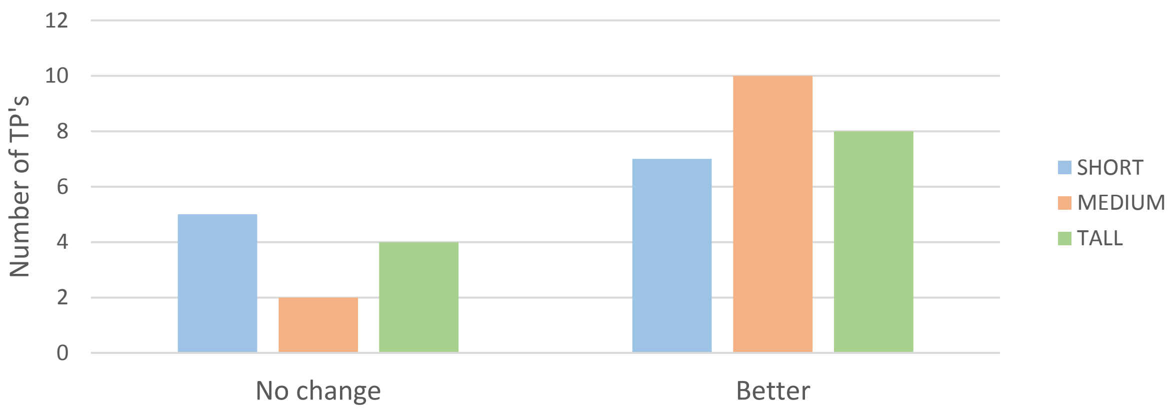


Table 17 Change of score when using the adjustable head support in the reading scenario

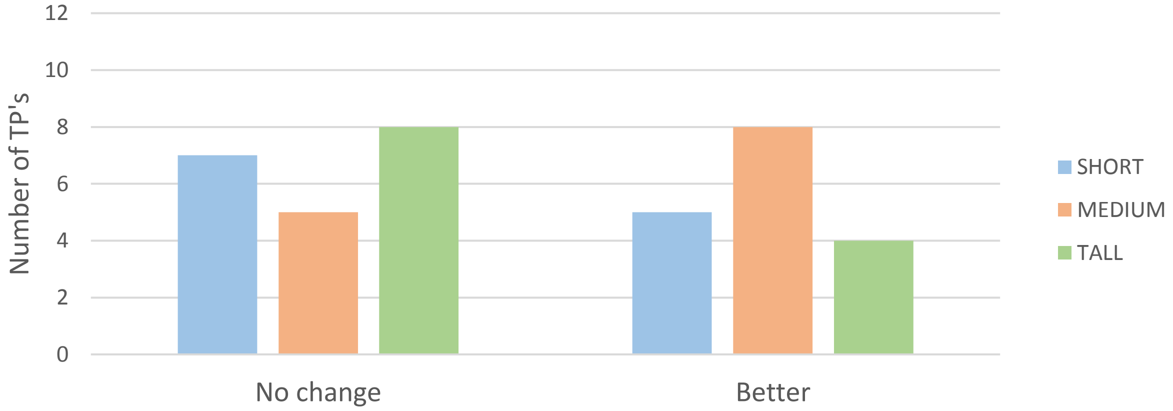


Table 18 Change of score when using the adjustable head support and the articulation in the back support in the reading scenario

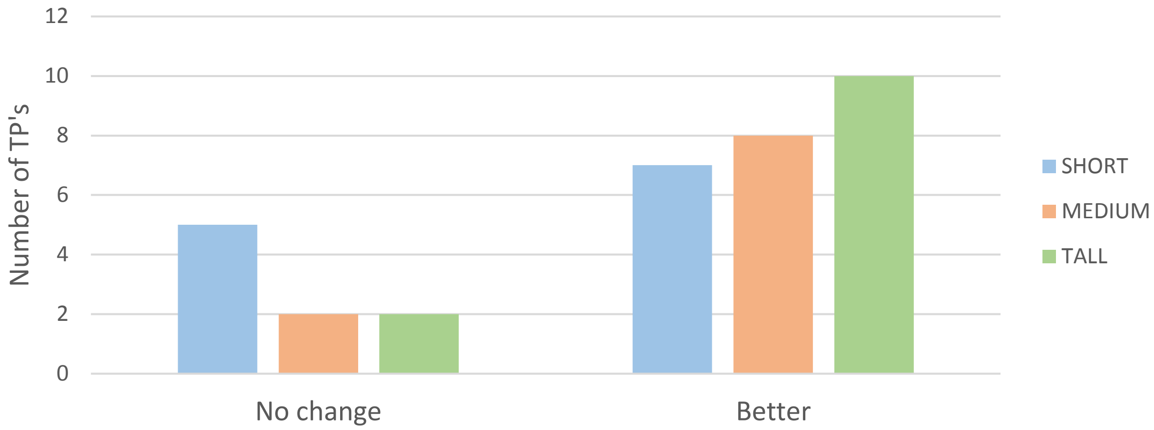
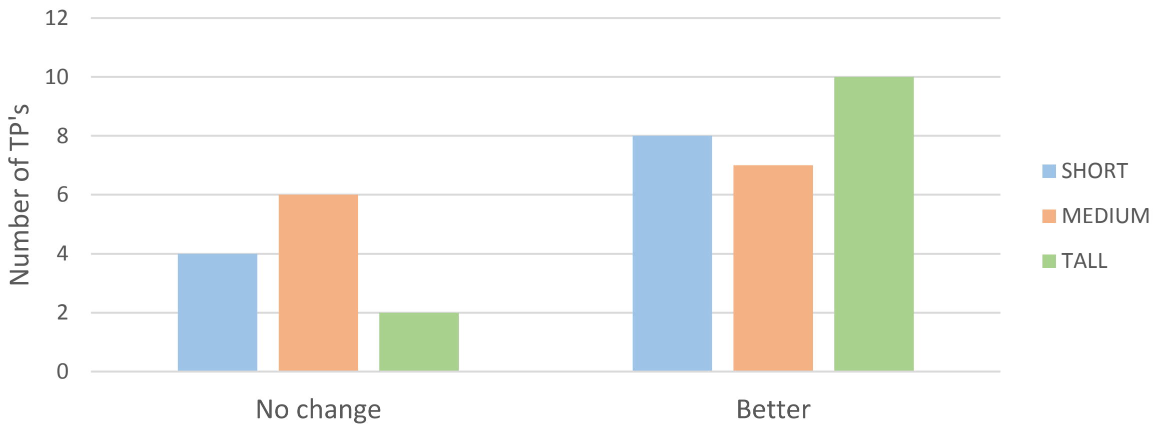


Table 19 Change of score when using the adjustable arm supports in the reading scenario.



The following section presents comments from part two of the scenario 'Reading using a handheld device'

Comments from the second part of user test two have been categorised using a KJ analysis where the categories have been matched with the different adjustment possibility.

Opinions regarding the articulation in the back support

When using only the articulation four short, eight medium and seven tall TP's gets more support for the upper part of the back. The support for the neck also gets better according to five short, five medium and two tall participants. Four short and two medium TP's do not experience a notable difference when only using the articulation in the back support. Three short TP's express that if using the function it compress the body posture to an uncomfortable position and therefore do not use it. Furthermore three medium and three tall TP's lack the arms support.

Opinions regarding the head support

When adjusting the head support the head gets a good support according to four short, five medium and two tall TP's. Four medium and four tall TP's do not want to use the head support when reading on the tablet. When having the ability to adjust only the head support six short, six medium and two tall people lack support for the upper part of the back. According to two short and three medium TP's, the articulation in the back support is seen as the best function.

Furthermore the head support do not adjust forward enough to provide the support desired for three medium and five tall TP’s. The head support is also too far down and puts pressure on the shoulders when used for four tall TP’s.

Opinions when adjusting both the articulation in the back support and the head support

When having the ability to adjust both the articulation in the back support and the head support three short, five medium and three tall TP’s express that it is better to use only the articulation in the back support. On the other hand, two short, three medium and four tall people finds it better to have the ability to combine the two functions. When using both of the functions, the support for the upper part of the back increases for three medium participants. The support for the neck is also seen as good for three medium TP’s. For four tall participants, the support for both the upper back and the neck is good when using the two functions. Moreover three short TP’s wants to adjust the head support backwards in order to use more of the articulation. The head support also makes contact with the head too high for three short and two medium participants. Three tall TP’s do not want to use the head support for reading.

Opinions regarding the arm support

When having the ability to use arm supports eight short, four medium and nine tall TP’s finds it better and more relaxing compared to not having arm supports at all. Four medium participants finds it easier to hold the tablet when using the arm supports. It is good to have adjustment possibilities on both sides for three short TP’s. Furthermore three short TP’s express that the arm supports is too far apart and for three tall TP’s the arm supports are placed too high. Three medium and four tall TP’s lack the support for the back and neck.

Working on a laptop - Part one: possibility to adjust all parameters

The following section presents result from part one, where TP’s were allowed to freely adjust all parameters of the seat for each scenario.

The difference in average score for comfort and position between the standard seat and the prototype seat is shown in Table 20, where for example “*Overall comfort and seating position +0.9*”, means that the average score for the prototype seat increased by 1.3 units compared to the standard seat, based on the scale of 1 to 10. A visual explanation of the categories can be seen in Figure 48 and the distribution for the change of score can be seen in Appendix E. When comparing the seats, a significant difference in average scores can be seen regarding overall comfort, the head and the back while the difference for seat cushion, legs and feet and arms are approximately zero or very close. The improvement for the comfort and position in overall comfort, head and back is common for all three body height groups, with exception for the back score for the short participants that do not display the same average improvement. The highest outcome for the scenario is the head comfort and position for medium people with an increase of 1.8 units.

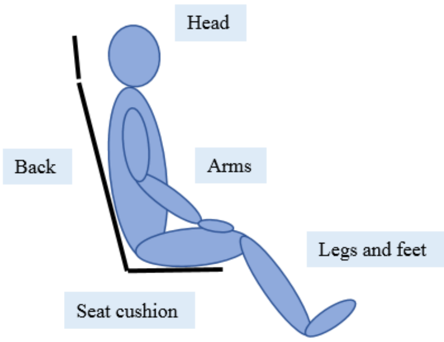


Figure 48 Explanation of the categories evaluated.

Table 20 Difference in average score for the working scenario of short, medium and tall people in user test two with the standard seat as reference based on the scale of 1 to 10.

SHORT PEOPLE (<161cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+0.9	**+1.1**	**+0.3**	**-0.1**	**+0.0**	**+0.4**

MEDIUM PEOPLE (162cm-191cm)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+0.7	**+1.8**	**+1.3**	**+0.1**	**+0.3**	**+0.4**

TALL PEOPLE (192cm<)					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
+0.7	**+0.9**	**+1.2**	**+0.1**	**+0.0**	**-0.2**

The chosen height and length position for the TP's is displayed in Figure 49 for the standard seat and for the prototype seat in Figure 50. According to the result, TP's use the rear section of the length adjustment area while the front part of the adjustment area is not used when working on a laptop using a defined laptop support. Short participants sits further up than tall TP's who sits low and far back in the adjustment area whereas most of the TP's in the medium group are spread between the short and tall TP's. The back support gradient used when working in the standard seat are viewed in Figure 51 and for the prototype seat in Figure 52. When comparing the different back support gradients for the two seats, it shows that a larger back gradient is used in the prototype seat. For the standard seat the back support gradient varies from, approximately, 15 degrees to 25 degrees and between 20 and 35 degrees for the prototype seat. The variation can be seen in all three body height groups. Adjustments made to the seat extension when working in the prototype seat is displayed in Figure 53 and the same result for the standard seat can be seen in Figure 54. The result displays that most of the participants use the seat extension and that the whole adjustment length is used. Most of the tall TP's use the maximum length of the seat extension while the short and medium groups are more evenly spread out.

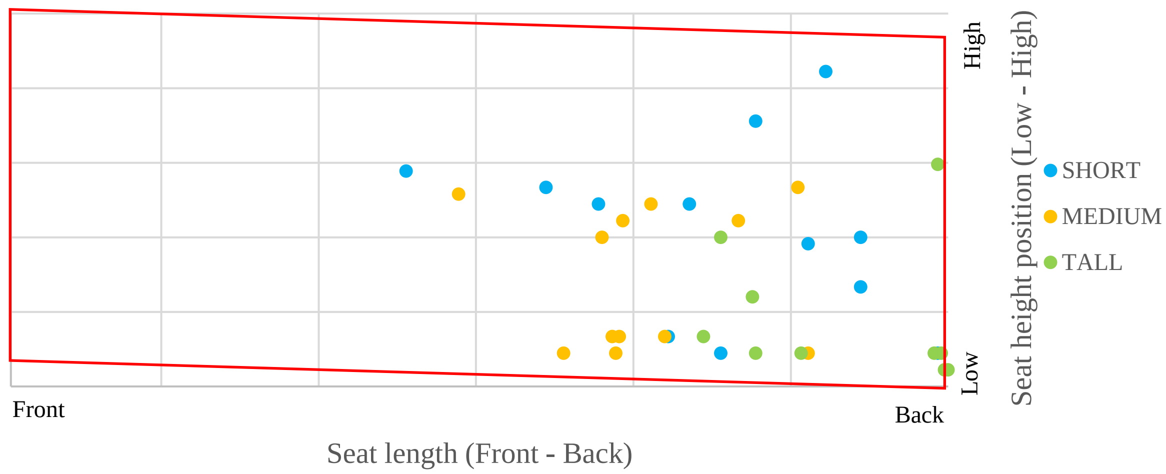


Figure 49 Seat length positon and seat height position for the working scenario in user test two and the standard seat.

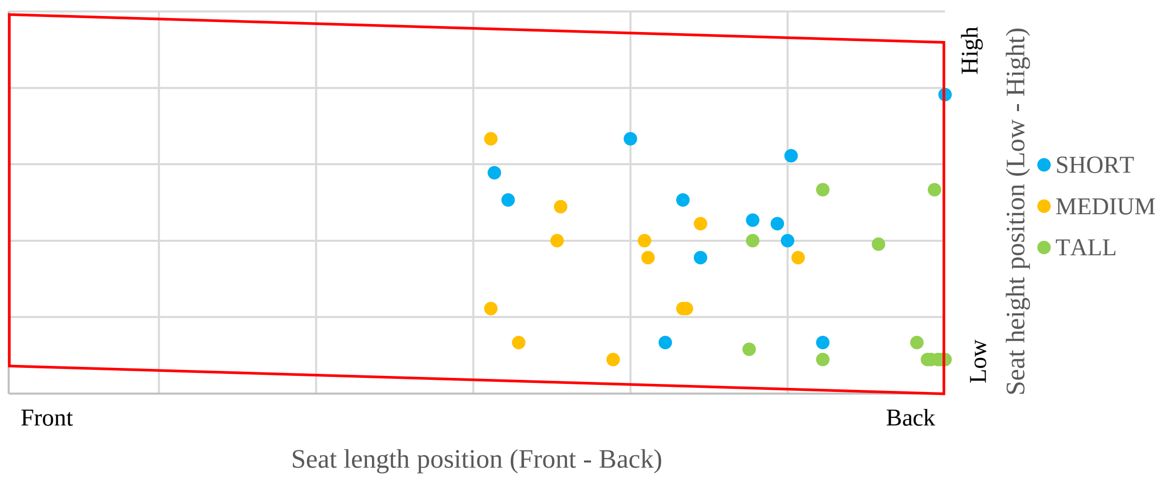


Figure 50 Seat length positon and seat height position for the working scenario in user test two and the prototype seat.

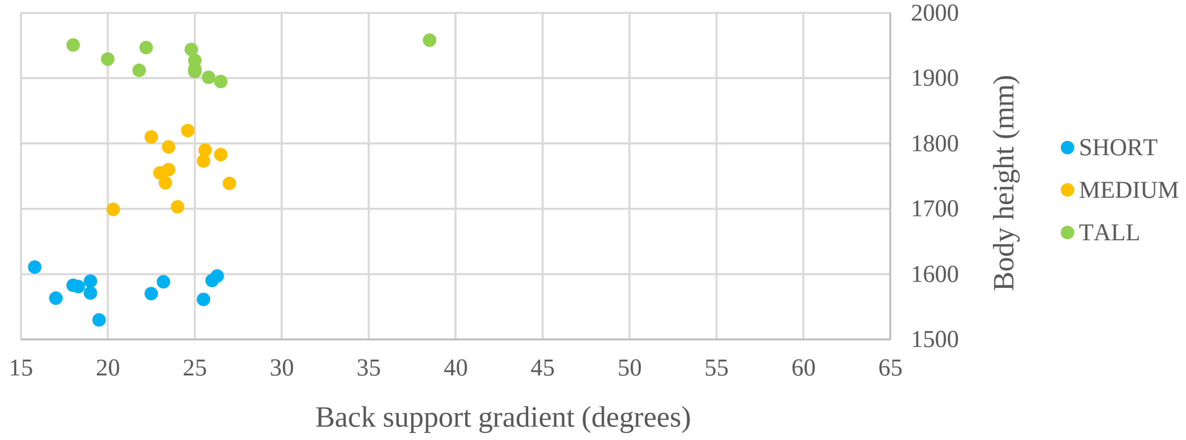


Figure 51 Back support gradient and body height of the test persons for the working scenario in user test two and the standard seat.

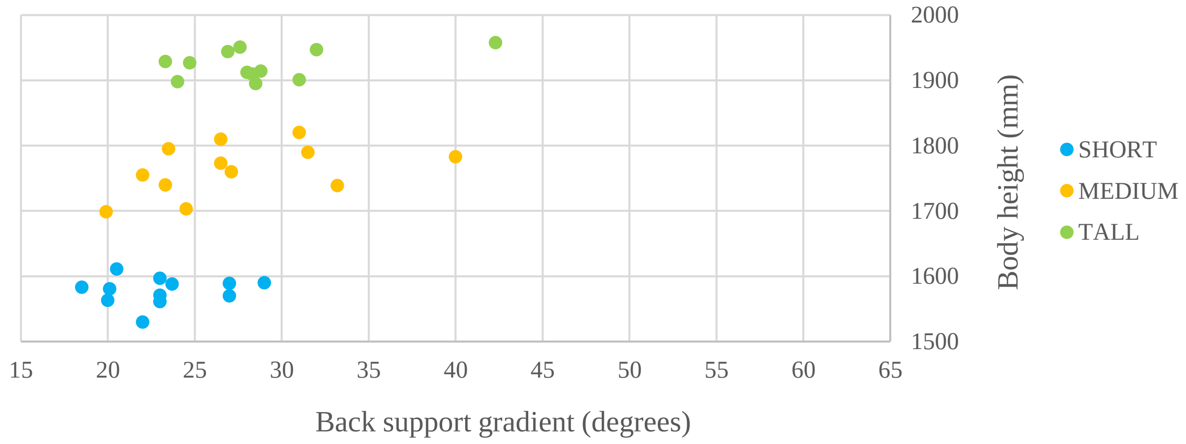


Figure 52 Back support gradient and body height of the test persons for the working scenario in user test two and the prototype seat.

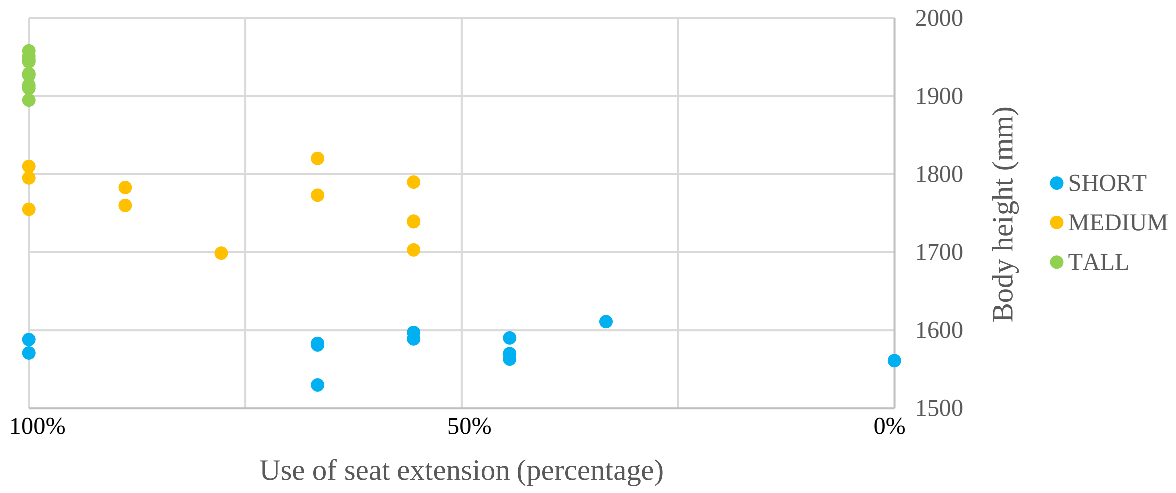


Figure 53 Use of seat extension and TP body height for the working scenario in user test two and the standard seat.

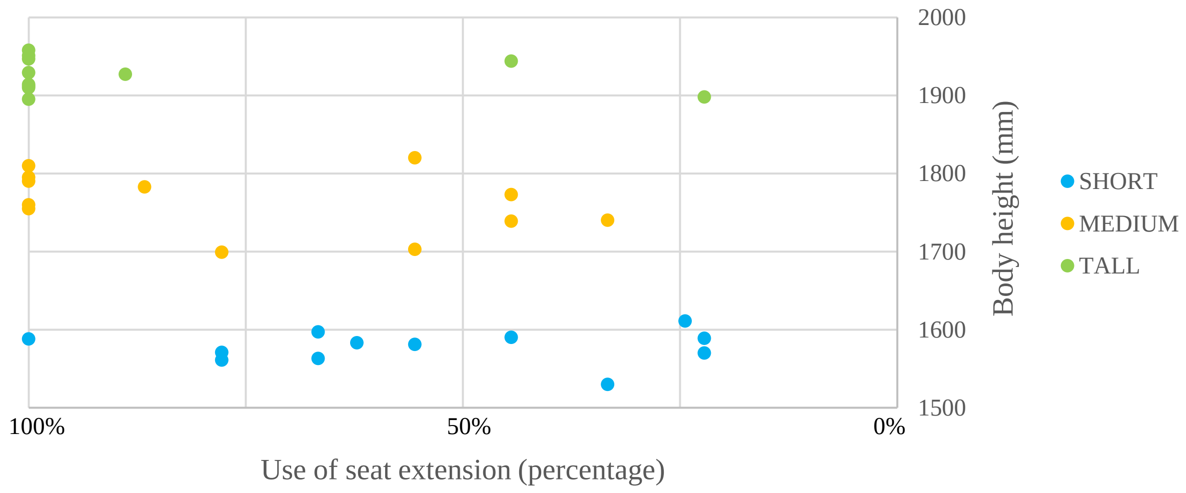


Figure 54 Use of seat extension and TP body height for the working scenario in user test two and the prototype seat.

The relation between the use of the back support gradient and the articulation in the back is displayed in Figure 55. The result shows that the whole adjustment area is used when working in the car and that most participants use the function, although some people use none or only little of the two adjustment possibilities. How the head support and the back support gradient have been used by the TP's are shown in Figure 56. When working, the head support is adjusted by most of the participants but some TP's, occurring for all three body height groups, choose to use none or only little of the adjustment possibility. How much the head support is adjusted differs dependent on TP's own preferences. Figure 57 displays the relation between the use of the head support and the articulation in the back support. Most TP's use both of the functions and finds a good position and good comfort. Some participants use only one of the functions where it is more common to use only the articulation in the back support. All of the participants adjusts at least one of the new parameters.

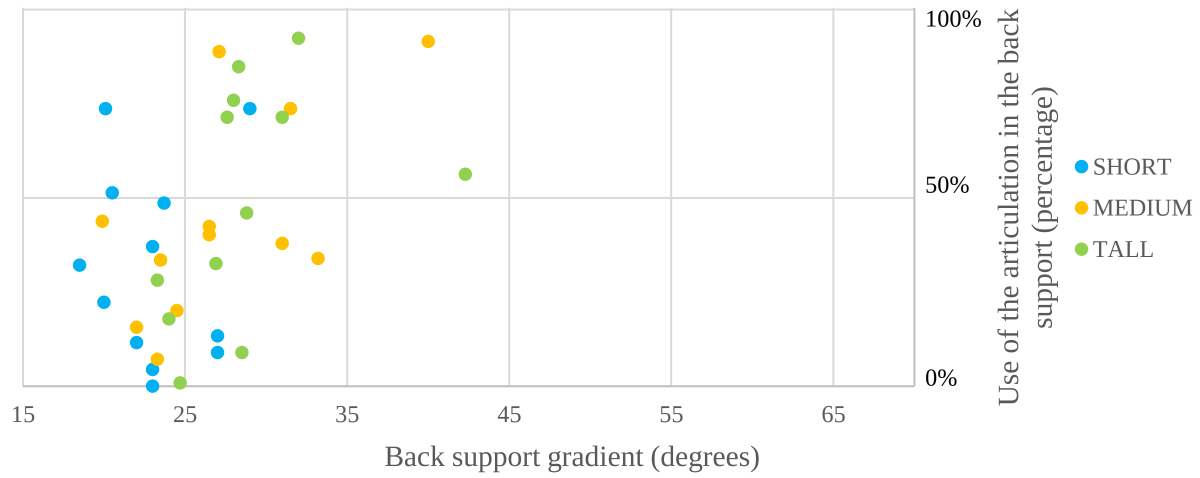


Figure 55 Back support gradient and the use of the articulation in the back support for the working scenario in user test two and the prototype seat.

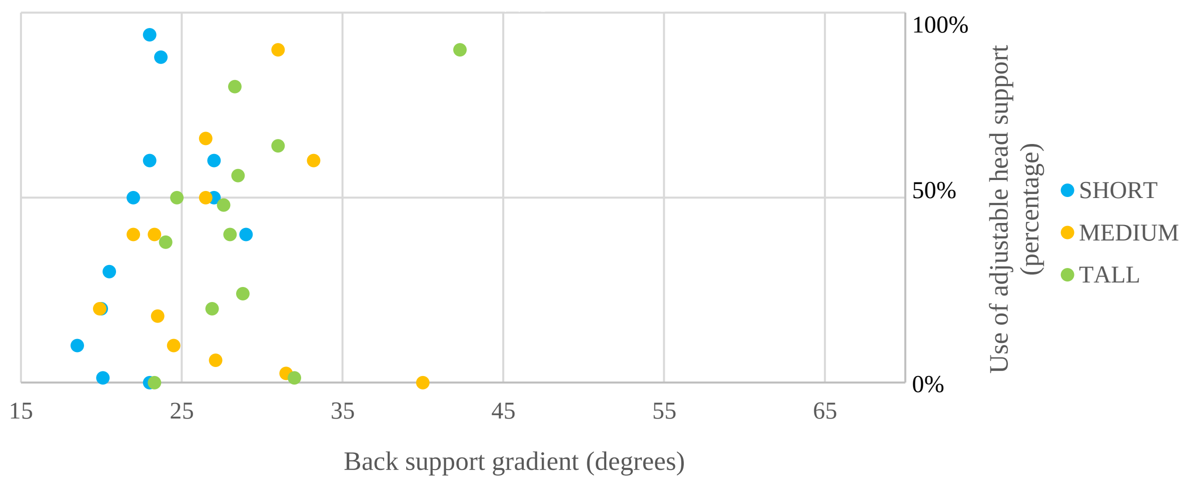


Figure 56 Back support gradient and the use of adjustable head support for the working scenario in user test two and the prototype seat.

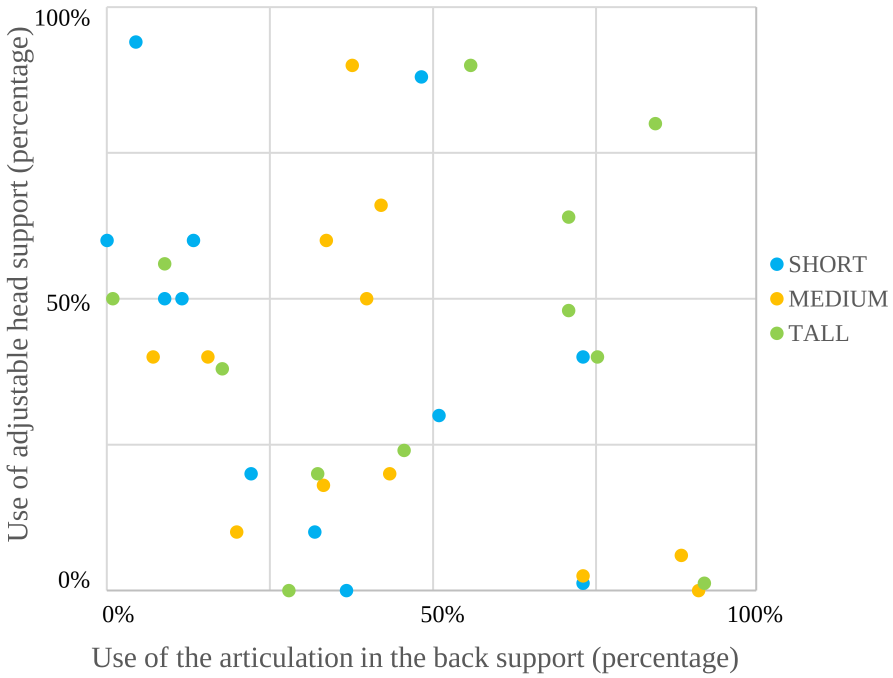


Figure 57 Use of the articulation in the back support and the use of the adjustable head support for the working scenario in user test two and the prototype seat.

The following section presents comments from part one of the scenario 'Working on a laptop'

Comments from user test two have been categorised using a KJ analysis where the categories have been matched with the categories of the interview form: head, back, seat cushion, legs and feet, arms and overall comments.

Opinions about the overall comfort and position comments

When using a laptop on the defined laptop support in the car, the rotation of the torso is annoying for eight short, four medium and eight tall participants in the standard seat and for seven short, eleven medium and eight tall people in the prototype seat. Furthermore six short, three medium and nine tall TP's want to have the laptop support directly in front of them in the prototype seat which is also noted by four medium and seven tall people in the standard seat. When working on the laptop support two short, three medium and three tall TP's want to have the laptop support higher up. For four tall TP's in the standard seat and for three tall TP's in the prototype seat the steering wheel is considered to be in the way.

Opinions about the head comfort and position

It is possible to get support for the head when working on the laptop for three short and three medium TP's in the prototype seat. There is good space for the head for four tall TP's in the standard seat. Three short and four tall TP's do not want to use the head support when working in the prototype seat and a similar result is described by two medium and three tall TP's for the standard seat. On the other hand six short, six medium and three tall participants experience a rotation in the neck which is not appreciated in the standard seat and two short, two medium and five tall TP's experience the same thing for the prototype seat. Furthermore four short and four medium TP's do not have support for their head in the standard seat. Three tall TP's need to bend their neck to look at the laptop in the standard seat. Furthermore the head support is too far down for four tall TP's.

Opinions about the back comfort and position

When working in the prototype seat the support for the back is good for three short and six medium TP's. Furthermore two short, three medium and seven tall TP's gets more support for the upper part of the back in the prototype seat. Four short TP's gets good support in the standard seat. When working on the laptop support in the car, the rotation of the torso is annoying for two short, eight medium and seven tall people in the standard seat and for four short and two tall TP's in the prototype seat. Three short, three medium and two tall participants lack the lumbar support in the prototype seat while three tall TP's lack the lumbar support it in the standard seat. Moreover two short and four medium TP's lack support for the shoulders in the standard seat.

Opinions about the seat cushion regarding comfort and position

The seat cushion gives good support for four short, two medium and three tall TP's in the standard seat and for two short and two medium participants in the prototype seat. The softness of the cushion in the prototype seat is good according to two medium and three tall TP's. Five tall people in the standard seat and four in the prototype seat want longer adjustment for the seat extension.

Opinions about the legs and feet comfort and position

For four short and four medium TP's, the space for legs and feet is seen as good in both seats and for three tall people the space for legs and feet is seen as good in the prototype. In the standard seat four medium and seven tall TP's experience that the pedals are in the way, and for the prototype seat, three tall TP's states the same thing. Three medium and four tall TP's finds the space near the pedals too narrow and want more space on the sides in the standard seat. Furthermore three medium and two tall TP's have contact with the laptop support during the test and states it as a problem.

Opinions about the arm comfort and positon

The support for the right arm is good when working on the laptop support for ten short, nine medium and five tall TP's in the standard seat and for five short, eight medium and three tall TP's in the prototype seat. On the other hand, there is no support for the left arm for seven short, eight medium and six tall TP's in the standard seat and it is further stated by six short, four medium and three tall TP's regarding the prototype seat. Furthermore five short, three medium and seven tall people cannot use the arm support on the left side in the prototype seat since it is too far away. Five medium TP's suggests that the arm support on the left side should be folded in towards the body the give support for the left arm.

Working on a laptop - Part two: possibility to adjust one parameter at the time

The following section presents result from part two, where TP's were allowed adjust only one of the new parameters at the time in the prototype seat for each scenario

When having the ability to change one new parameter at the time in the prototype seat with a predefined seating position based on part one, some TP's experience an improvement of the position and perceived comfort while others do not. Some of the TP's do not want to use the new parameters at all. The four different variants of the test included adjustment of only the back support articulation, only the adjustable head support, a combinations of the back support articulation and the adjustable head support and finally only by adjusting the arm supports. When having the possibility to adjust the articulation in the back support most short and medium TP's express an improvement, while more tall TP's do not express any improvement, see Table 21. When having the ability to adjust only the head support, more than 2/3 of the short and tall TP's do not experience any improvement. For the medium TP's on the other hand, more than half of the TP's experience an improvement. The result regarding the improvement when using the head support is displayed in Table 22. The result for improvement when having the possibility to use both the head support and the articulation in the back support is shown in Table 23. The result is similar to the result of only using the articulation in the back support, where it shows that the short and medium group are more positive while most TP's in the tall group do not feel an improvement. When adjusting only the arm supports almost all participants, regardless of body height group, do not feel an improvement, see Table 24. The distribution of improvement in relation to scale of 1 to 10 can be seen in Appendix F. The chosen position can be seen in Appendix G.

Table 21 Change of score when using the articulation in the back support in the working scenario

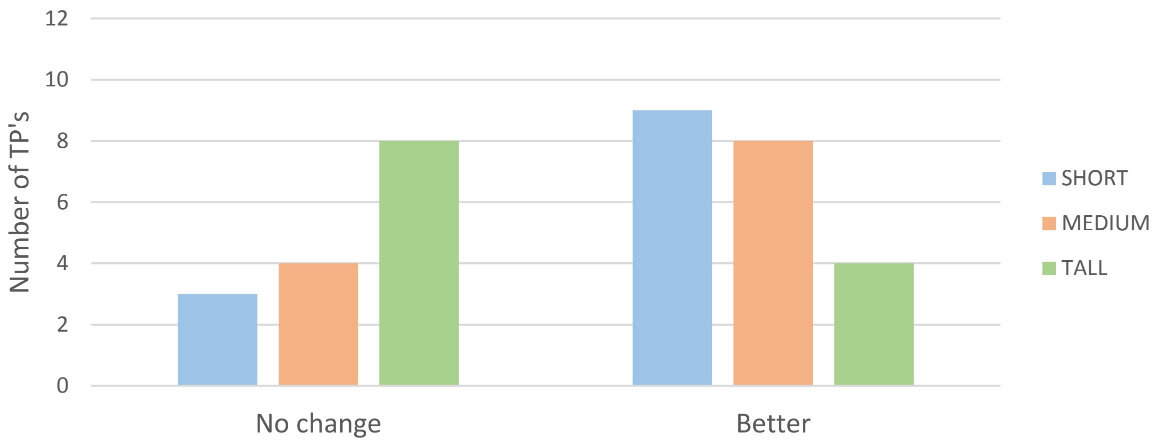


Table 22 Change of score when using the adjustable head support in the working scenario

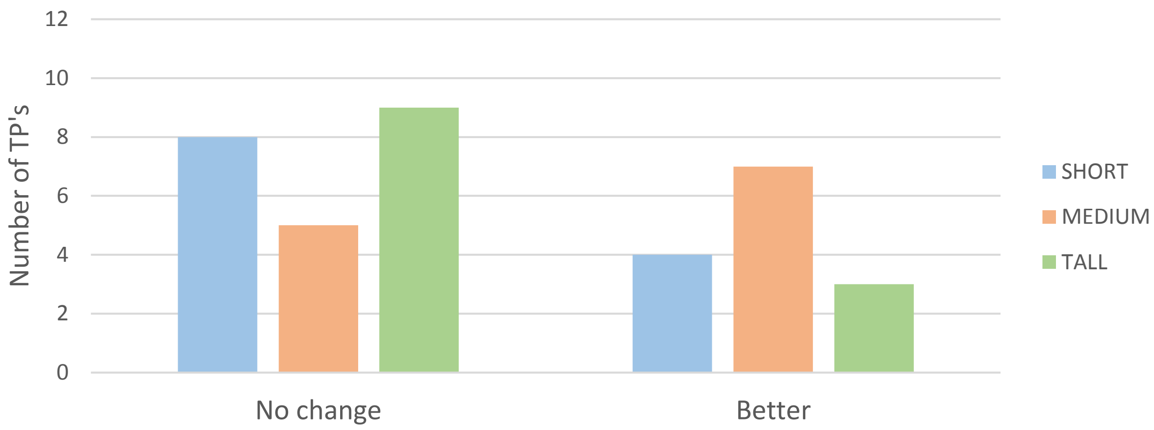


Table 23 Change of score when using the adjustable head support and the articulation in the back support in the working scenario

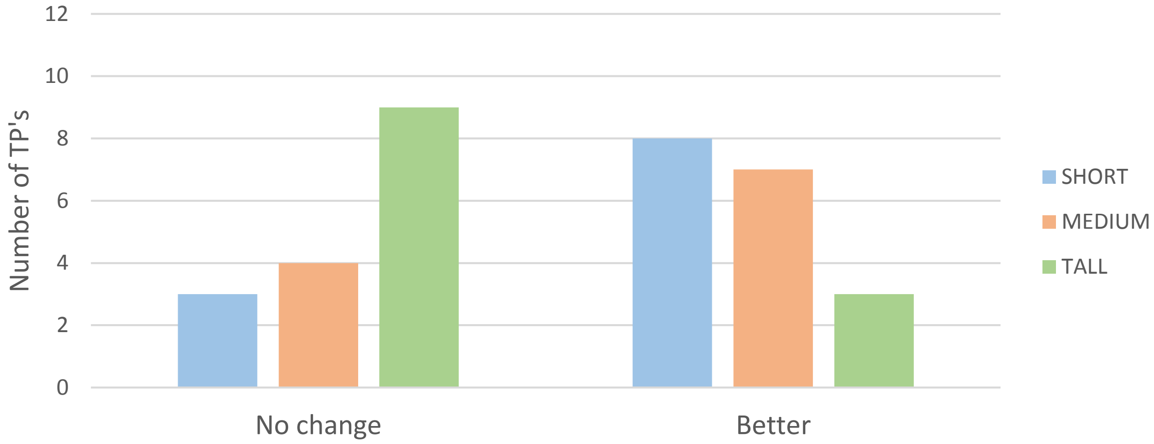
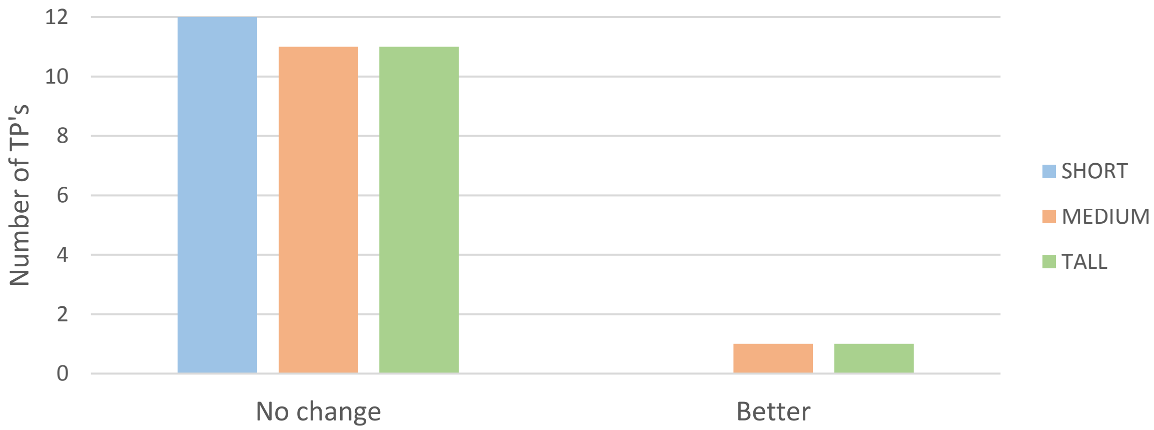


Table 24 Change of score when using the adjustable arm supports in the working scenario.



The following section presents comments from part two of the scenario 'Working on a laptop'

Comments from this part of user test two have been categorised using a KJ analysis where the categories have been matched with the different adjustment possibility.

Opinions regarding the articulation in the back support

When using the articulation in the back support, the support for the upper part of the back increase for eight medium and four tall TP's, while three short TP's thinks the back feels better. The support for the head also increase for five short and two medium TP's, three short people on the other and lack support for the head. The rotation of the torso is still a problem according to six short and two medium TP's. Three tall TP's want to be able to use the large back gradient adjustment together with the articulation in the back support to achieve a better position.

Opinions regarding the head support

When using the head support, the support for the head increase according to three short and five medium TP's. Three short TP's finds it good to be able to lean against the sides of the head support. When working two short and five tall participants do not see a need to use a head support. Moreover the head support is positioned too far down for three tall TP's and for five tall TP's it also puts pressure on the shoulders. Three medium participants think that the articulation in the back support is a better function.

Opinions when adjusting both the articulation in the back support and the head support

Two short and three medium participants finds it good to be able to combine the two functions. Four TP's in each length group do only want to use the articulation in the back support and not the adjustment possibility of the head support. The adjustments contributes to a better support in the upper part of the back for three short and two medium people. A problem for three medium and three tall TP's are that the torso still needs to be rotated towards the table. Some people, two medium and three tall, do not want to use any of the functions.

Opinions regarding the arm support

Three medium and four tall TP's finds it good to have a support for the left arm if and when taking a break from typing or using the laptop. Although when typing on the laptop ten short, ten medium and ten tall TP's cannot use the arm support on the left side since it is too far away.

7.3.5 Analysis of user test two

The analysis of user test two is presented for each of the three scenarios.

Relaxing

The new parameters in the seat increase the overall comfort and the possibility to find a good position when relaxing in the in car. The comfort score for the parts of the body where adjustments to the seat have been made also increases, which also indicates that the new parameters makes it better for specific parts or areas of the body, see Table 10. The new adjustment possibilities only affects part or areas of the body in contact with the new adjustments. This is shown since the average score for the seat cushion as well as for the legs and feet is close to zero and therefore have not been affected as much as other categories. Furthermore comments from TP's regarding these areas are similar regarding both seats.

All three body height groups finds an increased comfort and a better position for the back, although it does not increase as much for the group of short people as for the tall and medium groups. Short TP's have the same range of back gradient as the other groups and use the back support articulation in a similar way, but do not experience the same improvement, see Figure 41. This could be because of the placement for the back support articulation and where it makes contact with the back of the TP. According to comments, the new functions provides support for the whole back and the articulation in the back support also improves the position for the back, which can be connected to the average improved score.

The comfort and position for the head also gets better when test persons are able to use the new parameters, common for all three body height groups. According to comments from five short participants, the support is better in the prototype seat while ten medium and ten tall TP's also express having a better position indicating that support for the head improves. It is displayed that many short TP's are not using the head support, but still experience an improvement regarding comfort and position for the head when relaxing. This could be due to the fact the head places further down on the head support or on the back support itself and therefore the head is affected only by the movement of the back support articulation and not by the head support, see Figure 58. The head support also follows the movement of the back support articulation forward when used which also can affect the position of the head. Furthermore half of the short TP's express through comments that the head support is positioned too high, supported by Figure 58.

Figure 58 Position of a short person when relaxing without using the articulation in the back support (left) and position of a short person when relaxing using the articulation in the back support as much as possible (right).

Although the comfort and position improves for the head, 16 out of 35 TP's still lack a support for the neck when relaxing. Furthermore, side supports for the head are mentioned as missing by 14 participants. Lack of side support and neck support indicates that the design for the head support needs to be reconsidered when relaxing. The average score for all three body height groups also increase for the arm comfort and position when using the new parameters, see Table 10. The arm supports provide support for both arms and makes it possible to set the same height for the arm supports on both left and right side. Although the arm supports are placed too high for the tall group, even if they are adjustable, this due the fact that the centre tunnel limited the possibility to lower the position further. Short TP's experience the smallest improvement regarding the arm supports. Comments from eight of the short participants explains that the arm supports are positioned to far apart which can be connected to the not so noticeable change of improvement. Furthermore, comments indicate that the physical shape of the arm supports are too thin, which explained earlier can be connected to limitation of the interior space of the test object.

Positioning of the seat when relaxing

When relaxing in the car, the front of the adjustment area for the seat length position is not used, see Figure 30. The tall TP's also indicate the need for more space in the area for legs and feet.

The need of more space is based and can be related to nine tall TP's in the standard seat and eight in the prototype seat who thinks that the pedals are in the way. Furthermore other comments regarding not being able to fit the legs properly when relaxing are also supporting this argument. This shows that the adjustment area for the seat length position places too far ahead and that it might be better if the adjustment area places further back in the car for the specified scenario. For short TP's there are enough space but according to comments from eight short TP's, there are indication of a need for extra support for legs and feet when relaxing. The back support gradient is tilted far backwards when relaxing and increase when having the ability adjust the back support articulation forward. The back gradient is not dependent on the body height of the TP. The ability to adjust the seat extension is an important feature for all three body height groups when relaxing and there is a desire to be able to have even more extension possibility from tall people in the test.

Most of the TP's use less than 50% of the adjustment possibilities for both the head support and the back support articulation when relaxing. This indicate that only a small adjustment of these parameters is enough to improve the comfort and position when relaxing. Most people use both of the two functions but when just using one of the two, it is more common for people to use the back support articulation rather than the adjustable head support, see Appendix G. One explanation is that the head support follows the movement of the back support articulation and when using just the articulation there is always a small adjustment to the head support. Subjective data, comments and scores of improvement from part two in test two, also indicates that more people would prefer the articulation in the back support if having too choose between the two functions. The use and comments regarding the head support and articulation in the back support together indicates that both functions contributes to improved comfort and a better position but if having to choose function, articulation in the back support is the one preferred by most people.

Reading using a handheld device

The new parameters in the seat increase the overall comfort and position for all three body height groups. The comfort and position also gets better for all parts of the body where adjustments to the seat have been made, which indicate that the new functions have a positive impact, see Table 15. In parts or areas of the body where the seat is unchanged by the new functions, such as seat cushion and legs and feet, the average score remain similar with a difference being close to zero. Comments regarding the seat cushion are also similar, for example in both seats TP's state the possibility of getting good support from the seat. Furthermore the positioning of the seat extension is also similar in both seats. In categories where change has been made on the other hand, TP's state a notable difference, for example some TP's state to have a better support for the upper part of the back. Figure 47 also shows that the functions actually are being used and that there are a difference between the seats.

When using the new parameters the comfort and position for the head improves for people in all three body height groups. The biggest improvement is noted for the medium group, approximately one score higher than the other groups. Comments from TP's indicate that short people finds the head support to be placed too high and for tall people that the head support is placed too low and also puts pressure on the shoulders. The placement of the head support for one short person and for one tall person can be seen in Figure 59. Since short and tall TP's also have a lower average score of improvement than the medium group, the placement of the head support most definitely influenced the result and fitted TP's of the medium group better. Influenced the result. Furthermore comments displays that 21 out of 36 TP's do not get support for the head in the standard seat and 18 out of 36 do get support for the head in the prototype seat, which indicates that the new function provides more support for the head.

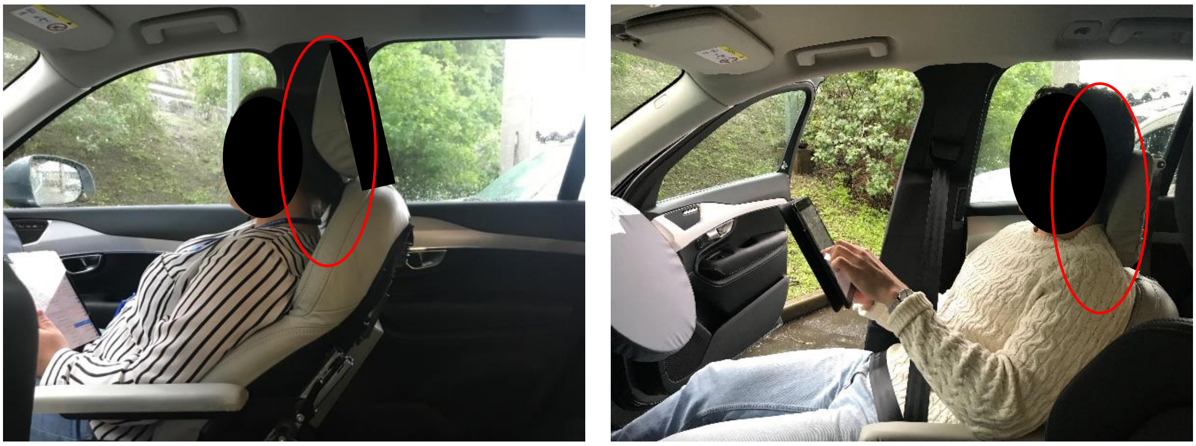


Figure 59 Position of the head support for short person in the reading using a handheld device scenario (left) and position of the head support for a tall person (right).

The comfort and position for the back is also increased when using the new parameters. Comments display that the support for the back is better for the prototype seat which can be related to the improvement of average score. Furthermore the new functions provides a better support for the back. Comments also indicates that even if the new functions improves the experience, the lumbar support is still an important function in the seat that is missing.

The improvement for short participants is lower, which also use less of the adjustment possibility for the articulation in the back support and have not commented on getting better support for the upper part of the body, only a better support for the whole back. This indicate that the articulation does not help short people as much as the other groups and the placement of the function is not for the benefit of short people. When using the new parameters the comfort and position for the arms are also improved. Comments indicates that the arm support provides more support for both arms and not just the right arm. Although more support is provided, the arm supports are too far apart for many of the short participants. The tunnel is also a problem in relations to the arm supports since it prevents the tall TP's from lowering the right arm support. The arms supports are an important feature for the participants based on tables and figures presented in in user test two, part two and comments from 21 out of 36 TP stating that arm support is good to have when you plan on reading in the car.

Sitting position when reading

When reading on a tablet in the car TP's are not using the front part of the adjustment area for seat height and seat length position, see Figure 40. Tall participants sit furthest back in the adjustment area and furthermore eleven TP's express that the pedals are in the way. Moreover, six tall TP's express that the space for legs and feet are not enough. Taking these facts into account, it indicates that the there is a need for more space and the possibility to move the adjustment area further back in the car. Furthermore, TP's that do not think there is a need for more space, instead express a need for an additional support for the legs or feet when reading. The seat extension is also an important part to adjust and it provides good support. When reading, the whole adjustments length of the seat extension is used by almost all of the tall TP's and comments indicates an even larger adjustment possibility. Some of the short TP’s on the other hand do not use the extension at all and retracts the extension as much as possible. This means that the adjustment possibility for the seat extension needs to be extended to bring better conditions for tall people.

When reading more people have a larger back support gradient when using the prototype seat compared to the standard seat, see Figure 41 and Figure 42. What back support gradient the TP’s choose differs, but it is displayed that short TP’s in general use less back support gradient when reading than the other groups. Most people also use the back support articulation when reading, see Figure 47, which can be the reason for increasing the back support gradient. The result presented in Figure 45 indicates that when using more back support gradient TP’s also use more of the adjustment possibility for the back support articulation. Furthermore, tall and medium TP’s adjust the articulation in the back support more forward than short participants. The same tendency is seen when analysing the position for the head support, where more tall and medium participants adjust the head support forward, although most people use less than 50% of the adjustment possibility for the head support, especially short participants.

To find good position and comfort, most TP’s use both the articulation in the back support and head support, see Figure 47. It is displayed that few people use a lot of the adjustment possibilities for both functions at the same time. Which parameter that is adjusted the most varies between TP’s, some use more of the articulation in the back support and others use more of the adjustable head support. In part two of the test it displays that when having the ability to use both functions, 14 of the participants only adjusts the articulation in the back support and none of the TP’s choose to only adjust the head support, see Appendix G. Further comments show that 19 out of the 36 participants gets support for the back while 12 out of 36 gets support for the head when adjusting only the articulation. When only adjusting the head, 11 out of 36 TP’s gets support for the head but 14 out of 36 also lack support for the upper part of the back. Furthermore, more TP’s express an improvement when adjusting the articulation in the back support in relation to adjusting the head support. These facts combined indicates that both the head support and the articulation in the back support contributes to comfort, but if having to choose function, the back support articulation is seen as the preferred one. The fact that the back support articulation is the preferred function can be related to that the movement of the head support is also related to the movement of the back support articulation when adjusted.

Working on a laptop

The overall comfort increase for all three body height groups when provided with new functions in the seat when using a laptop, see Table 20. However, the improvement is not that notably big which can be dependent by the rotation of the torso needed to be able to work use the laptop support. 20 out of 36 in the standard seat and 26 out of 36 in the prototype seat express that the rotation of the torso in the seat is annoying. The rotation is a big problem when working on the table, displayed in Figure 60. It is noted in both observations and comments regarding the comfort and position for each area or part of the body. According to comments and observations, the rotation affects the head, back and the left arm when working on the table.

Figure 60 Rotation of the torso in the working on a laptop scenario for a tall person.

The comfort and positon for the head improves when able to use the new functions of the seat for all three body height groups, see Table 20. Medium TP's express the biggest improvement, which can be due to the fact that the head support is positioned in a more correct way in relation to the body height of medium people. Even if the average score improves, the rotation of the head is still an issue even with the new functions provided, both expressed in comments and seen during the test. The comfort and position for the back is also better for the medium and tall group. Comments from TP's in these two groups display that the support for the upper part of the back are better when using the new functions and less people complain on the rotation of the torso. For the group of short people, the scores are similar even if having the new functions. Neither does the comments from short people point towards any experienced increase of comfort or position. The score for categories where no physical change have been made in the seat by the new functions, is around zero, which indicates that TP's feel that no change have been made and that the new functions do not effect these parts of the body. Furthermore comments regarding these parts of the body is similar in both seats. The score regarding the arms is also similar in the two seats, which indicate that the new functions do not provide more comfort and a better position for the arms when working on the table. This is also supported by the scores in part two of the test, where almost all participants did not feel any improvement when provided with arm supports. According to comments, the left arm support is too far away to use when typing on the laptop, stated by 30 out of the 36 TP's in part two of the test. This is also supported by comments in part one. Support for the left arm is something that TP's lack but the support for the right arm is good, which appears in comments regarding both seats.

Seating positions when working on the table

The front part of the adjustment area for seat length and seat height is not used when working on that table. Short TP's sits in general further up than the other groups and tall TP's sit further down, often in the lowest position possible or very close. Medium TP's sit in between the other groups. Most of the tall TP's use the whole length of the seat extension and some express a desire to extend it even further. Short and medium TP's use a wider span of the seat extension adjustment. Most participants want to sit quite upright when working on the table, see.

When working in the prototype seat, the back support gradient is increased in comparison to the standard seat. Result from Figure 57 show that all TP's use the back support articulation or the adjustable head support, which can be connected to the fact that the use of the new functions support the possibility to have a larger back support gradient. The use of back support gradient are spread out for the different groups, where medium and tall people use a more leaned back position compared to the group of short people, although the distribution between all the different back support gradients are more narrow for the working scenario and also more upright. A more upright position is supported by the data in Figure 51 and can be the result of having the laptop support in a fixed position.

The articulation in the back support is used by almost all participants and the amount of adjustment made differs between the TP's, see Figure 55. It is seen though that the short TP's often do not use more than 50% of the adjustment possibility, while the other groups are spread out using the whole adjustment span. Most people use the adjustable head support and there is no clear connection between the adjustment of the head support and chosen back support gradient. The whole adjustment area for the head support is utilized and the different body height groups are spread out using the whole span. How the functions are used together is also spread out using the whole adjustment area and it is hard to identify a correlation between them. All the participants use at least one of the functions and most of them use both of them. There are more people who use only the back support articulation, even if only adjusted minimal. It is also displayed that for the short and the medium group, more people experience an improvement when using only the back support articulation than when using only the head support. When using the articulation, the group of short people gets support for the neck while the medium and tall group gets support for the upper part of the back. When adjusting both the parameters in part two, 12 out of 36 participant prefers to only use the back support articulation. This is also supported by how the parameters have been used, see Appendix G. When working in the car both the adjustable head support and the back support articulation contributes to a better position and better comfort but if needed to choose between the two functions, the back support articulation is seen as the better one. When adjusting the articulation in the back support, the head support follows the movement, thereby also getting a new position which could be why the back support articulation is preferred.

7.4 User test three –Validation

User test three was developed to validate the result from user test two. Furthermore it investigated if and how the aspect of performing a test in a dynamic environment affected the test result. The test was based upon the structure of user test two with the same procedure and layout. The difference between user test two and user test three was that user test three was performed in a moving vehicle with fewer participants representing a normal distribution of different body heights.

7.4.1 Planning of user test three

The goals of user test three were:

- To validate the result from user test two.
- To investigate if the result was affected by a dynamic test environment, e.g. a moving vehicle.

Most of the planning for user test three was based on user test two and thereby follows the same procedure in terms of setup and questions. In user test three only one car, the right hand drive XC90 with the prototype seat, was used to reduce the duration of each test. To reduce the duration even further the second part of user test two where one new parameter was tested at the time was removed. What was left was the first part of user test two where the TP's were asked to position the seat freely based on the given scenario. The scenarios tested in user test three were the same as for user test two: relaxing, reading or using a handheld device and working on a laptop. The interview form from user test three was similar to user test two and can be seen in Appendix H.

User test three were performed with participants representing potential customers with a body height normally distributed were the shortest woman was a 10^{th} percentile (~1580mm) and the tallest man was a 97^{th} percentile (~1925mm). The number of participants were thirteen people, where twelve is the number of participants needed for a good result according to Osvalder, et al., 2015. The duration of the test was planned to be around 40 minutes, where the scenario of reading or using handheld device was planned to be 10-15 minutes, the working scenario to 10-15 minutes and the relaxing scenario to 15-20 minutes. The test always started with either the scenario of reading using a handheld device or the working scenario and finished with the relaxing scenario. The fact that the relaxing scenario had a longer duration and was placed last in order was because it would let the TP's have time to unwind after doing the first two scenarios and get the possibility to enter a more relaxed mode.

Before the test started each TP was provided information about the test and how the data would be used, see Appendix I and Appendix J.

7.4.2 Test environment for user test three

The test was performed with the same prototype seat in the same vehicle as user test two, a right hand drive Volvo XC90. Unlike user test two, this test was a dynamic test performed on a closed test track at Volvo's test facility Hällered Proving Grounds. The track used represented a road similar to a country road and was used with a maximum spread limit of 60km/h. The car was driven by a driver sitting on the right hand side while TP's were seated on the left hand side.

7.4.3 Execution of user test three

In total, thirteen people participated in the test with a duration of approximately 40 minutes, where each TP tested three different scenarios: Relaxing, reading or using a handheld device and working on a laptop, see Figure 27 - Figure 32.

7.4.4 Result of user test three

The average scores in user test three are based on the total average from all three body height groups in user test two, which does not represent a normal distribution regarding body heights. The participants in user test three are chosen to represent a normal distribution regarding body height and their average score are compared to the average score in user test two with the aim of investigating if the average score correspond with each other or not. Graphs in this chapter also review data from user test two where all data is represented by grey dots. Red dots representing user test three are displayed together with the grey dots from user test two to see how well data in user test three correspond with a normal distribution and how well the data is spread over the data from user test two.

Relaxing

The difference between average scores for the prototype seat, with the prototype seat from the static user test two set as reference, are presented in Table 25. The difference is based on the scale of 1 to 10 scale used in all of the three user tests. For example, the category: "*Overall comfort and seating position -0.9*", means that the average score for the prototype seat in user test three decreased by 0.9 units compared to the standard seat in user test two. Further result is presented in Figure 61- Figure 65 where red dots represent the data from user test three and the grey dots represent data from all three body height groups in user test two; short, medium and tall.

Data gathered from user test three shown as red dots are spread over the graphs in a very similar way to the grey dots simulating user test two. For the average score, all categories have a difference less than one, except the category for head comfort and position, where the difference is negative by 1.3 points.

Table 25 Difference in average score for the relaxing scenario between prototype seat user test two (reference) and prototype seat user test three.

USER TEST THREE					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
-0.9	**-1.3**	**-0.7**	**-0.6**	**0.0**	**-0.9**

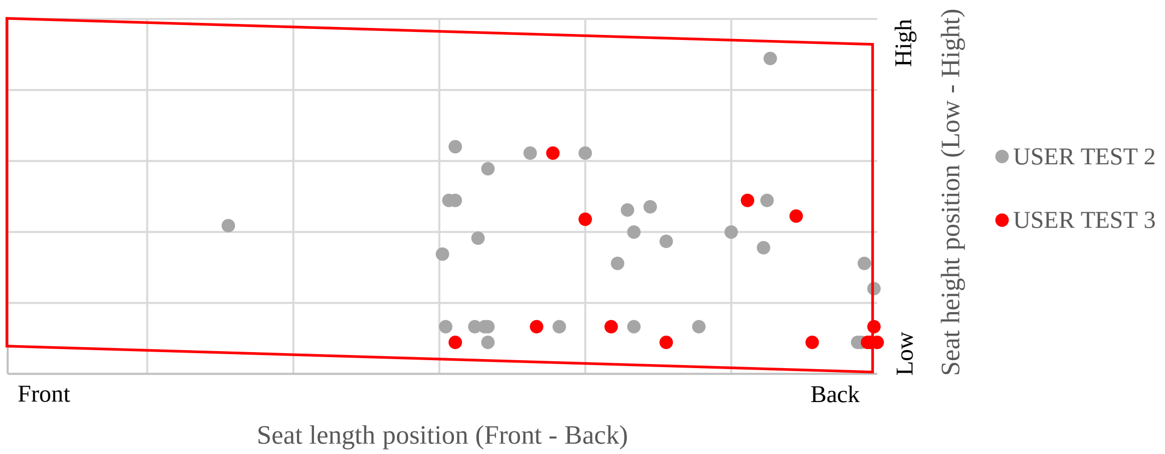


Figure 61 Seat length positon and seat height position for the relaxing scenario in user test three and the prototype seat.

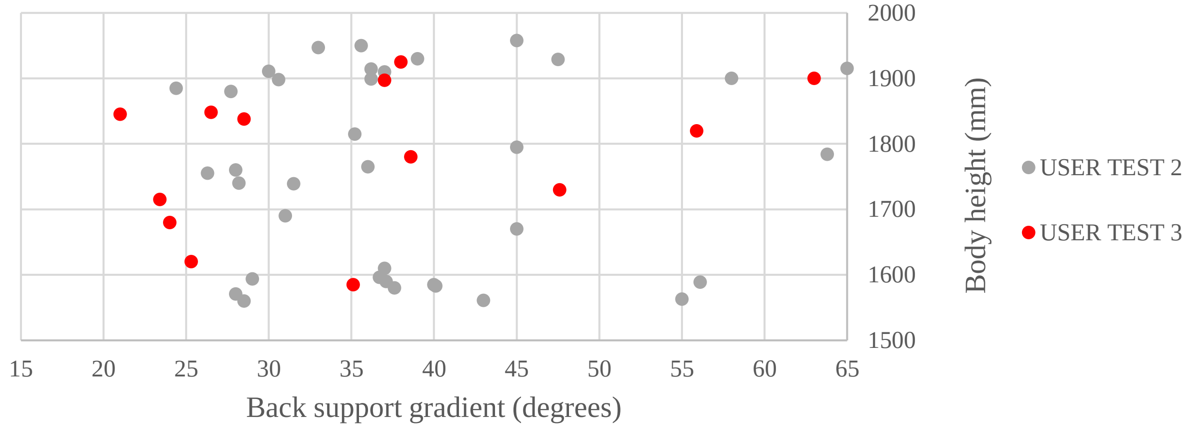


Figure 62 Back support gradient and body height of the test persons for the relaxing scenario in user test three and the prototype seat.

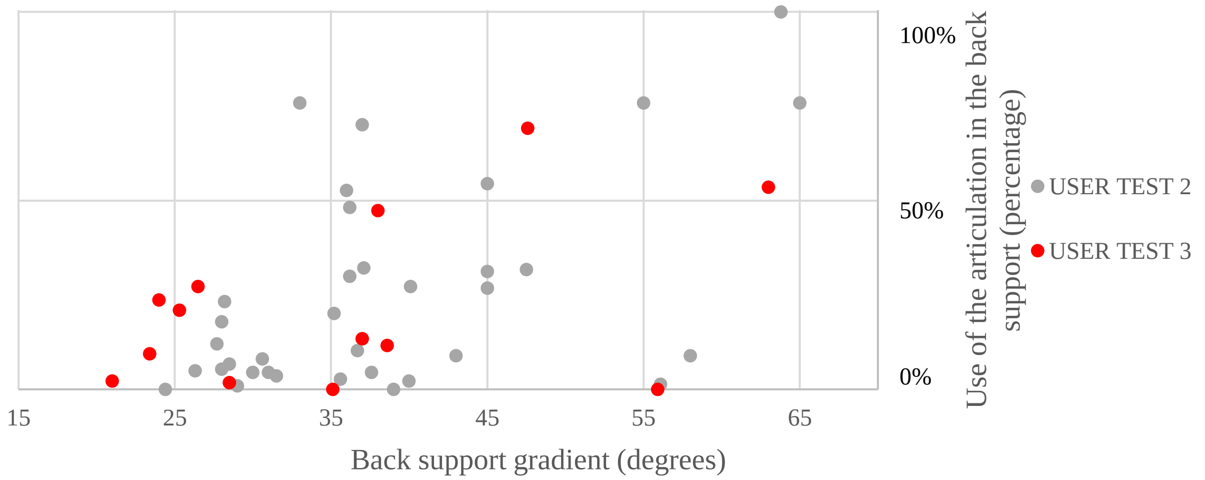


Figure 63 Back support gradient and the use of the articulation in the back support for the relaxing scenario in user test three and the prototype seat.

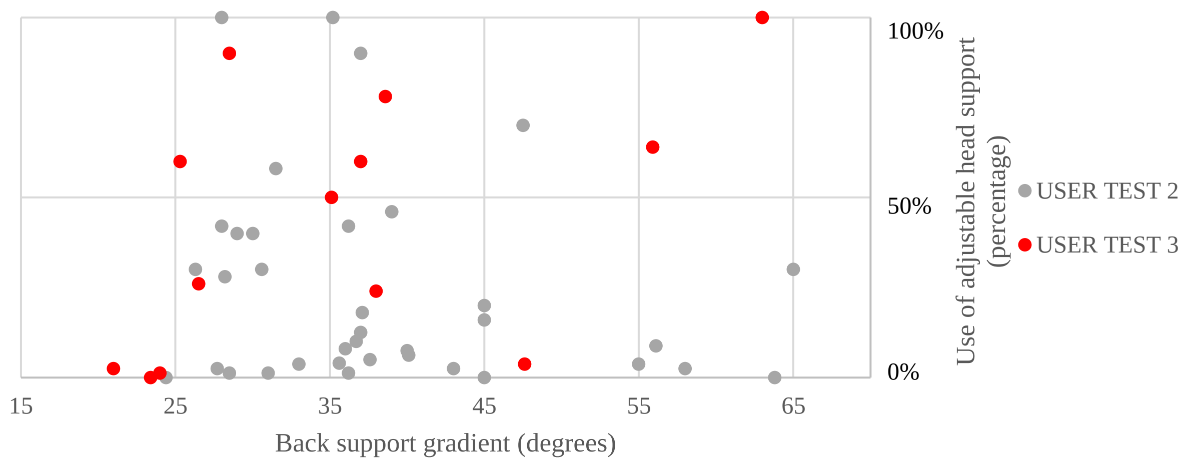


Figure 64 Back support gradient and the use of the adjustable head support for the relaxing scenario in user test three and the prototype seat.

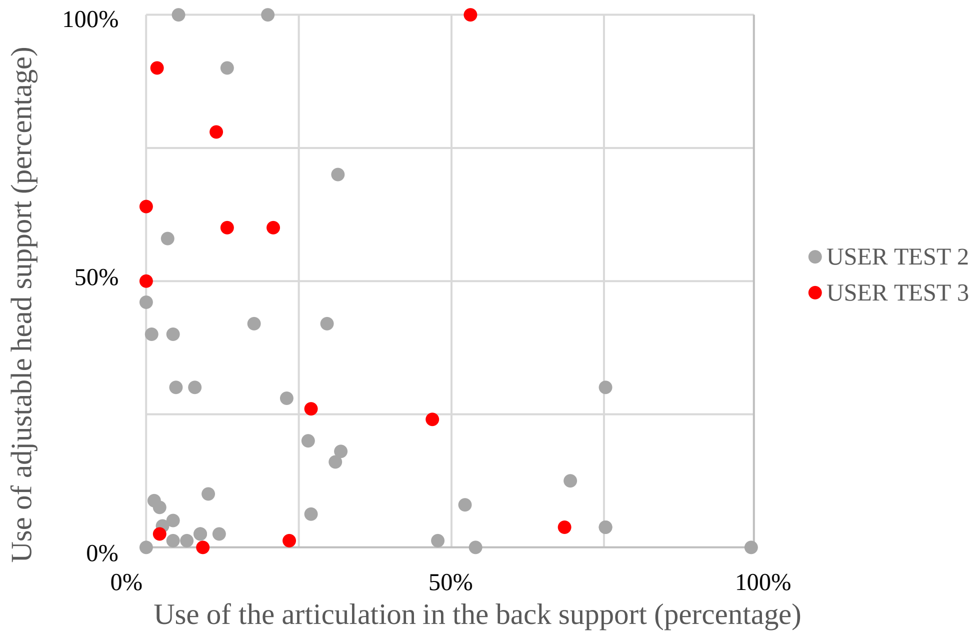


Figure 65 Use of the articulation in the back support and the use of the adjustable head support for the relaxing scenario in user test three and the prototype seat.

Comments from the validation have been categorised using a KJ analysis where the categories have been matched with categories from the interview form: head, back, seat cushion, legs and feet, arms and overall comments. The most frequently made comments are presented below.

Seven out of thirteen TP's want more support around the neck when relaxing. Five of them also want to have more support on the side of the head and five of the TP's thinks the head support is too hard. When relaxing, a more relaxed position is supported by the ability to use the arm supports according to six TP's. Seven of the participants thinks the arm supports are too narrow and five of the TP's thinks the arm supports are placed too high.

Reading using a handheld device

The difference between average scores for the prototype seat, with the prototype seat from the static user test two set as reference, are presented in Table 26. The difference is based on the scale of 1 to 10 scale used in all of the three user tests. For example, the category: "*Overall comfort and seating position -0.4*", means that the average score for the prototype seat in user test three decreased by 0.4 units compared to the standard seat in user test two. Further result is presented in Figure 66-Figure 70 where red dots represent the data from user test three and the grey dots represent data from all three body height groups in user test two; short, medium and tall.

The average score for categories regarding the reading scenario differs between -0.6 points to 0.4 points, with the biggest difference being for the arm comfort and position. The red dots representing data from user test three are spread evenly over the graphs together with the grey dots representing user test two. A notable difference can be seen in Figure 68, where the use of the articulation in the back support is under 50% for twelve out of thirteen TP's.

Table 26 Difference in average score for the reading scenario between prototype seat user test two (reference) and prototype seat user test three.

USER TEST THREE					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
-0.4	**-0.4**	**-0.5**	**0.4**	**0.4**	**-0.6**

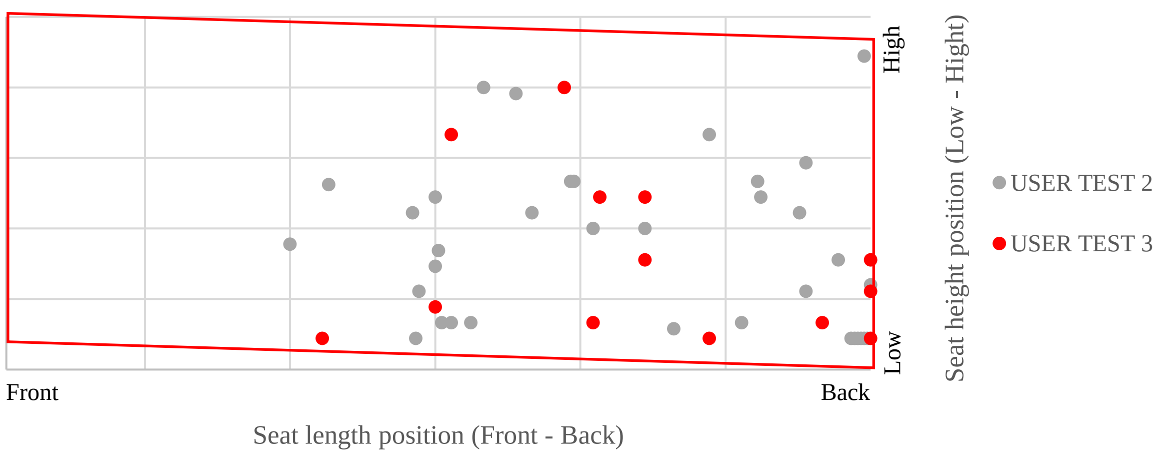


Figure 66 Seat length positon and seat height position for the reading scenario in user test three and the prototype seat.

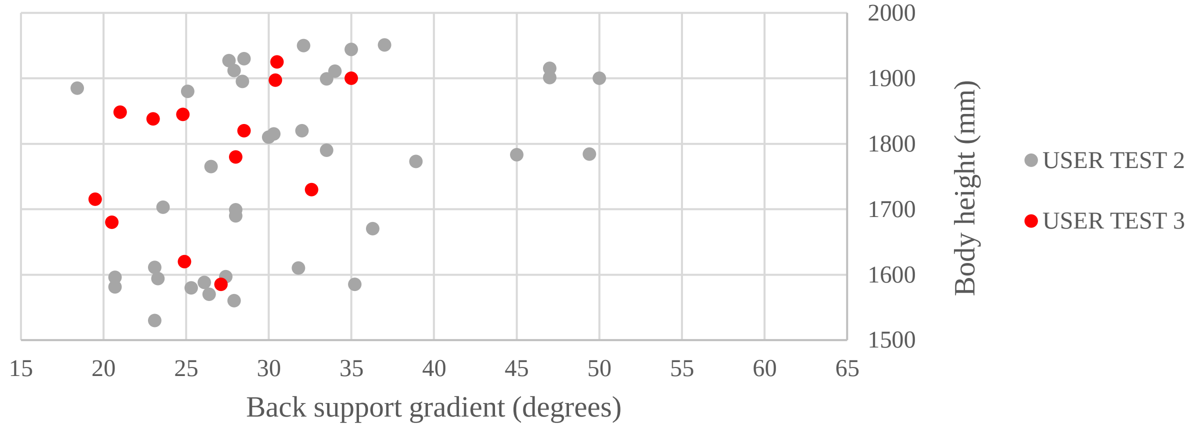


Figure 67 Back support gradient and body height of the test persons for the reading scenario in user test three and the prototype seat.

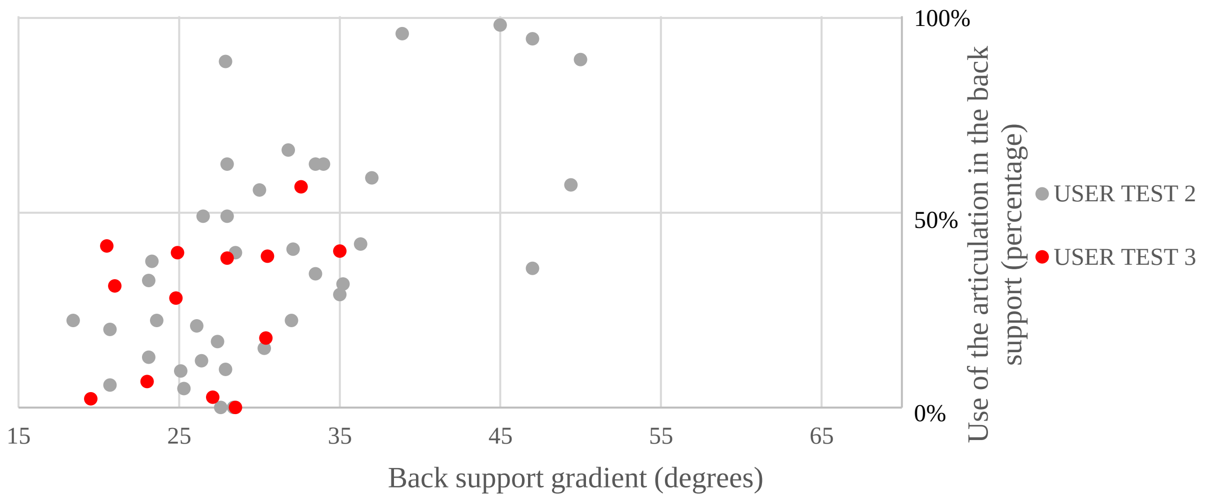


Figure 68 Back support gradient and the use of the articulation in the back support for the reading scenario in user test three and the prototype seat.

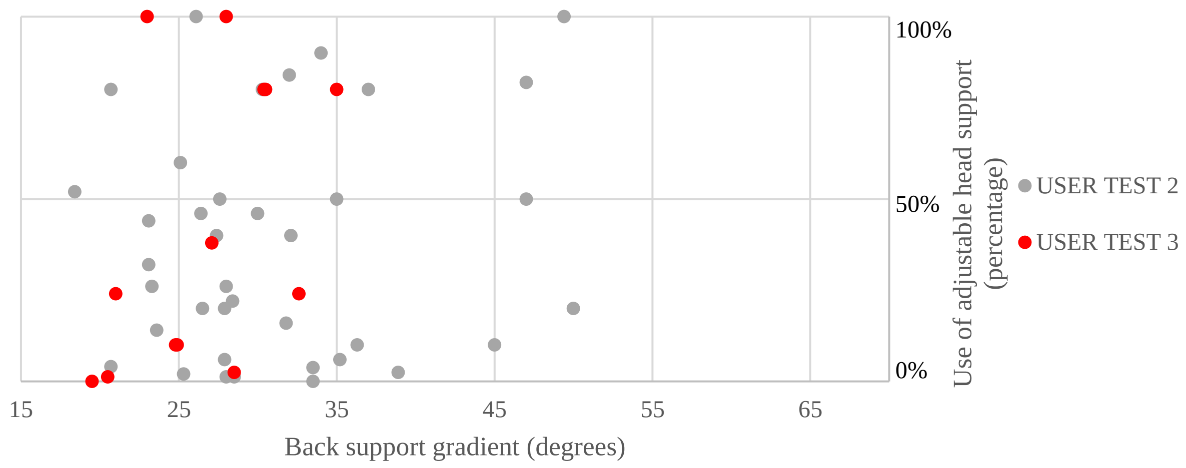


Figure 69 Back support gradient and the use of the adjustable head support for the reading scenario in user test three and the prototype seat.

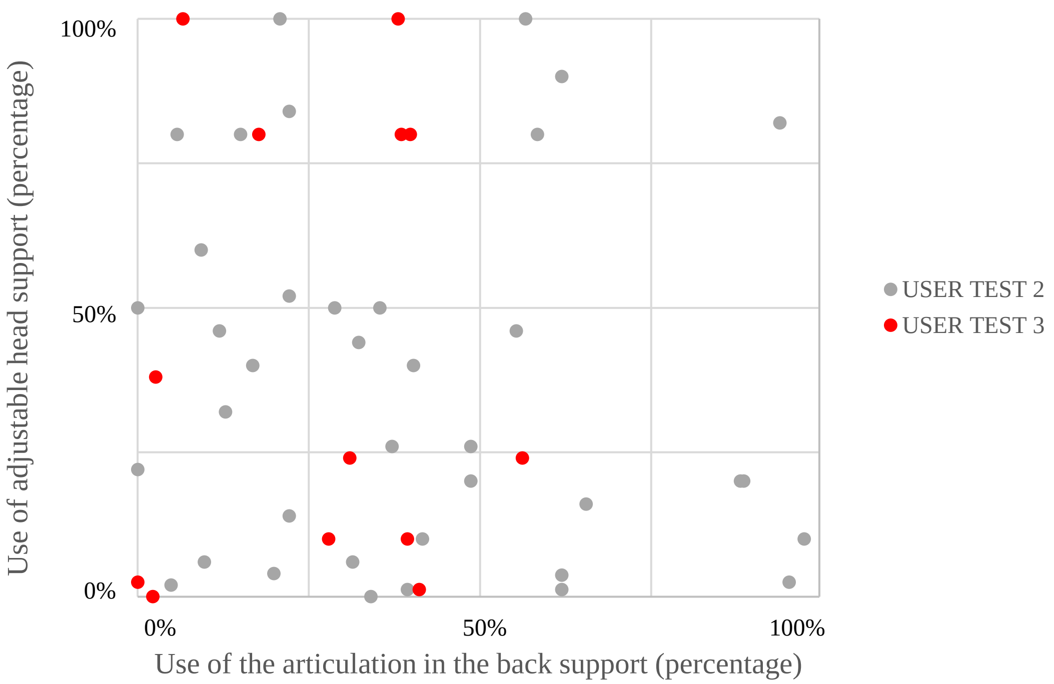


Figure 70 Use of the articulation in the back support and the use of the adjustable head support for the reading scenario in user test three and the prototype seat.

Comments from the validation have been categorised using a KJ analysis where the categories have been matched with categories from the interview form: head, back, seat cushion, legs and feet, arms and overall comments. The most frequently made comments are presented below.

When reading on a tablet in the car nine out of thirteen TP's lack a support for the tablet. Five of the participants wants to have the tablet placed higher up. Concerning the head, six of the thirteen TP's experience a good support for the head. Three TP's express that it is good to have adjustment possibilities for the head support. Furthermore, three TP's finds it annoying when having to look down to read on the tablet, thereby also having to position the neck in an uncomfortable position. Regarding the back four out of thirteen TP’s express that they have a good support for the back and four other TP’s gets a good support for the upper part of the back. Six out of the thirteen TP’s lack the lumbar support. When asked about the seat cushion, three TP’s thinks that the adjustment possibilities are good and three TP’s appreciates the seat extension. The softness of the seat cushion is also good according to three TP’s. Concerning the arms, seven TP’s gets a good support for the arms when reading using the tablet in the car. Five participants explains that the arm supports makes them more relaxed. For five TP’s the arm supports are too narrow.

Working on a laptop

The difference between average scores for the prototype seat, with the prototype seat from the static user test two set as reference, are presented in Table 27. The difference is based on the scale of 1 to 10 scale used in all of the three user tests. For example, the category: "*Overall comfort and seating position -0.3*", means that the average score for the prototype seat in user test three decreased by 0.3 units compared to the standard seat in user test two. Further result is presented in Figure 71- Figure 75 where red dots represent the data from user test three and the grey dots represent data from all three body height groups in user test two; short, medium and tall.

The average score for categories regarding the working scenario differs between -0.6 points to 0.1 points, with the biggest difference being for the leg and feet comfort and position. The red dots representing data from user test three are spread evenly in the graphs together with the grey dots from user test two. A notable difference can be seen in Figure 73, where the use of the articulation in the back support is under 50% for twelve out of thirteen TP's.

Table 27 Difference in average score for the working scenario between prototype seat user test two (reference) and prototype seat user test three.

USER TEST THREE					
Overall comfort and seating position	Head comfort and position	Back comfort and position	Seat cushion comfort and position	Leg and feet comfort and position	Arm comfort and position
-0.3	**0.1**	**-0.5**	**0.0**	**-0.6**	**0.0**

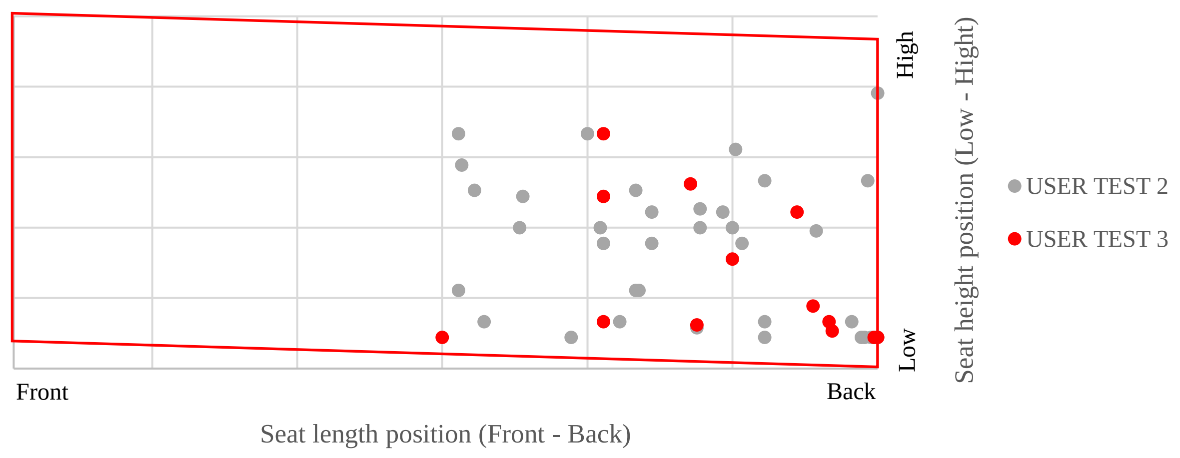


Figure 71 Seat length positon and seat height position for the working scenario in user test three and the prototype seat.

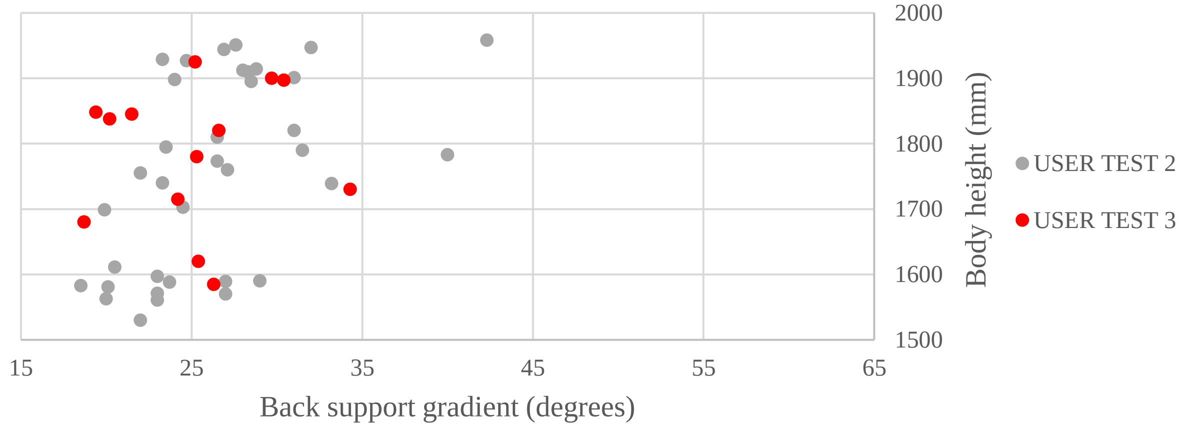


Figure 72 Back support gradient and body height of the test persons for the working scenario in user test three and the prototype seat.

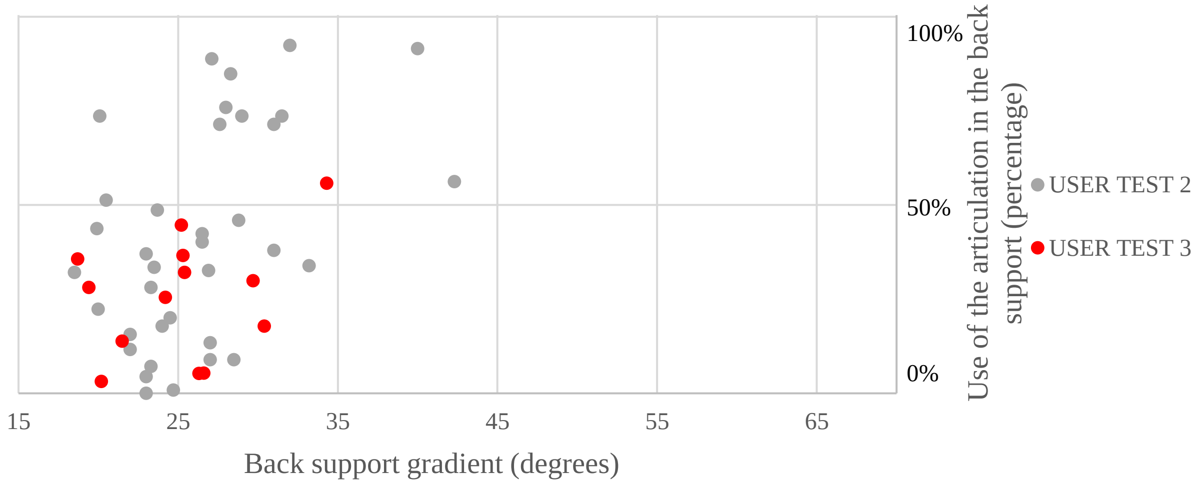


Figure 73 Back support gradient and the use of the articulation in the back support for the working scenario in user test three and the prototype seat.

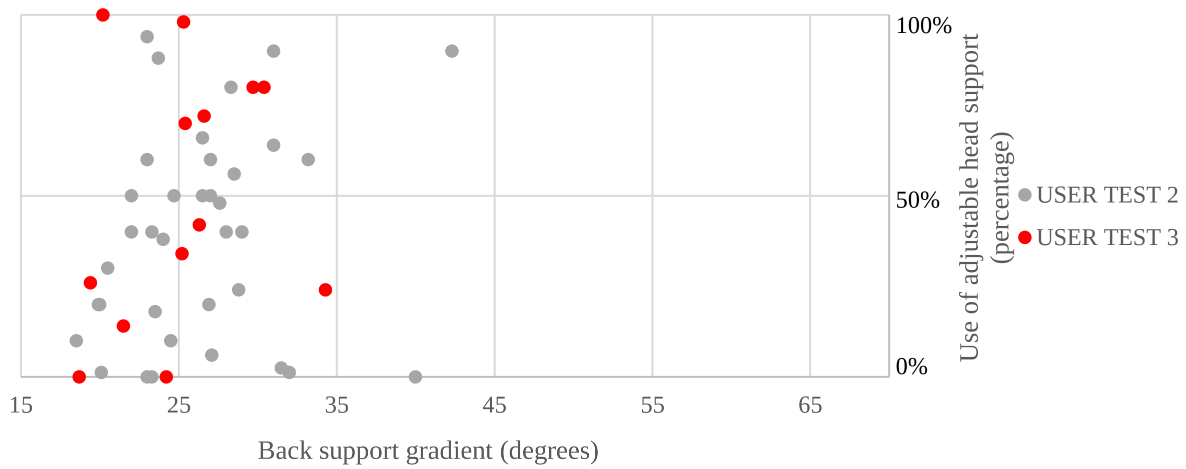


Figure 74 Back support gradient and the use of the adjustable head support for the working scenario in user test three and the prototype seat.

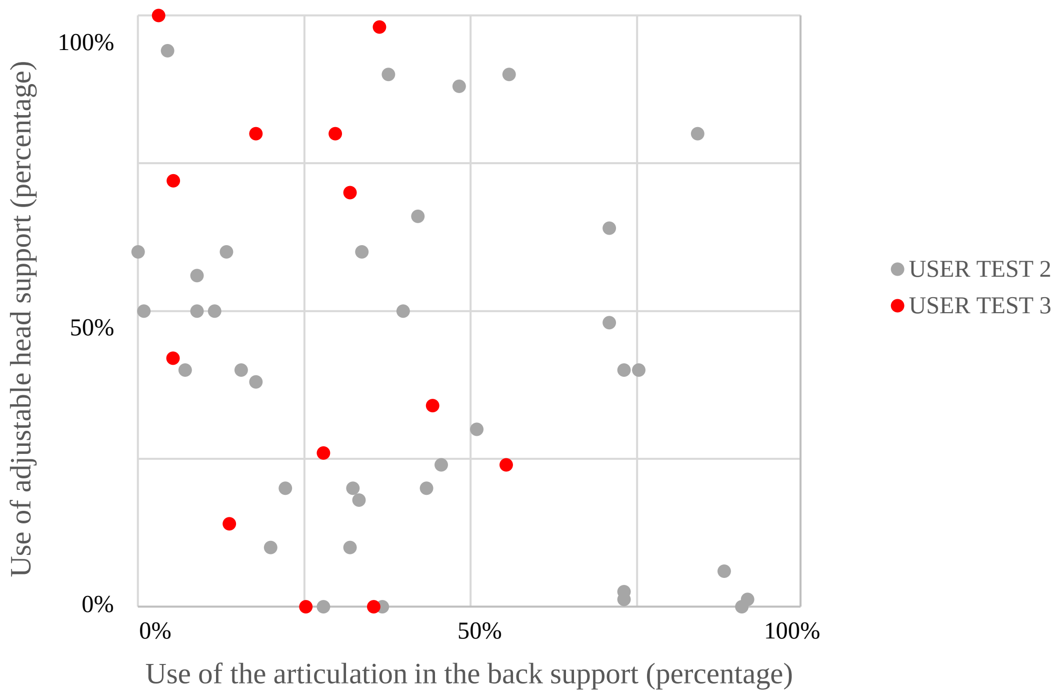


Figure 75 Use of the articulation in the back support and the use of the adjustable head support for the working scenario in user test three and the prototype seat.

Comments from the validation have been categorised using a KJ analysis where the categories have been matched with categories from the interview form: head, back, seat cushion, legs and feet, arms and overall comments. The most frequently made comments are presented below.

When working on the defined laptop support with a laptop, ten out of thirteen TP's are disturbed by the fact that they need to rotate the torso to be able to work and ten TP's would rather have the laptop placed straight in front of them. Furthermore four TP's thinks the steering wheel is in the way when using the laptop. Three TP's have a desire to see the road while working on the laptop. Regarding the head support three TP's finds it good to have adjustment possibilities. Concerning the back, seven of the thirteen TP's are affected negative because of the rotation of the torso. Furthermore, four of the TP's lack the lumbar support and four participants gets a good support for the back. For the seat cushion five TP's appreciates the adjustable seat extension. Furthermore the arm on the right side is in a good position for six TP's. A negative aspect for the position of the arms are that the left arm needs to be stretched towards the center of the car for six TP's. Moreover five TP's thinks the pedals are in the way.

7.4.5 Analysis of user test three

The analysis of user test three is presented for each of the three scenarios.

Relaxing

The change in average score for different areas or parts of the body compared with the average score from the prototype seat in user test two differs between 0 (leg and feet comfort) to negative 1.3 (head comfort and position), which can be seen in Table 25. The negative deviation of the head comfort and position indicates that the dynamic environment of a car in movement puts more stress to the head. Comments from the test indicates that, when driving, the head support is more often experienced as hard. Comments from this test are also confirms that people lack a support around the neck. The negative deviation of the arm comfort and position can also be connected to the dynamic environment where TP's express the design of the arm supports to be too narrow and slippery when the car is moving. Some categories have less or none deviation compared to user test two which implies that the result of user test two is not that affected by the fact that the test was performed in a static environment.

Graphs comparing the grey dots of user test two and the red dots of user test three shows a good distribution between the two tests, Figure 61- Figure 65. The even distribution of red dots indicates once more that result from user test two is not that affected by being performed in a static environment. It also support the normal distribution for participants in user test three. The only notable difference between the two tests are some people having a back support gradient more closely to 25 degrees or less in user test three, which can be seen in Figure 62. A more upright back support gradient relates to the desire of having a good vision of where the car is going on the road, which is previously stated.

Reading using a handheld device

The biggest deviation for the average scores for the reading scenario is for the arm comfort and position. This can be related to the fact that some TP's expressed the arm supports being too narrow and also slippery. These type of comments were not as frequent in user test two, and can be an effect of the test being dynamic, thereby involving vibrations and other movements. The other categories; leg and feet, seat cushion, back, head and overall differ from negative 0.5 to positive 0.4, see Table 26. This small deviation indicates that the test result is not effected or very little affected by the fact that the test was dynamic and that the group of people participating also represents a normal distribution in terms of body height. The normal distribution of people in test three is also shown in the graphs, Figure 66- Figure 70, where the red dots are spread evenly over the grey dots from user test two. The even distribution of red dots is also an indicating that the result from user test two is not affected by being performed in a static environment. One notable difference between test two and three is how the articulation in the back support is used. In the dynamic test, almost all participants use less than

50% of the adjustment possibility for the articulation in the back support whilst in the static test some users adjusts more than 50%.

In both test two and three there is a desire for having a support for the tablet when reading, where nine out of thirteen people expressed this in user test three. There is also a frequent desire for using the lumbar support in both user test two and user test three.

Working on a laptop

The average scores for the working scenario differs from negative 0.6 to positive 0.1, see Table 27, which is a small deviation from user test two. This indicates that the test is not that affected by the fact that the test was dynamic and that the group of people participating in the test represents a normal distribution in terms of body height. The small deviation from user test two is further presented in the graphs from the working scenario in user test three, Figure 71- Figure 75, where the red dots representing TP's from user test three are well spread over the results from user test two. The graphs together with the average scores indicates that the test result from user test two representative even though the test were static and have thereby be validated. There is one exception to the even distribution when comparing test two and three concerning the articulation in the back support. In the static test more participants adjusts the back support articulation further forward than in the dynamic test, where most people use less than 50% of the adjustment possibility.

Comments from user test three correspond with comments from user test two, where negative comments about the torso rotation needed when using the laptop on the laptop support are the most frequent. Furthermore TP's express the wish for having the laptop straight in front of them, something frequently mentioned in user test two as well. Regarding the arm comfort and position, comments from user test three confirms a positive support for the right arm when using the laptop but also the lack of support for the left arm in the very same position.

7.5 Comparison of scenarios

When comparing the different scenarios, there are both similarities and differences. There are more similarities between the two scenarios relaxing and reading using a handheld device than with the scenario of working on a laptop. In relation to how people position the seat in different scenarios, there are most significant differences between the relaxing scenario and the working scenario, where the reading scenario places somewhere in between. This can be seen when comparing the figures presented in the result chapter of user test two and three. Furthermore the result from the static user test, user test two, is validated by the dynamic user test, user test three, where the result from both tests turns out to be similar in all of the scenarios. The only exception is for the head comfort and position in the relaxing scenario during user test three, where the average score was 1.3 units lower compared to the same category and score in user test two. The close relation between results from the two user tests also validate that there is no big difference of how the seat is positioned when the car is moving compared to a static test. One exception to this is how the articulation in the back support are positioned in the reading and working scenario. In the dynamic test almost all participants use less than 50% of the adjustment possibility for the articulation in the back support whilst in the static test some participants use more adjustment forward.

The overall comfort and position have been improved for three scenarios. The average improvement is bigger for the scenarios of relaxing and reading than for the working scenario.

The slightly smaller improvement concerning the working scenario could be connected to the rotation needed in order to use the defined laptop support. Comments from the working scenario displays that the rotation is perceived as annoying, which supports the argument. Regarding the head, the back and the arms, an improvement of comfort and position can be seen for the relaxing and reading scenario. For the working scenario, the arm comfort and position did not improve, where comments from both user test two and user test three indicate that, due to the rotation, the arm support for the left arm is not enough and too far away. In categories where no physical changes have been made to the seat, seat cushion and legs and feet, the average score is similar in all three scenarios, which indicate that the new parameters do not affect others parts of the seat or the body.

In all three scenarios, TP’s position the seat in the rear part of the adjustment area for the seat length and seat height adjustment. Another similarity is the use of seat extension, where tall TP’s use the whole length of the extension in all three scenarios and wants to have an even further adjustable length. Other TP’s use the whole span of the seat extension adjustment, but does not use the maximum length as frequent as tall TP’s.

The back support gradient differs for the scenarios, where in the relaxing scenario a large back support gradient is used leaning backwards, and where in the working scenario the back support gradient is positioned more upright. The back support gradient for the reading scenario generally places between the two other scenarios. Furthermore the span for used back support gradient in the relaxing scenario is similar for all three body height groups, whilst for the working and reading scenario short participants tend to have a smaller back support gradient. Common for all three scenarios is that a larger back gradient is generally used in the prototype seat. When comparing the use of the back support articulation, the working scenario is related to having a the back support articulation adjusted more forward than for the relaxing scenario, with the reading scenario placing approximately in between the two. This could also be connected to the back support gradient, where a more upright back support gradient is related to a bigger adjustment of the back support articulation. In all scenarios, short people use less adjustment of the back support articulation than the other groups.

When adjusting the head support, there are more people adjusting the head support further forward in the working scenario and the reading scenario than in the relaxing scenario. Most people use the adjustable head support, but there are more people in the relaxing scenario that does not use the function at all. When comparing the relation between the head support and the back support articulation, people often adjusts both of the functions, but few participants use a combination of the functions where both functions utilizes a large part of their adjustment area. There is also a difference of how much of each function TP’s use in each scenario, where more adjustments are made in the working scenario and the reading scenario compared to the relaxing scenario. Additionally, most people in all three scenarios experience an improvement when being able to adjust both the adjustable head support and the back support articulation. A similarity between all three scenarios is that more people express an improvement when using only the back support articulation, compared to when only using the adjustable head support. Furthermore, it is preferable to be able to adjust both functions in all three scenarios, but if having too choose one of the two, the back support articulation is the one most preferred. Regarding the arm supports there are more people that experience an improvement for the relaxing scenario and the reading scenario, whilst for the working scenario the arm support cannot be used and therefore do not contribute to a better position and better comfort.

In both the reading scenario and the relaxing scenario, the adjustable head support contributes to a better support for the head. More support around the neck is desired by all three body height groups in the relaxing scenario and by short participants in the reading scenario. Furthermore the head support is positioned too high for short participants in both of these scenarios and it is also positioned too far ahead in the relaxing scenario. In the working and reading scenario, where less back support gradient is used, the head support is positioned too far down for tall TP’s. In all the three scenarios participants gets support for the upper part of the back. Furthermore in the relaxing and the reading scenario more support for the whole back is provided, but also the lack of lumbar support is noticeable. Regarding the arms the arm supports provides support for both arms in the relaxing and the reading scenario, but in the working scenario the left do not get any support whilst the right arm is supported by the laptop support. Both when relaxing and reading the arm supports are positioned too far apart for short participants and too high on the right side for tall participants, since the tunnel limits the height adjustment. For the dynamic test when the car is moving, the arm supports are also too narrow, both when relaxing and when reading in the car. The seat cushion provides good support in the relaxing and the reading scenario, but in all three scenarios there is a desire to have a longer seat extension. Another similarity between all scenarios is that the pedals obstruct the position of the feet for tall people. Short participants on the other hand have a desire for a leg or a foot support in terms of the relaxing and the reading scenario.

7.6 Discussion of phase three

According to Hägg, et al., (2015) comfort can change over time and instantaneous comfort is not excluding the feeling of discomfort after a longer time. When testing the different scenarios in all of the three user tests, the time spent in each of them where limited. The result is therefore tested on initial comfort and conclusions regarding long time comfort can therefore not be made with the results from these tests.

Furthermore, when evaluating the different scenarios and types of prototypes the order in which they are evaluated can affect the result. If one position is perceived as bad and discomfortable the next one might feel better since it is leading to a relief from the previous position and this could influence the result. Since the scenarios is altered in the user tests it is seen as a small influence on the result in these cases.

The preference of improvement of the seat is based on subjective data from the TP’s. According to Osvalder, et al., (2015) it is hard to quantify subjective data regarding comfort and it is hard to draw conclusions for the whole populations based on subjective data. Although, Osvalder et al., (2015) state that when combining objective data with the subject evaluation it is possible to get a better understanding of the situation. Observations and chosen seating position is providing information regarding most of the improvements, for example that the head support is too high for short people when relaxing can be seen in observations. Others is harder to verify with objective data, for example the need of a lumbar support since this is built into the seat. Therefor the results for improvements is seen as indications on improvements but since not all of them can be linked to objective data some needs further evaluations.

In test two and three both the original XC90 seat and the prototype seat were measured by hand using a ruler and a digital electronic angle finder to determine the seating position of the TP’s. This may have resulted in a small margin of error in the exact seating position. Although all of the measurements have been measured in the same way so the comparison between different seating positions, results and scenarios is more accurate. Since this study is focusing more on general positioning in different scenarios this is not seen as necessary to have a more specific result regarding seating position.

7.6.1 User test one

As stated earlier the seat in this test was placed in a predefined position thereby making it possible to isolate and evaluate one parameter at a time since only one parameter is changed. Since the test persons were not able to choose position this might not have been how they should have placed the seat if they had a choice which may have had impact on the result. The comparison between the different types of prototypes on the other hand is seen as result since this has impacted in the same way in all the tests.

Furthermore this was a static test and the result has not been validated in a dynamic test environment. When driving there is more movement and vibrations and this could have influenced how people in the test evaluated the parameters.

Since many TP's were not able to use the leg support, the number of people actually testing it was low. This result is therefore seen as indications that this type of support needs to be further evaluated. The prototypes for the foot support and leg support was not able to be adjusted which is making the measurements of the TP's a big influence on the result. Furthermore the fixed location for the leg support also influenced the possibility to evaluate the leg support. Since the result of the leg support and foot support in both of the tests was quite similar, further testing is needed to determine which one that is preferred in the different scenarios. An evaluation to see if these parameters are adding value in the different scenarios is also needed. To evaluate this, the parameters need to be adjustable in order to fit different test persons.

7.6.2 User test two

Due the fact that user test two were static and not dynamic, meaning that the cars used for the test were standing still, may have affected the behaviour of the TP's during the scenarios and thereby also the result. The static test setup may also have affected the TP's ability to embark on different scenarios that are supposed to take place in a dynamic environment. A dynamic environment would also imply vibrations and other aspects such as sight and the desire to see the road when travelling in a car.

The results in part two of the test could be affected by the previous seat position. The predefine position was chosen by the TP but when choosing this position the new parameters was not available. The possibility to adjust more parameters may affected the adjustment to other parts of the seat.

When evaluating comfort it is influenced by the persons own expectation and emotions (De Looze, et al., 2003). It was noticed that some test persons after a while lost focus, since the test was long. This could therefore have affected the result in the second part of the test.

Even if the trust part in AD is not evaluated in this study it could still have influenced the result of the test. The chosen positions in the seats could have been affected by the need to still feel in control of the car. Even if each TP got the explanation of not needed to have control over the vehicle during the AD scenarios, some TP's still explained that it was important to be able to reach the pedals and the steering wheel.

The design of the head supports is different in the two seats, in the standard seat the head support is flat while in the prototype seat the head support has small elevated supports on the sides. The result regarding comparison between the seats is therefore influenced by both design and possibility to adjust the head support.

When evaluation the working scenario the design and position of the laptop support have influenced the result. The rotation which is needed to work on the laptop support affected the whole position when working, meaning that the result in the test only can be related to working on the specific laptop support and not working generally in the car. Therefore another placement for the laptop support might lead to that the new parameters in the seat affects people in a different way.

A pilot study was conducted to evaluate the layout of the test. This displayed that the testing time was too long and which lead to the fact that the previous tested leg support and foot support was chosen not to be taken into consideration in the test. This since the test environment is too narrow for the leg and foot support to be used by all the test persons. To get a better understanding if leg and foot support can contribute to a better comfort and position it would be good if they were adjustable and tested in an environment with more space. This could not be tested in this study due to the timeframe.

7.6.3 User test three

The result of the dynamic test was influenced by the test track on which the test was took place. The road had several turns creating increased movement for the TP's in the car where the extra movement might have influenced the test. For the very first fully autonomous cars, the roads are likely to be less curvy which will mean less movement of the car and a more stable seating position.

When performing the test, the driver were visible for the TP's during the entire test, making the environment less credible in terms of autonomous driving. This aspect can also affect how much trust people tend to have for the vehicle, where it is believed to be easier to trust a human driver than a car driving itself. Since this study do not investigate the trust part of autonomous drive, instead using a potential future where people already fully trust the car, it was seen as a benefit that people was able to see the driver throughout the test. To understand how the trust part effect the seating position is something that needs to be investigated in further studies.

Most of the result from user test two has been validated with the dynamic test with some exceptions. The average score regarding comfort and position for the head when relaxing is lower in the dynamic test. This could be due to the face that the head moves around more when the car is moving. Although the score regarding comfort and position differs between the tests, the same comments regarding support for the neck and support on the side of the head support are identified. This indicates that the same issues with the head support is identified in both tests. Furthermore it is validated that the head support is being used when relaxing and how it is being used. Regarding the articulation in the back support the result presents that the parameter is contributing to comfort and a better position and this is validated in user test three. Moreover it has been validated that the parameters are being used in all of the scenarios. The aspect of how the articulation is used in the reading and working scenarios needs to be further evaluated to validate the result in the static test.

7.7 Conclusions of phase three

The new parameters are being used in all the different scenarios. However, the use of the new functions differs between the scenarios. The position for seat length and seat height are similar in all scenarios but the back support gradient is more unique and connected to each specific scenario and activity. The use of the head support and the articulation in the back support are unique in each different scenario and activity. The head support, articulation in the back support and the arm supports contributes to a better overall comfort and a better position in all the investigated scenarios, most value is added in the scenarios of relaxing and reading. Parts of the body where the comfort and position improves are head, back and arms when relaxing or reading on a tablet in the car. When working there is an improvement in comfort and position for the head and the back. Furthermore there are indications of that a leg or foot support could be a possible addition to already added parameters when relaxing and reading.

8 DISCUSSION

The following chapter presents discussion of the result as well as discussion of the methods used in each phase of the project.

8.1 Discussion of result

The fact that all people participating in all three of the user tests were Volvo Cars employees, may have an effect on the outcome depending on how familiar the participants were with the subject and what relation the participants had with the department responsible for the thesis. Having Volvo employees as participants was also positive in the aspect of having a relevant user to match the target group for the subject. As stated by Osvalder, et al., (2015), the user is supposed to match the chosen target group set for the product in the best way possible, which supports Volvo Cars employees participating in the user tests.

The result and process have also been affected by the availability of test objects. The given test object, a Volvo XC90, had an original interior affecting the space available in the car. Future AD cars are likely to involve a completely different interior and interior space, which also could influence how people experience the tested activities. The result of the thesis is therefor to be seen as a result of how people experience different AD scenarios and activities in a car of today, but is a good starting point for the development of seats in future AD vehicles.

The use of prototypes and mock-ups, as supported by Wikberg Nilsson et al., (2015), allowed different ideas to be tested in an effective and easy way, although the quality of the prototypes varied through the project. The quality and effort put in to making a prototype most likely affected the perceived experience when finally tested and thereby also affected the result. As Wikberg Nilsson et al., argue, the use of mock-ups is a good tool for understanding the human interaction with a future product, but is very dependent of how well-made the prototype actually is. A prototype of certain quality sets a certain condition for the test.

The result from this study has amplified and confirmed findings from literature regarding the aspect of which parameters are found to be important in the seat when performing different activities. Furthermore it has also been amplified and confirmed that chosen position and how the seat is used are differing dependent on activity. Different activities performed when traveling are also identified and combined into different scenarios in the thesis. These activities and scenarios however can not be confirmed by the results of the study as the found parameters and the chosen positions. To see if the scenarios formed from the literature study is applicable for the future, further investigations of the subject is needed.

8.2 Discussion of method

8.2.1 Introduction and phase one

The literature study provided a lot of useful information which laid the foundation for the created scenarios in phase one. Attempts of recreating or evaluating any of the scenarios were not made before moving on to the next phase of the project, which means that all scenarios are strictly based on findings from literature. The use of scenarios is according to Lindgren (2003), an effective planning tool, but also as Foster (1993) defines it "A description of a 'possible future'", which entails what also could be a negative aspect of the method. The fact that Foster (1993) defines it as a 'possible future' puts pressure on the test subjects ability to imagine the actual scenario, in which the result will be affected by.

Semi-structured interviews with experts within the field gave useful information early on in the project, but was only made with three persons. Osvalder, et al. (2015) explains the method as series of questions with some pre-defined as well as open questions with the possibility to ask follow-up questions. The layout for the expert interviews in this project had mostly open questions which provided a very broad answer and result, something that could have been developed further with more interviews later on in the project with questions targeting a more specific area or detail.

8.2.2 Phase two and three

User tests of phase two had a large number of participants and turned out to be very time consuming, which is also stated in literature by Osvalder, et al., (2015). Utilisation of user test as a method were very effective in terms of the amount of gathered data, but it could also have benefited from being supplemented by other methods which for example could have meant saving time by doing methods that is less time consuming. The large number of participants in user test two was a choice made to enable the possibility to test three scenarios, where each TP tested two scenarios to keep the duration of the test as short as possible. To get twelve people to do each scenario, a figure supported by Osvalder, et al., (2015) for comparing two test groups, a total number of fifty four participants were needed, something that was very time consuming but also exhausting.

To get as many perspectives as possible from the user tests, subjective data was supplemented with objective data, an approach supported in literature by Hennik, et al., (2015), Osvalder, et al., (2015) and Wikberg Nilsson, et al.,(2015). By supplementing the two approaches for data gathering with each other, a result found by subjective data methods could easily be evaluated and compared with corresponding data found by objective data methods and the other way around. The use of subjective data such as comments contributed to another time consuming stage when compiling the data. Comments were sorted and analysed using the KJ method, an effective method for sorting large amounts of data according to Wikberg Nilsson, et al., (2015), though the method was conducted by only one person and thereby influenced by that persons own thoughts and ability when sorting the comments.

According to Helander (2003), it is important when measuring comfort and discomfort to ask different questions depending on what is being evaluated. The interview forms used in the user tests had open questions regarding what was perceived as good or bad after each evaluated position, which did not highlight any specific topic of comfort or discomfort. By not targeting a specific topic, compiling the open comments turned out to be time-consuming, but allowed the duration of each test to be reduced since more specific questions regarding comfort or discomfort would have meant more questions after each evaluated seating positon.

As supported by Ulrich & Eppinger (2012), the use of benchmarking as a method was useful for investigating competitors and getting inspiration, though the benchmarking was mainly performed digitally, searching through for example websites or articles. Only one competitor was investigated on-site. A benchmarking containing more hands-on experience from competitors or concepts related to the subject of the project could have made the method even more useful in terms of inspiration and development.

9 FINDINGS AND RECOMMENDATIONS

This chapter presents findings for chosen seating position as well as what parameters contributes to better comfort and a better position. Furthermore the hypotheses used in the study will be answered and recommendations for design of a seat for autonomous driving are presented.

9.1 Hypotheses and what contributes to comfort in defined AD scenarios

When adding new functions in the seat the comfort and position will be improved when performing activities in the car. Articulation in the back support, adjustable head support and adjustable arm support are contributing to increased comfort and the ability to find a good position when relaxing, reading on a tablet and working on a laptop on the laptop support placed on the center console compared to the standard seat. Furthermore the comfort and position for the head, the back and the arms when relaxing and reading in the car are improved when having new functions integrated in the seat. Moreover the head and back support is improving the comfort and position when working on a laptop on the laptop support placed on the center console. The comfort and position for the arms is not improved in this scenario since the arm support cannot be used due to the rotation in the body. The rotation in the body is necessary to be able to work on the laptop support and it is creating an unwanted position when working. This contributing to lower improvements of comfort and position in the working scenario.

9.1.1 Hypotheses result

The hypotheses used in the study will be answered for each of the scenarios investigated in the test. The two scenarios who have not been evaluated is seen as future work and what is needed in order to answer this hypotheses is presented in the chapter *10. Conclusion*.

Relaxing

When the car is in AD mode and the driver wants to relax, the back support gradient will be increased. Furthermore support of the whole back will contribute to increased comfort. There is also a desire to have a supported head. Additionally arm supports will increase the level of comfort when relaxing. In increased comfort will also be achieved by providing foot support.

When the car is in AD mode and the driver wants to relax the back support gradient is increased. Furthermore the articulation is contributing to support of the whole back and is contributing to increased comfort. There is a desire to have a supported head which is fulfilled through the adjustable head support and the articulation in the back support. Additionally arm support is increasing the level of comfort when relaxing. The study is indicating that there is a desire for a foot support but further investigation is needed to evaluate of it is contributing to comfort when relaxing.

Reading or using a handheld device

When the car is in AD mode and the driver wants to read a book or use a smaller handheld electronic device, it is desirable to have arm supports. Furthermore, foot support will increase the level of comfort in the performed activity. A head support that enables support for the head in different positions will also increase the level of comfort. Moreover support of the whole back will also contribute to improved comfort when using a handheld device.

When the car is in AD mode and the driver wants to read on a tablet arm support is a desirable parameter that is contributing to better comfort and a better position. An adjustable head support and an articulation in the back support enables support for the head and is increasing the level of comfort. Moreover support of the whole back provided by an articulation in the back support is also contributing to improved comfort when using a handheld device. The study is indicating that there is a desire for a foot support but further investigation is needed to evaluate of it is contributing to comfort when reading.

Working on laptop

When the car is in AD mode and the driver wants to work on a laptop using a laptop support placed in the car, the level of comfort will be increased by the ability to use an arm support. Furthermore support of the whole back adds additional comfort when performing the activity. A head support in different positions will also improve comfort when working on a laptop.

When the car is in AD mode and the driver wants to work on a laptop on the laptop support in placed on the centre console the level of comfort is not increased by the arm support since they cannot be used. Furthermore support of the whole back provided by an articulation in the back is adding more comfort when performing the activity. A head support in different positions is improving the comfort when working on a laptop on laptop support in placed on the centre console.

9.2 Chosen position in scenarios for autonomous cars

The chosen position is dependent on what activity the user performs when traveling in the autonomous car. The following section presents trends regarding the seating position for defined scenarios.

Relaxing

When relaxing in the car the following trends have been identified:

- People of different body heights sits far back in the adjustment area for seat length and seat height.
- People of different body heights use a large back support gradient (backwards).
- The seat extension is used by all three body height groups, where tall and medium people use the entire adjustment area, often with as much extension as possible.
- People of different body heights use a small part of the adjustment possibilities for the adjustable head support and the articulation in the back support.
- When adjustment is made to either the adjustable head support or the back support articulation, there is less or none adjustment made to the other function.

Reading

When reading using a handheld device in the car, the following trends have been identified:

- People of different body heights sits far back in the adjustment area for seat length and seat height.
- People of different body heights use an increased back support gradient (backwards).
- The seat extension is used by all three body height groups, where tall and medium people use the entire adjustment area, often with as much extension as possible.
- The group of short people use a small part of the adjustment possibilities for the adjustable head support and the articulation in the back support. The two groups of medium and tall people use a bigger span for the adjustment possibilities for the adjustable head support and the articulation in the back support.
- When more than 50% of the adjustment possibility of either the articulation in the back support or the adjustable head support is made, the other function is used less or not at all.

Working on laptop

When working using a laptop placed on a laptop support positioned on the center console, the following trends have been identified:

- People of different body heights sits far back in the adjustment area for seat length and seat height.
- People of different body heights use an upright back support gradient.
- The seat extension is used by all three body height groups, where tall and medium people use the entire adjustment area, often with as much extension as possible.
- People with tall and medium body height is spread out on the whole adjustment span in for both parameters. The same is seen for people with short body height regarding the head support.
- The group of short people use a small part of the adjustment possibility for the articulation in the back support. The two groups of medium and tall people use a bigger span of the adjustment area for both the adjustments adjustable head support and back support articulation.
- A rotation of the torso is needed to work using the laptop support placed on the center console of a car. The rotation affects the head, the back and the left arm.

9.3 Recommendations for future design of seats in autonomous cars

Using today's seat as a reference, modifications to the seat are needed to add value for potential customers when traveling in an autonomous car. To increase customer value, the seat needs to have additional adjustment possibilities to enable more adjustments for the individual user. The following section presents recommendations for future design of seats in autonomous cars.

Additional space for legs and feet

More space for the legs and feet is recommended when traveling in AD mode. This could be achieved by having the adjustment area for seat length and seat height to be moved backwards in the car. It could also be achieved by creating more space in front of the driver or under the instrument panel.

Larger adjustment area for the seat extension

A longer seat extension is recommended to provide better support for the thighs and buttocks when performing activities other than driving in an autonomous car.

Articulation in the back support

An integrated articulation in the back support is recommended to improve the possibility for adjusting the back support more individually and provide a better support for the back of the user.

Adjustable head support

An adjustable head support is recommended to support a more individual placement. The head support should be adjustable both vertically and horizontal, and be able to move forward, backwards, up and down. Furthermore the head support should provide support under the neck when the user relaxes. The head support should also have elevated side supports, allowing the user to lean against them.

Integrated arm supports

Arm supports integrated in the seat are recommended in a seat for autonomous driving. The arm supports should be adjustable in height and furthermore it is important that both arm supports are positioned in the same height. The position of the arm supports also need to be able to be adjusted closer or further away from the torso, and the arm supports is recommended to be wider than 50 mm.

10 CONCLUSIONS

The following chapter presents conclusions for the project by answering research questions stated in the first chapter, Introduction.

RQ1. *What critical parameters affect seating comfort and position when traveling in AD mode?*

Critical parameters differs dependent on the activity performed when traveling in AD mode. For the activities and scenarios evaluated in this study; relaxing, reading or using a handled device and working on a laptop, the following parameters have been identified as important when traveling in AD: back support, head support, arm support and support area (table).

RQ2. *How can integration of new parameters in the seat affect the ability to find a good position and increase comfort compared with today's seat when traveling in AD mode?*

By integrating new parameters in the seat, such as articulation in the back support, adjustable head support and adjustable arm supports, the possibility of finding a good position improves, which results in an overall increased comfort experience compared to the seat of today.

RQ3. *How should different comfort support systems for the driver's seat be designed to add customer value when traveling in AD mode?*

In addition to parameters in the seat of today, new functions such as articulation in the back, adjustable head support and adjustable arm supports should be integrated in the seat to increase customer value. Among the new functions is an articulation in the back support the most favourable, even if it is the combination of the three that together contributes to overall increased comfort. By improving the ability to adjust different parts of the seat, making the seat more customizable for each individual person, the customer value will be increased.

10.1 Future work

This chapter highlights and summarizes areas in need of further investigation. All areas are relevant to the subject of the thesis and include indications that could not be substantiated with enough data or other findings related to the result.

- Scenarios

Scenarios stated in phase one are based on findings from literature and needs to be evaluated in a trustworthy environment with fully autonomous cars to test their credibility for future applications.

- The two scenarios eating & drinking and travelling together.

Three out of five scenarios found in phase one were tested and evaluated through user tests. The remaining two scenarios, eating & drinking and travelling together needs to be tested and evaluated in the same way to be able to draw conclusions about seating comfort and position in each specific scenario.

- The aspect of trust

Cars used during user tests had a driver fully visible for the TP, which meant that TP's did not have to worry handling the car and thereby could trust the system. A test with similar setup but with a fully autonomous car is needed to test the aspect of trust and how people would react both in terms of acting and in terms of seating position when needed to fully trust an autonomous system.

- The aspect of motion sickness

Motion sickness as a subject is not covered in the thesis, though some TP's mentioned in user test three that it is a potential problem for situations similar to the reading and working on a laptop scenario when not actively watching the road. The aspect of motion sickness in autonomous vehicles needs to be investigated further for future evaluation of scenarios, especially if the scenario is related to activities that draws the user's attention off the road.

- Leg and feet support for seats in autonomous cars

Different variants of feet support and leg support were tested in the thesis, but further investigation is needed to see if a foot or leg support can contribute to the seating comfort and position in autonomous cars. Test environment where the different variants were tested was not enough in terms of space and needs to be done in an environment where the placement and design of a possible support is not affected by the interior space of a car. In addition to design and placement of a foot or leg support, the solution of how to integrate the solution in the existing seat design will need to be explored.

- Positions when using a laptop in an autonomous car

The chosen position and design for the laptop support needs to be investigated further to find the optimal solution. The chosen position in the thesis inhibited the experience of the user by causing an unwanted rotary motion when using the laptop support.

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12 APPENDIX

12.1 A - Compilation of activities

Activities observed in other types of transports. Numbers showing percentage of people in observations doing different activities in different studies.

	Trains					Buss
	KAMP	GROENESTEIJN	RUSSELL	GRIPSRUD Commuting	GRIPSRUD Business	RUSSELL
Sleep/relax	37,1	25	6,9	9,9	8,7	2,9
Watch/observe	8,6		31,5	22,6	24,6	51,8
Read	19,7	26	16,0	9,6	7,6	8,4
Talk/Sociolizing	23,6	10	9,3	5,5	10,1	9,2
Eating/Drinking	3,2	4	3,0	0	0	2,5
Working	3,9	20	6,8	24,0	30,5	1,0
Using Phone/Pads	3,9	12	17,9	25,1	16,0	18,2
Other	0	3	3,4	3,3	2,5	2,9
Handeling belongings	0	0	5,1	0	0	3,1

Desire for activities in different transports. Numbers showing percentage of people in with desire of doing different activities in different studies.

	Dolcera	Jorlöv (long)	Jorlöv(short)	China	India	Japan	U.S	U.K	Australia
Sleep/relax	10	1,5	28,1	10,8	4,7	12,6	6,8	7,2	7,1
Watch/observe	21	4,4	15,6	36,1	30,7	33,2	35,5	44,0	43,4
Read	21	5,9	9,4	10,5	10,2	5,6	10,8	7,6	6,5
Talk/Sociolizing	26	13,2	0,0	20,8	15,0	7,4	9,8	5,5	7,9
Eating/Drinking	0	10,3	6,3	0,0	0,0	0,0	0,0	0,0	0,0
Working	7	2,9	9,4	5,4	16,3	0,7	4,8	4,9	5,1
Using Phone/Pads	0	0,0	9,4	0,0	0,0	0,0	0,0	0,0	0,0
Other	0	0,0	3,1	0,7	0,8	0,2	1,4	1,7	1,0
Games	7	30,9	0,0	1,3	2,1	1,2	2,0	1,9	2,0
Watching screens	8	26,5	3,1	11,3	12,3	6,2	6,0	4,2	5,7

12.2 B - User test one interview form

Inledning

TILL TESTLEDARE

Italia- Detta ska sägas till testperonerna

Bold- Detta ska utföras av testledaren

Vanlig text är frågor som ska besvaras av testpersonerna.

Välkomna och förklara vad vi håller på med.

Vi skriver vårt ex-jobb på ergonomiavdelningen och det vi undersöker är komfort samt position för en förarstol i en AD bil (ej för ergonomi). Idag ska vi utvärdera fotstöd, benstöd och en arbetsyta för olika AD scenarion som vi har tagit fram. Med fotstöd syftar vi på ett stöd framför stolen för fötterna och benstöd är ett stöd vid stolen som ger stöd åt benen. Du kommer vara med och säga vad du tycker om de olika sakerna vi ska testa och du kommer att få värdera hur bra du tycker de är utifrån Volvoskalan. (Ergonomi- Det är du själv som person som ska utvärdera vad du personligen tycker) Skalan är 10 gradig och du kommer att se den på ratten framför dig.

Du ska under testet tänka dig att du är i en självkörande bil vilket kommer att möjliggöra att du kan göra andra saker i bilen. Du kommer få tänka dig in i tre olika scenarios under de olika testerna, ett där du ska relaxa (vila), ett där du ska använda en laptop och ett där du ska läsa från en läsplatta. I alla scenarion kommer vi ha ställt in stolen så du får inte röra stolsinställningarna. Under testets gång ska du ha bältet på dig.

Vi kommer att ta kort under testet och de kommer enbart att användas för att analyser testerna. Är det okej för dig?

Är det några frågor?

Introfrågor

TP: nummer

Namn

Typ av sko

Innan vi börjar testet har vi några inledande frågor som vi vill att du besvarar. För svar på frågor ska du tänka dig att du precis aktiverat AD-funktionen och längre inte kör bilen manuellt.

Anser du att det finns ett behov av fotstöd i bilen vid en viloposition i bilen?

1	2	3	4	5
Inget behov				Stort behov

Anser du att det finns ett behov av fotstöd i bilen när du ska läsa?

1	2	3	4	5
Inget behov				Stort behov

Anser du att det finns ett behov av benstöd i bilen vid viloposition i bilen?

1	2	3	4	5
Inget behov				Stort behov

Anser du att det finns ett behov av benstöd i bilen när du ska läsa?

1	2	3	4	5
Inget behov				Stort behov

Anser du att det finns ett behov av en arbetsyta när du ska arbeta på en laptop i en bil?

1	2	3	4	5
Inget behov				Stort behov

Fotstöd

Du kommer att få testa två olika scenarion i vilka vi ska utvärdera fotstöd, ett i viloposition där du ska vila i bilen och ett där du ska läsa i bilen.

Relax- Fast stolsposition LNLB, Stor ryggvinkel

Du ska testa tre olika fotstöd. Du kommer att få placera det första fotstödet vart du vill på mattan och sedan kommer vi placera ut de andra. Du får inte ändra stolspositionen och du ska ha på dig säkerhetsbältet under testet. Vi ska nu placera ut det första fotstödet i en bra position.

Du åker i en självkörande bil och du har nu intagit en position för att vila/relaxa i bilen. Det är viktigt att du har fötterna på fotstödet.

Börja med att testa mellanpositionen på fotstöden för att se vart det ska vara placerat på mattan. Tänk på att variera vilket av alternativen av fotstöd som kommer efter det mellersta. Låt personen komma till rätta med sin position innan du börjar ställa frågorna.

Låg

TA KORT PÅ FOTSTÖD

Hur upplever du din komfort vid denna position?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Byt till nästa fotstöd

Medel

TA KORT PÅ FOTSTÖD

Hur upplever du din komfort vid denna position?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Byt till nästa fotstöd

Hög

TA KORT PÅ FOTSTÖD

Hur upplever du din komfort vid denna position?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Upprepa samma sak för Reading

Benstöd

Du kommer att få testa två olika scenarion i vilka vi ska utvärdera benstöd, en i viloposition där du ska vila i bilen och en där du ska läsa i bilen.

Relax- Fast stolsposition LNLB, Stor ryggvinkel

Du ska testa tre olika benstöd som kommer vara placerade vid stolen. Du får inte ändra stolspositionen och du ska ha på dig säkerhetsbältet under testet.

Du åker i en självkörande bil och du har nu intagit en position för att vila/relaxa i bilen.

Tänk på att variera vilket ordningen på benstöden som testas. Låt personen komma till rätta med sin position innan du börjar ställa frågorna. Benstödet ska vara placerat vid stolkanten.

Liten vinkel

TA KORT PÅ BENSTÖD

Hur upplever du din komfort vid denna position?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Byt till nästa benstöd

Stor vinkel

TA KORT PÅ BENSTÖD

Hur upplever du din komfort vid denna position?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Upprepa samma sak för Reading

Arbetsyta

Working on Laptop- Fast stolsposition LNLB, Liten ryggvinkel (26 grader)

Du ska nu få testa att arbeta på en anvisad arbetsyta i bilen. Arbetsytan placeras i tunneln och är utmärkt med tre olika områden. Du kommer under tre tillfällen få utföra en kort uppgift på en laptop. Inför varje uppgift kommer jag att berätta inom vilket område du ska placera laptopen. Du får inte ändra stolspositionen och du ska ha på dig säkerhetsbältet under testet.

I detta tester ska du tänka dig att du åker i en självkörande bil och du har intagit en position för att arbeta på din dator.

Varsågod och placera dig. Du får skjuta arbetsytan framåt bort från dig eller närmare dig om du vill innan testet börjar, under testet ska arbetsytan vara på samma position

Tänk på att slumpmässigt välja vilka ytor som testas och inte alltid börja med samma.

TA KORT PÅ PLACERINGEN AV ARBETSYTAN

Stor

I detta test får du använda hela arbetsytan. Kanten fram till tangentbordet får vara utanför ytan. Nu ska du få instruktioner av oss för att arbeta på datorn.

Öppna word och skriv alla månader och där efter veckodagar med enterslag emellan varje månad så de hamnar på en rad under varandra.

POSITION- Notera vilken typ av position som TP

Vridning i axel **Vridning i överkroppen** **Vridning i sittytan**

Lutning av överkropp mot tunnel **Lutning/vridning mot fönstret**

TA KORT PÅ ARBETSYTAN

Hur upplever du din sittposition och komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Hur bra tycker du att denna avlastningsyta är för att arbeta med en laptop?

Medel

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

I detta test får du använda den mellersta arbetsytan. Kanten fram till tangentbordet får vara utanför ytan.

Öppna word och skriv alla månader och där efter veckodagar med enterslag emellan varje månad så de hamnar på en rad under varandra.

POSITION- Notera vilken typ av position som TP

Vridning i axel **Vridning i överkroppen** **Vridning i sittytan**

Lutning av överkropp mot tunnel **Lutning/vridning mot fönstret**

TA KORT PÅ ARBETSYTAN

Hur upplever du din sittposition och komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Hur bra tycker du att denna avlastningsyta är för att arbeta med en laptop?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Liten

I detta test får du använda den minsta arbetsytan. Kanten fram till tangentbordet får vara utanför ytan.

Öppna word och skriv alla månader och där efter veckodagar med enterslag emellan varje månad så de hamnar på en rad under varandra.

POSITION- Notera vilken typ av position som TP

Vridning i axel **Vridning i överkroppen** **Vridning i sittytan**

Lutning av överkropp mot tunnel **Lutning/vridning mot fönstret**

TA KORT PÅ ARBETSYTAN

Hur upplever du din sittposition och komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Hur bra tycker du att denna avlastningsyta är för att arbeta med en laptop?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Nu är vi klara. Tack för att du har deltagit i vårt test!

12.3 C - Distribution of result in used test one

RELAXING

Distribution of the result in the relaxing scenario are displayed in the table below.

RELAXING	Number of specific answer									
Foot support	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Low		1		2	1	4	1		1	
Medium						1	6	3		
High					2	2	3	2	1	
Leg support										
Small angle						1	7	1	1	
Large angle					1		4	2	3	

Identification of who can use the leg support in the relaxing scenario where the cross represents how cannot use the leg support, see table below.

Can not use leg support	Small	Large
TP1	x	
TP2		
TP3	x	x
TP4		
TP5		
TP6		
TP7	x	x
TP8	x	x
TP9		
TP10	x	

READING

Distribution of the result in the reading scenario are displayed in the table below.

READING	Number of specific answer									
Foot support	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Low	1			1	5	3				
Medium					1	3	3	2	1	
High			1	1	1	5		1	1	

Leg support										
Small angle			2		2	1	2	2	1	
Large angle					2	5	1	2		

Identification of who can use the leg support in the reading scenario where the cross represents how cannot use the leg support, see table below.

Can not use leg support	**Small**	**Large**
TP1	x	
TP2		
TP3	x	x
TP4	x	
TP5		
TP6		
TP7	x	x
TP8	x	x
TP9		
TP10		

WORKING

Distribution of the result on position and perceived comfort in the working scenario are displayed in the table below.

WORKING	**Number of specific answer**									
Support area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Small	2	1	4	2		1				
Medium		1	1	3	2			3		
Large				1	2	2	2	2	1	

Distribution of the result on how good the different working areas are to work on is displayed in the table below.

Working	**Number of specific answer**									
Support area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Small	1	5	1	1	1	1				

Medium		1	1	4	1		2	1		
Large			1	2		2	2	2	1	

Observation regarding the rotation in different body parts and how many of the TP´s who is rotating on the different sizes.

	Rotation in shoulder	**Rotation in Upper body**	**Rotation in the seating area**	**Tilt of upper body towards tunnel**	**Rotation/tilt towards the window**
Small	10	10	3	2	
Medium	10	6	1		
Large	7	1	1		

Placement of table (APPROXOMETLY). The numbers is displaying how far the table have been moved towards the TP´s from the gear lever when in parked.

	Placement of table from gear lever	**Total arm length**
TP1	9 cm	799
TP2	7 cm	786
TP3	7 cm	846
TP4	2 cm	800
TP5	8 cm	0
TP6	11 cm	755
TP7	3 cm	901
TP8	6 cm	950
TP9	7 cm	741
TP10	0 cm	868,5

12.4 D - User test two interview form

Inledning

TILL TESTLEDARE

Italia- Detta ska sägas till testpersonerna

Bold- Detta ska utföras av testledaren

Vanlig text är frågor som ska besvaras av testpersonerna.

Välkomna och förklara vad vi håller på med.

Vi skriver vårt ex-jobb på ergonomiavdelningen och det vi undersöker är komfort samt position för en förarstol i en AD bil (ej för ergonomi). Idag ska vi utvärdera två olika säten för olika AD scenarion som vi har tagit fram. Du kommer vara med och säga vad du tycker om de olika sakerna vi ska testa och du kommer att få värdera hur bra du tycker de är utifrån Volvoskalan.

Du ska under testet tänka dig att du är i en självkörande bil vilket kommer att möjliggöra att du kan göra andra saker i bilen. I de flesta scenarion kommer vi ha ställt in stolen så du får inte röra stolsinställningarna. Under testets gång ska du ha bältet på dig.

Vi kommer att ta kort under testet och de kommer enbart att användas för att analyser testerna. Är det okej för dig?

Är det några frågor?

Introfrågor

TP: nummer	
Namn	
Typ av sko	

DEL 1 – Komfortstol i XC90

(Glöm ej slumpa ordning på komfortstol/prototypstol)

RELAX

Fri positionering av alla parametrar vid viloposition (ryggvinkel, längd, höjd, tilt, dynförlängning)

Notera stolsposition till nästa del. Ta bild.

Hur upplever du din sittposition/komfort (ett helhetsperspektiv)?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Var det något som du upplevde som bra?

Var det något som du upplevde som dåligt?

Hur upplever du din huvudposition/komfort?

1-10? Bra? Dåligt?

Hur upplever du din ryggposition/komfort?

1-10? Bra? Dåligt?

Hur upplever du din sittposition och sittkomfort i nedre delen av stolen?

1-10? Bra? Dåligt?

Hur upplever du din ben- och fot position och komfort?

1-10? Bra? Dåligt?

Hur upplever du din armposition/komfort?

1-10? Bra? Dåligt?

Upprepa samma sak för Reading och Working

DEL 2 – Prototypstol i XC90

RELAX 1

Fri positionering av alla parametrar vid viloposition

Ta bild.

Hur upplever du din sittposition/komfort (ett helhetsperspektiv)?

1-10? Bra? Dåligt?

Hur upplever du din huvudposition/komfort?

1-10? Bra? Dåligt?

Hur upplever du din ryggposition/komfort?

1-10? Bra? Dåligt?

Hur upplever du din sittposition och sittkomfort i nedre delen av stolen?

1-10? Bra? Dåligt?

Hur upplever du din ben- och fot position och komfort?

1-10? Bra? Dåligt?

Hur upplever du din armposition/komfort?

1-10? Bra? Dåligt?

Upprepa samma sak för Reading och Working

DEL 2.2 – Prototypstol i XC90

RELAX 2

Ställ in stolsposition från del 1.

Fördefinierad stolsposition vid viloposition + Fri artikulering

Hur upplever du din sittposition/komfort?

1-10? Bra? Dåligt? Ta bild.

Fördefinierad stolsposition vid viloposition + Fritt nackstöd

Hur upplever du din sittposition/komfort?

1-10? Bra? Dåligt? Ta bild.

Fördefinierad stolsposition vid viloposition + Fri artikulering + Fritt nackstöd

Hur upplever du din sittposition/komfort?

1-10? Bra? Dåligt? Ta bild.

Fördefinierad stolsposition vid viloposition + Fria armstöd

Hur upplever du din sittposition/komfort?

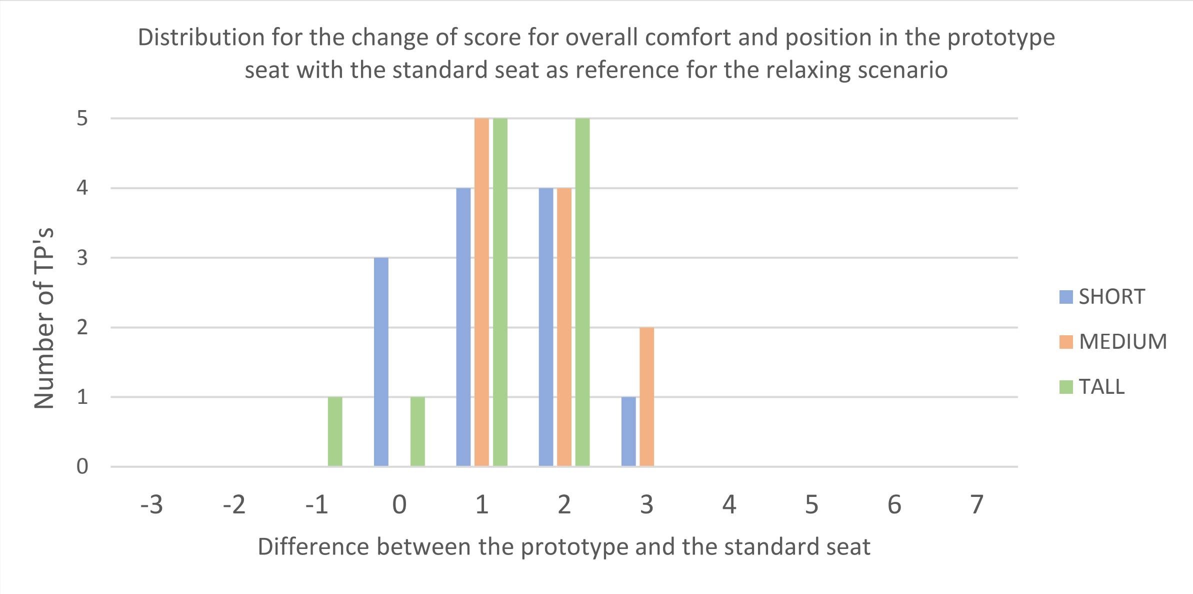
1-10? Bra? Dåligt? Ta bild.

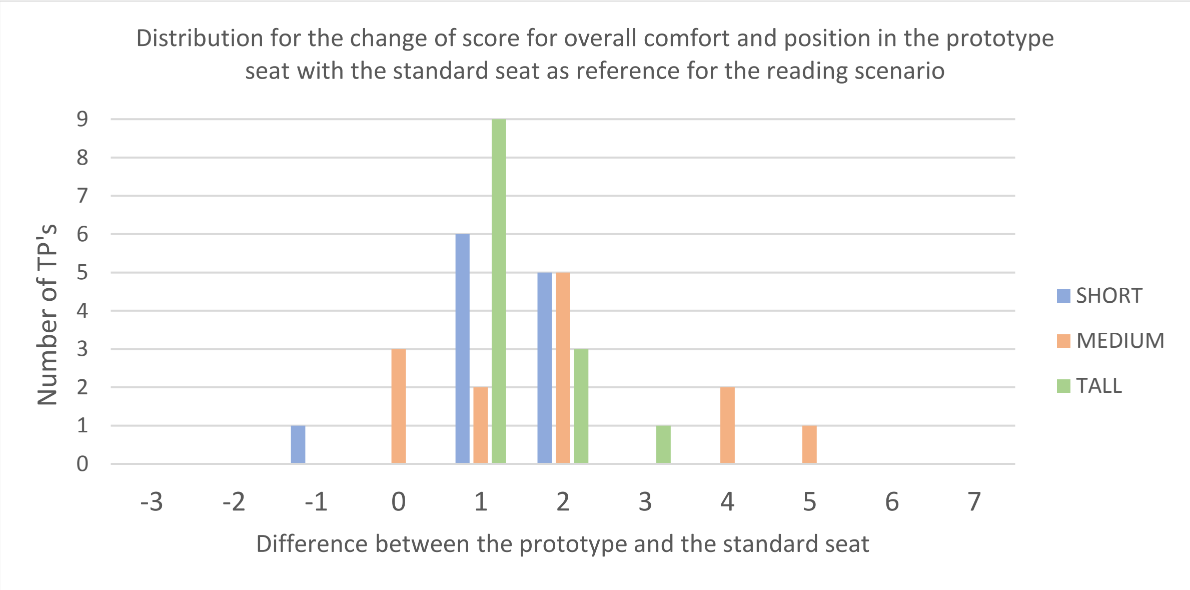
Upprepa samma sak för Reading och Working

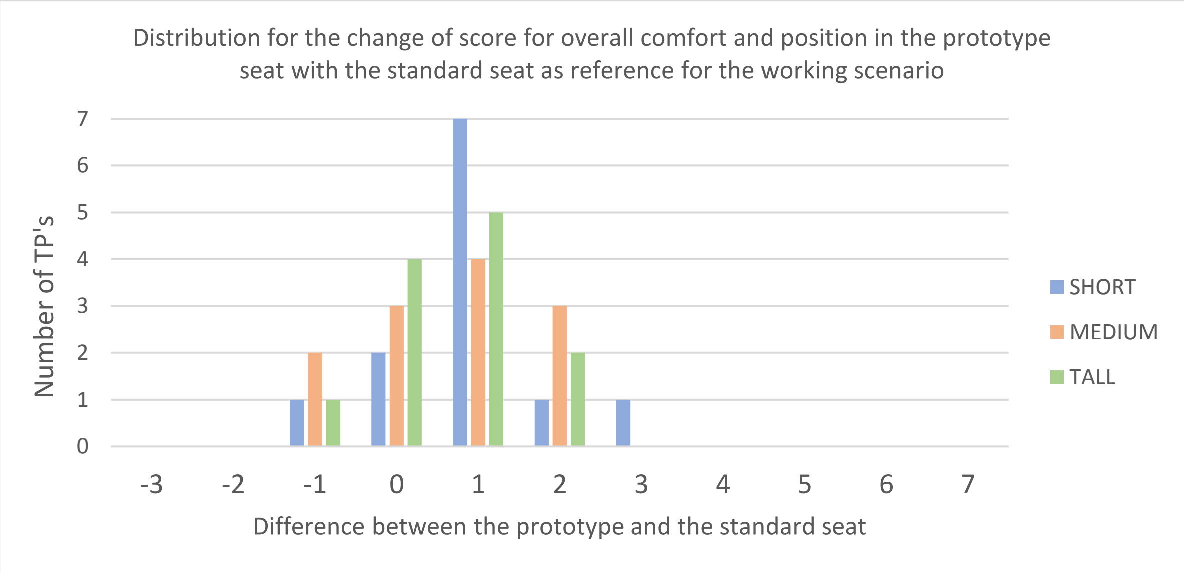
12.5 E – Distribution for the change of score

Using the scale graded 1-10 the figures below are illustrating the change in score for comfort and position in the prototype seat with the standard seat as reference. Meaning if the difference is *two* the prototype is two steps better on the defined scale then the standard seat.

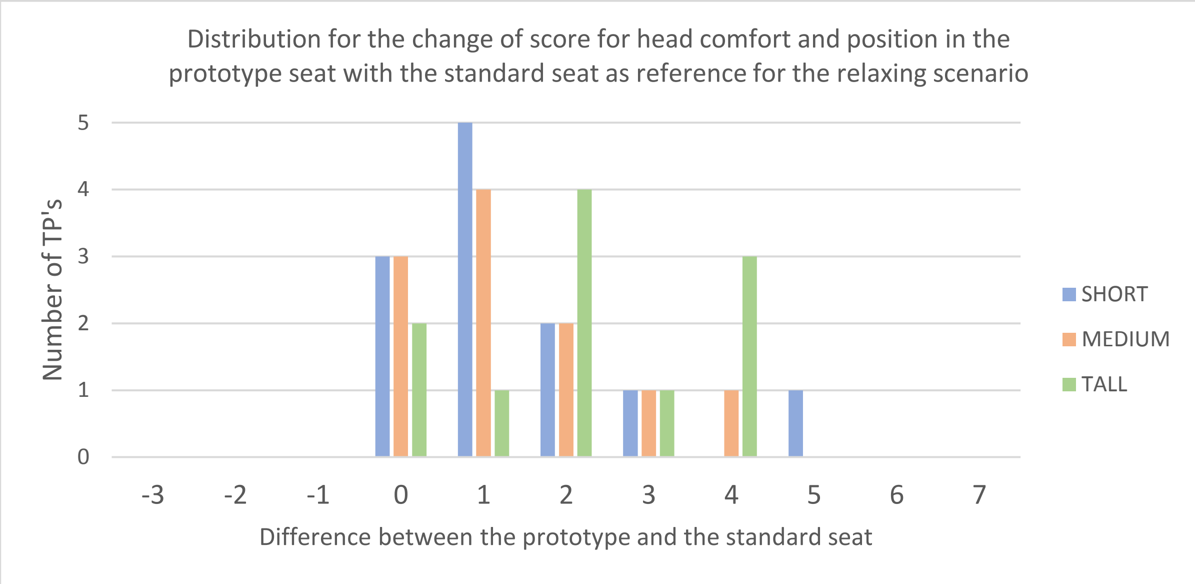
Overall comfort and position

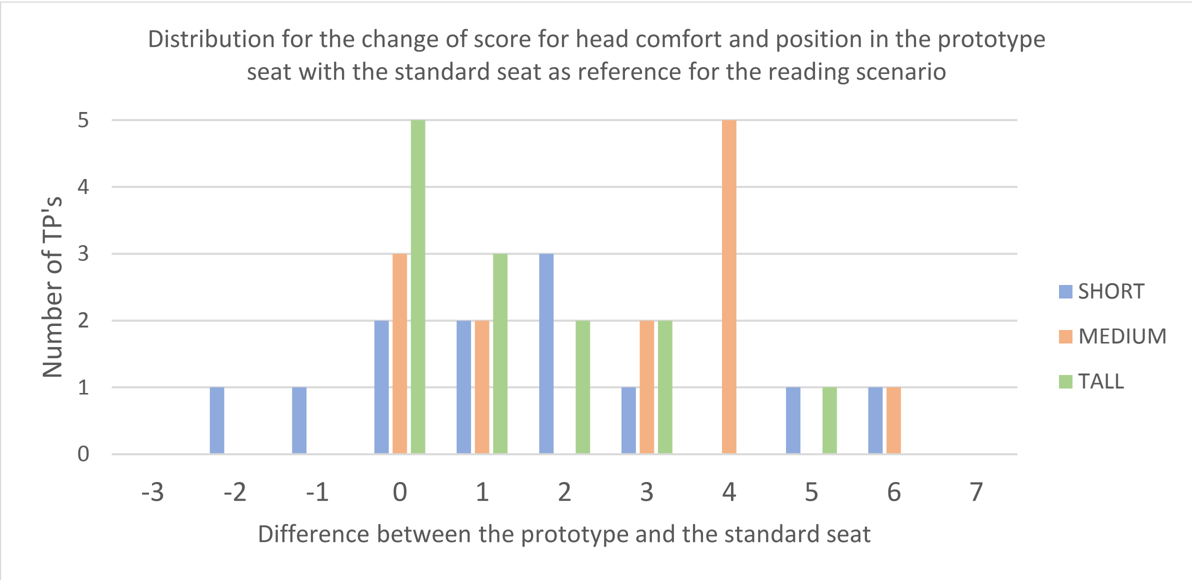


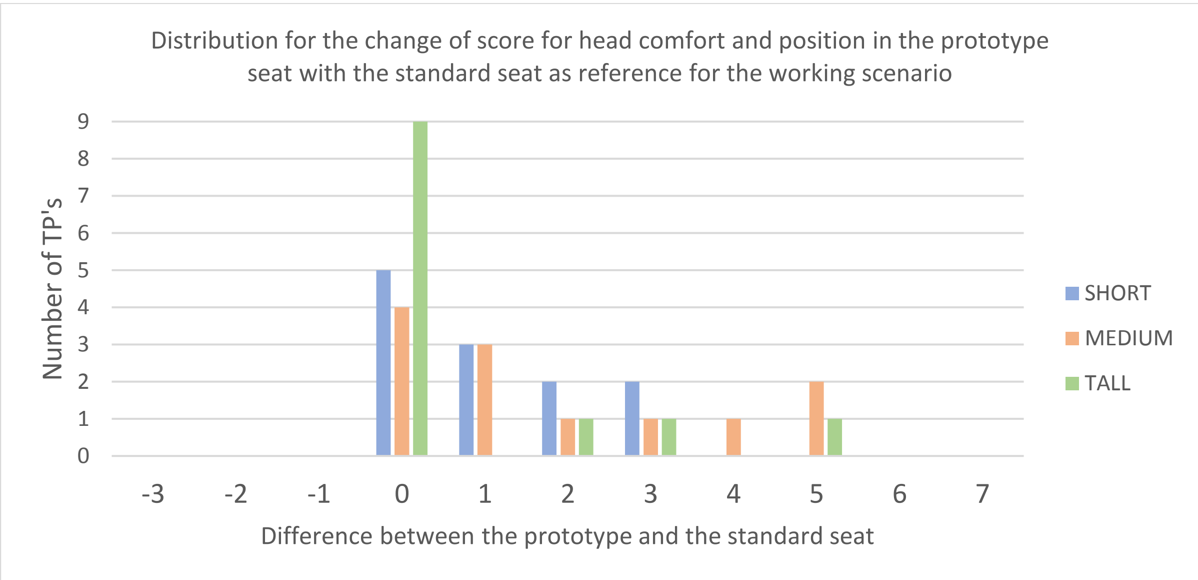




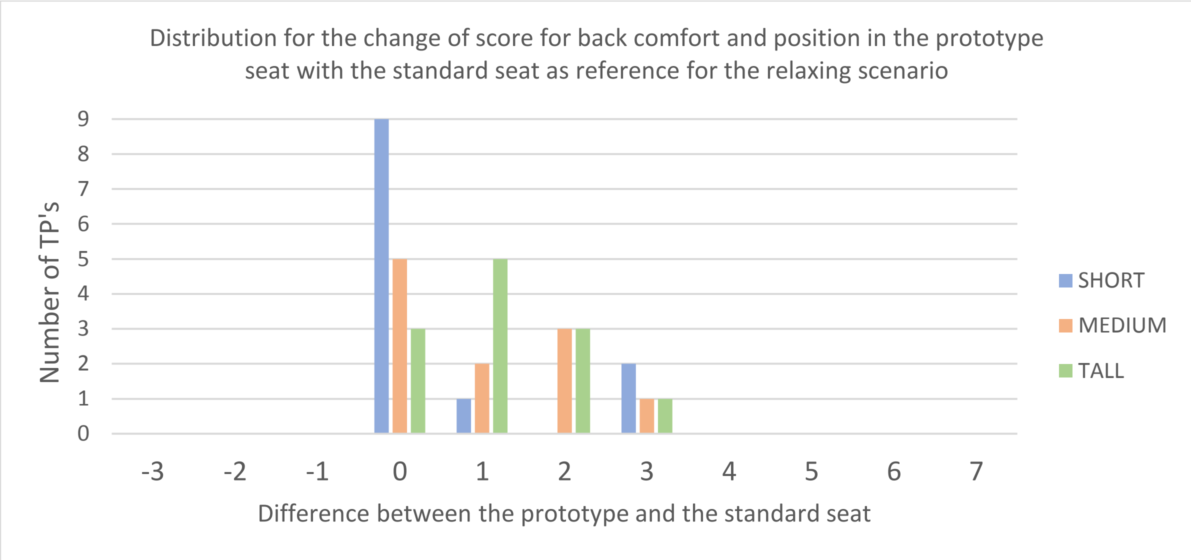
Head comfort and position

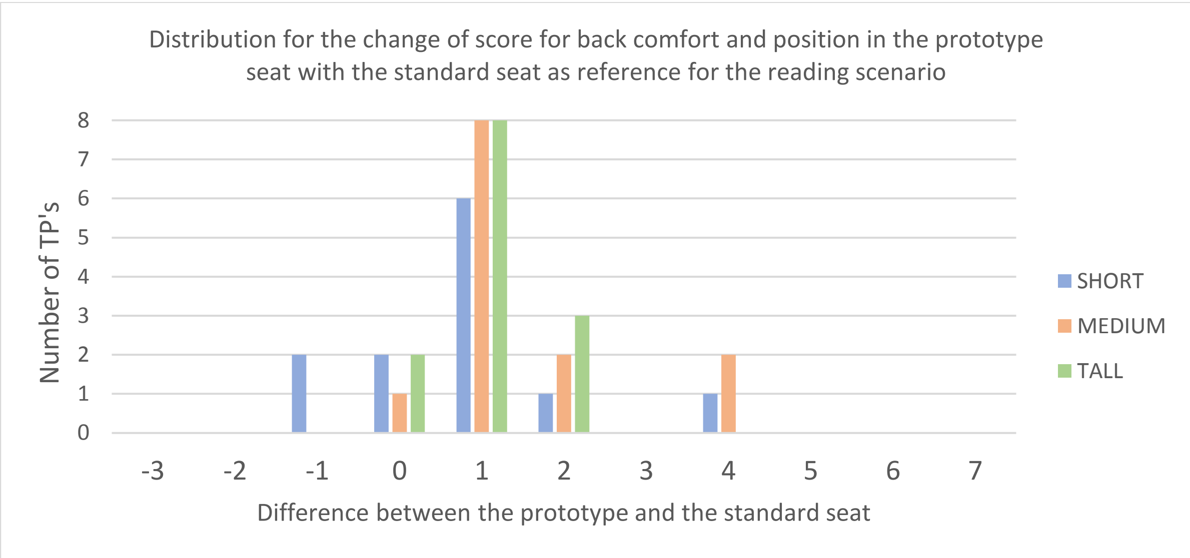


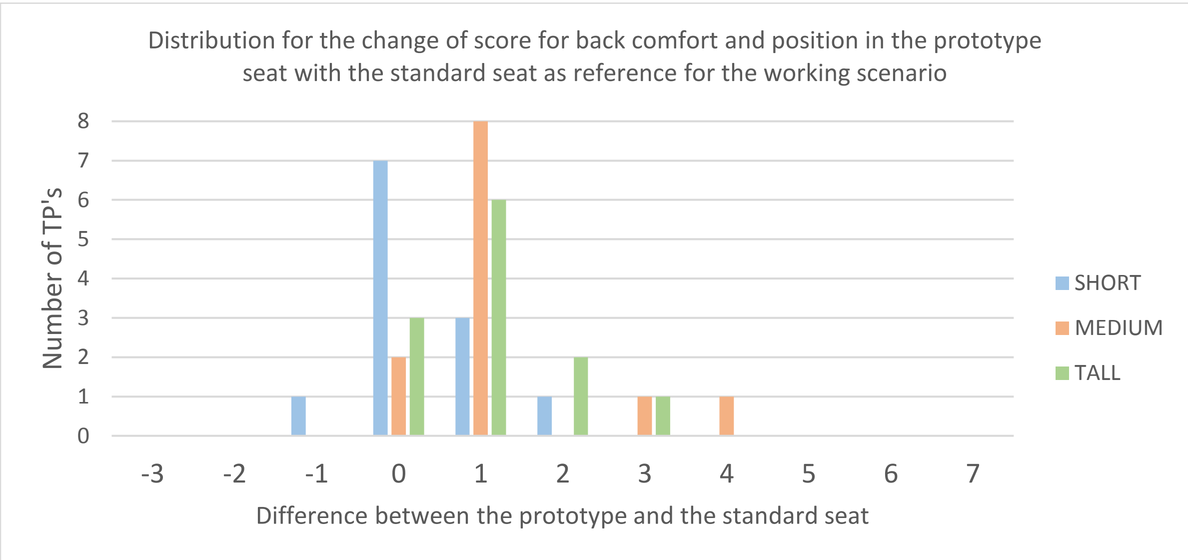




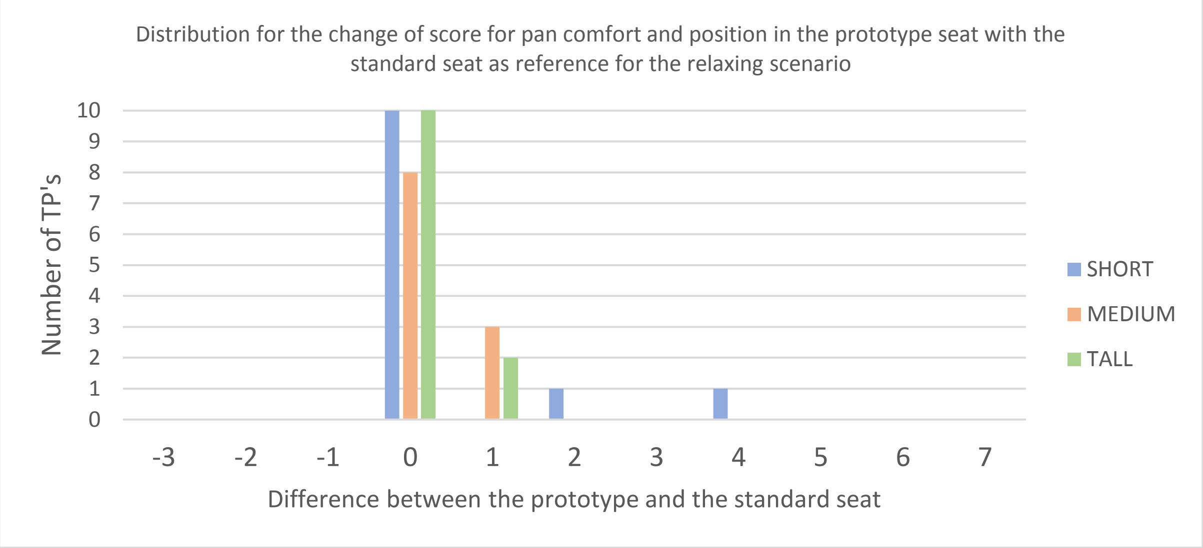
Back comfort and position

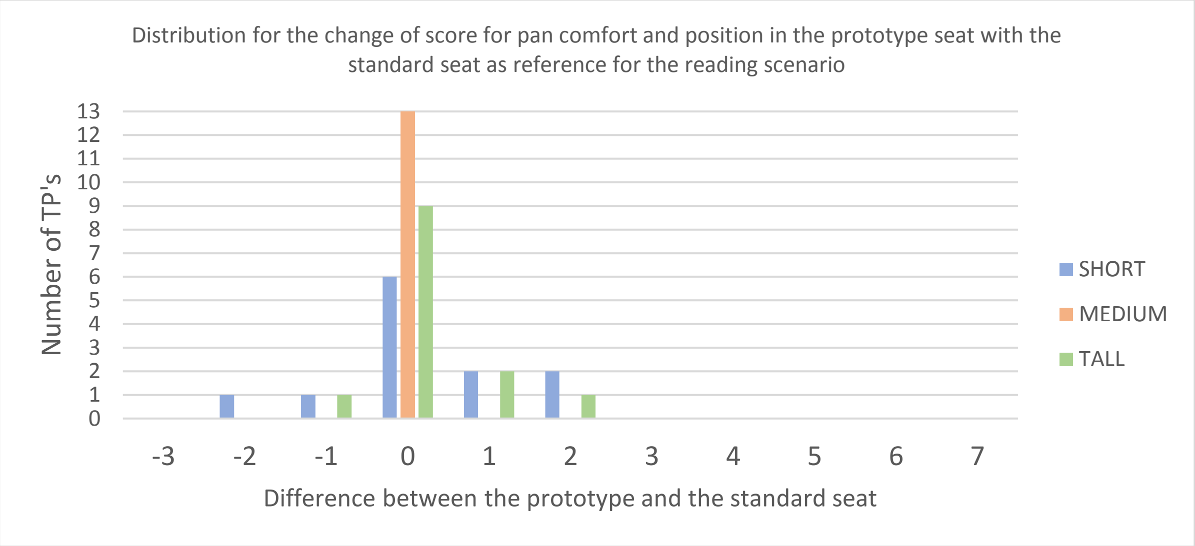


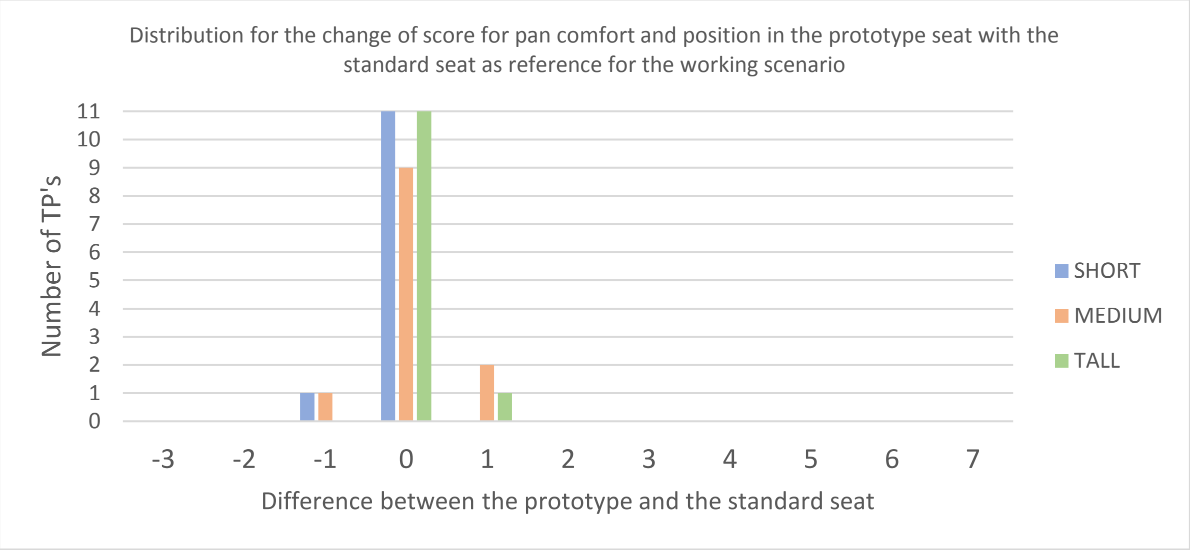




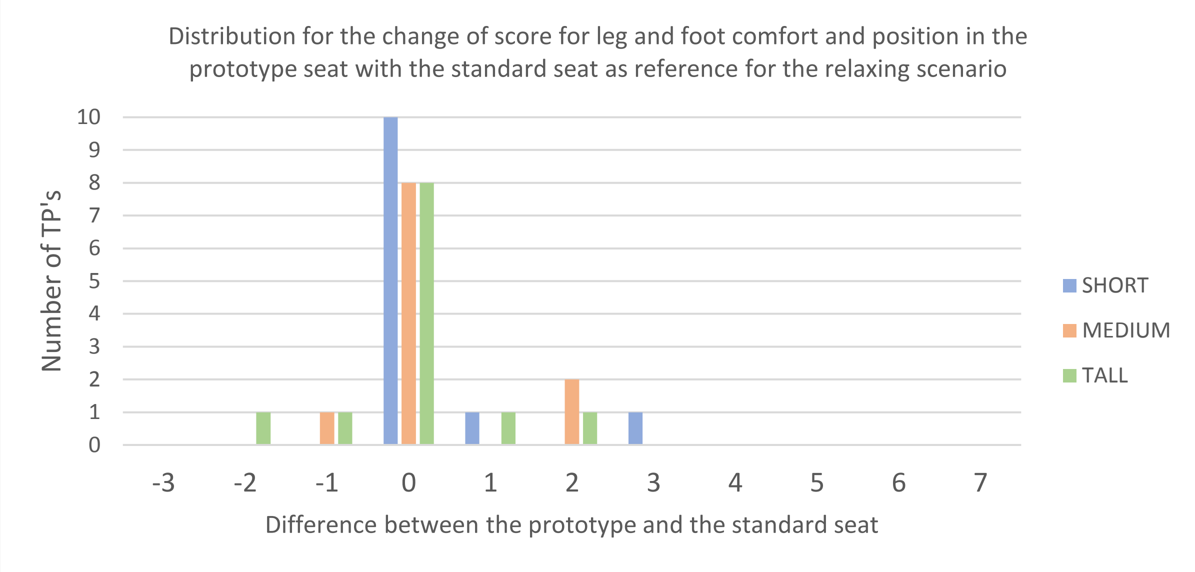
Pan comfort and position

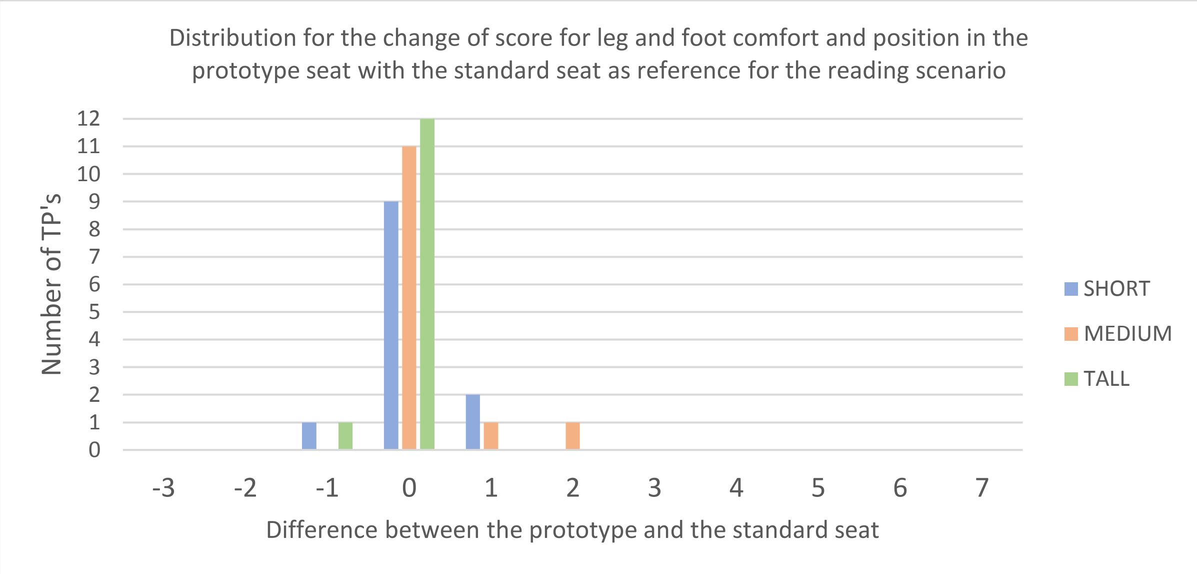


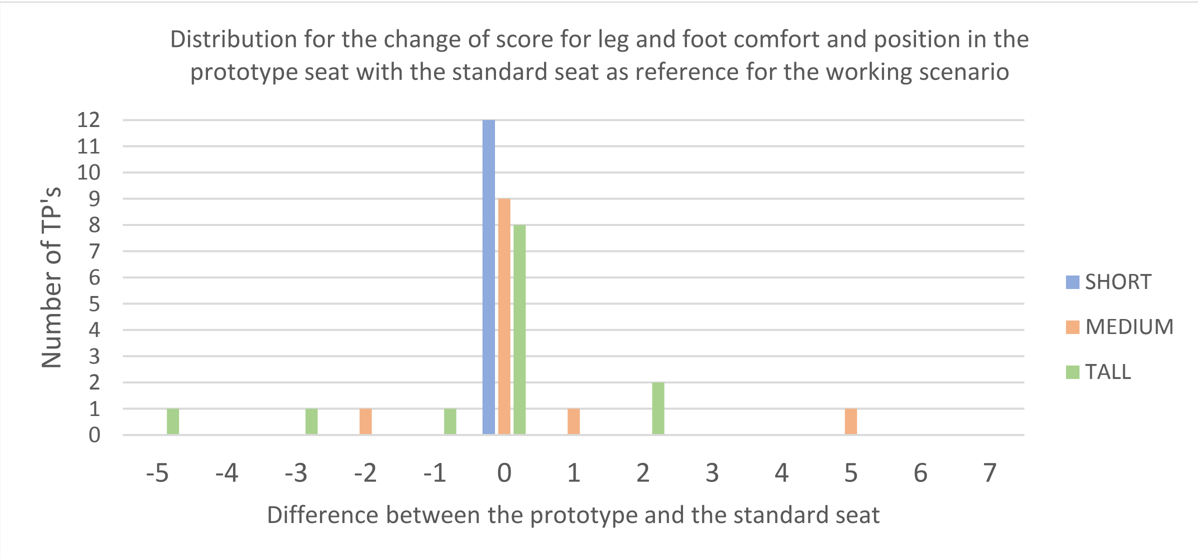




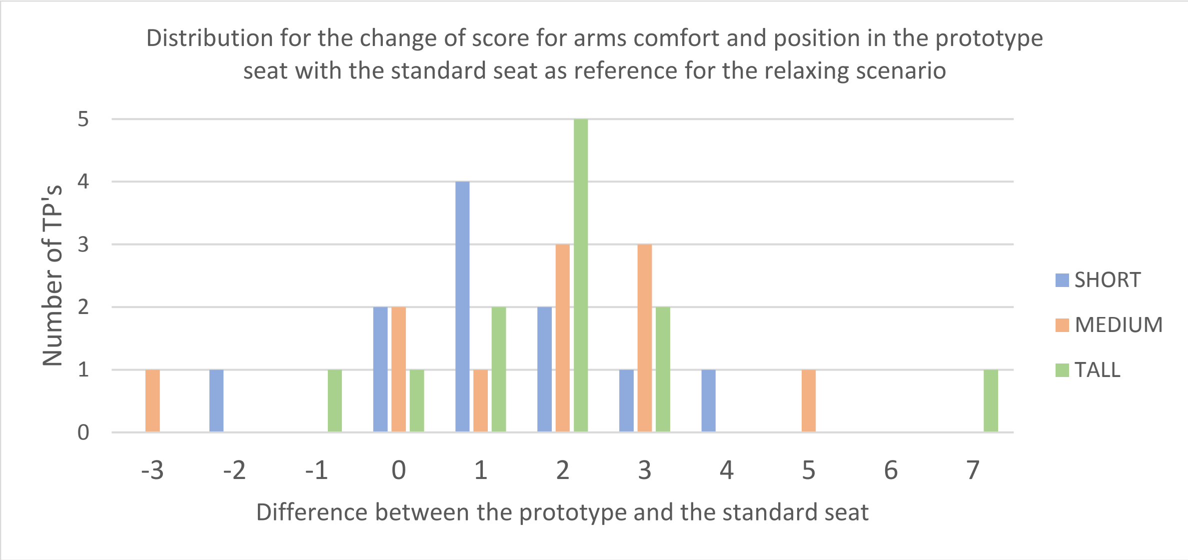
Leg and foot comfort and position

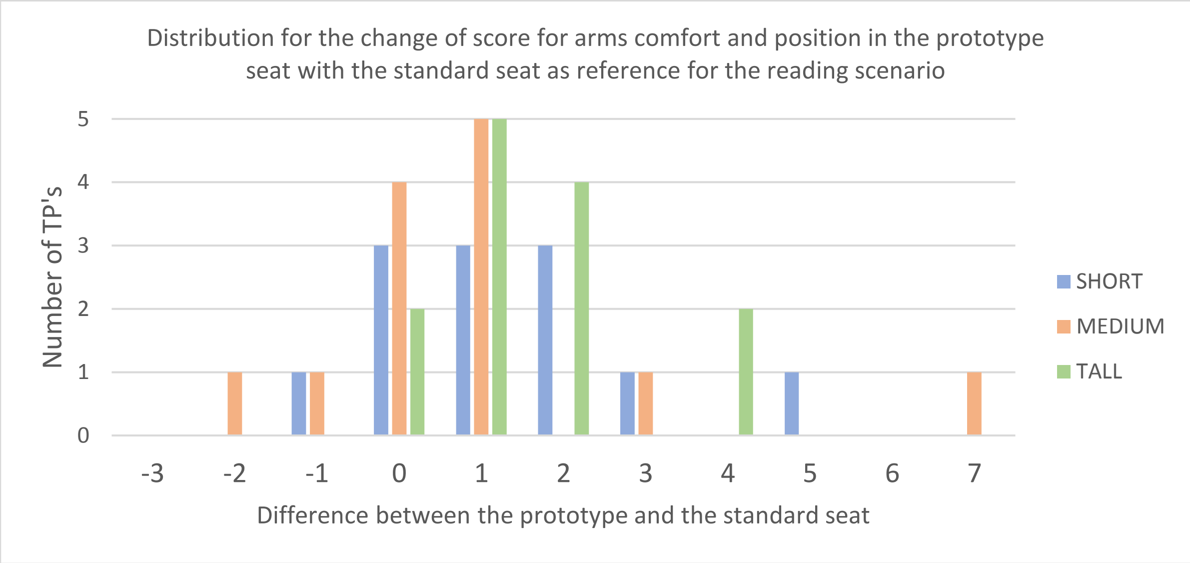


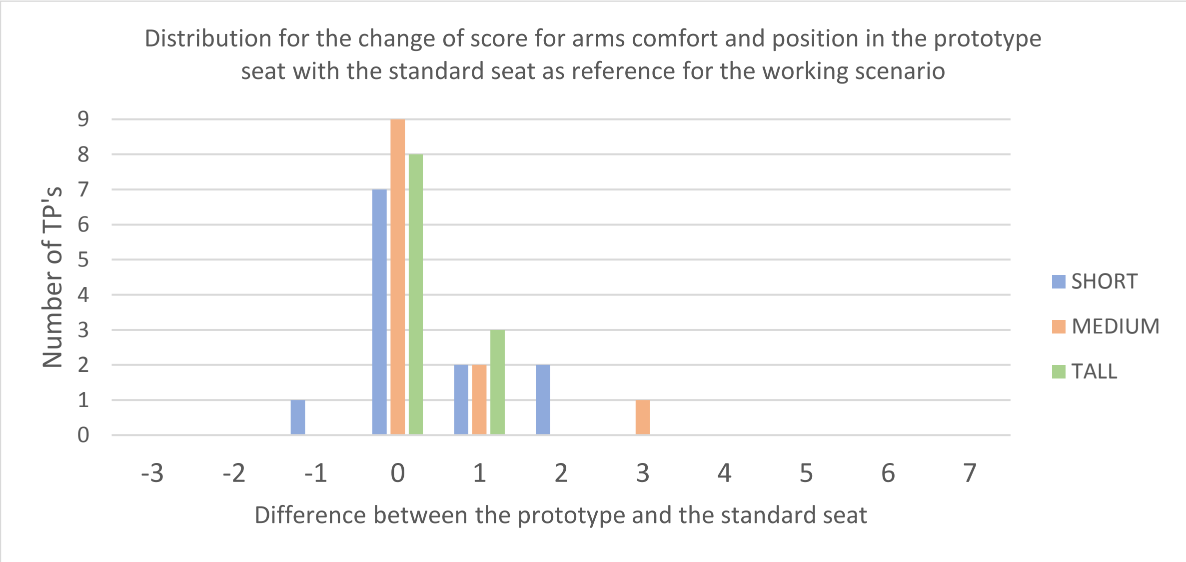




Arm comfort and position

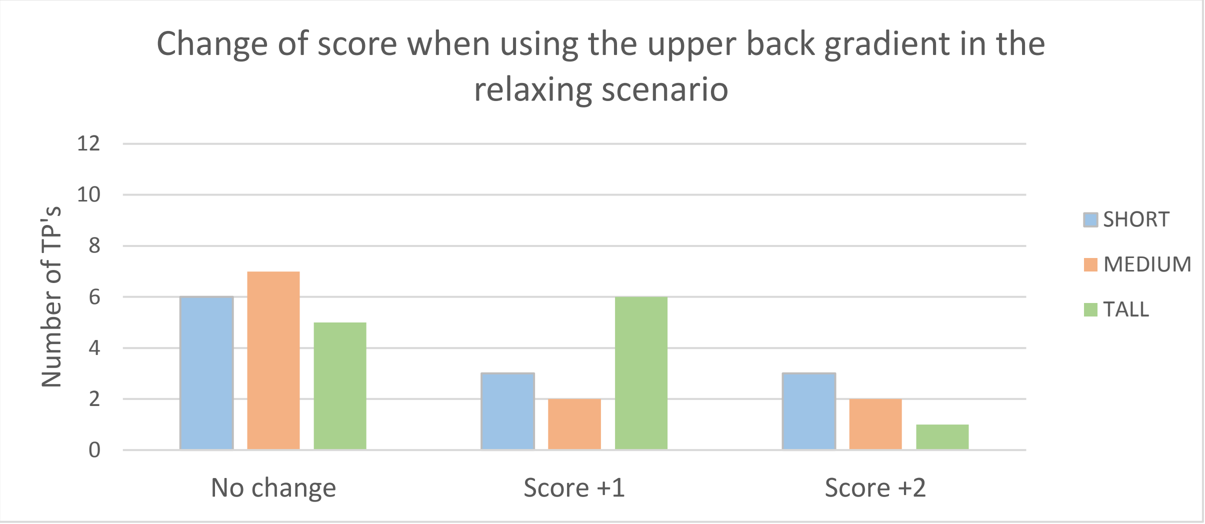


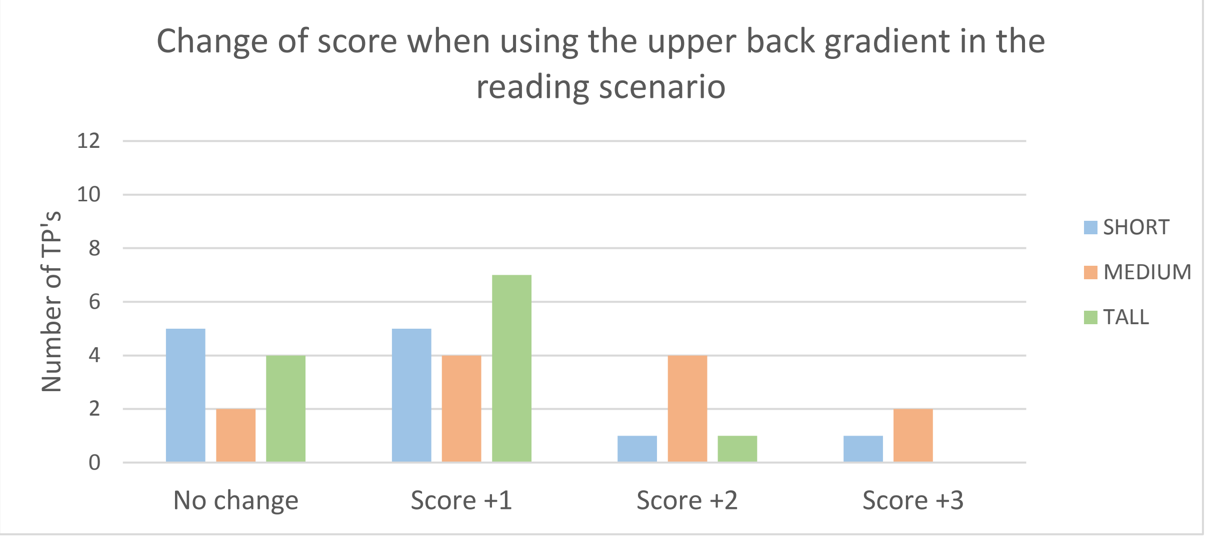


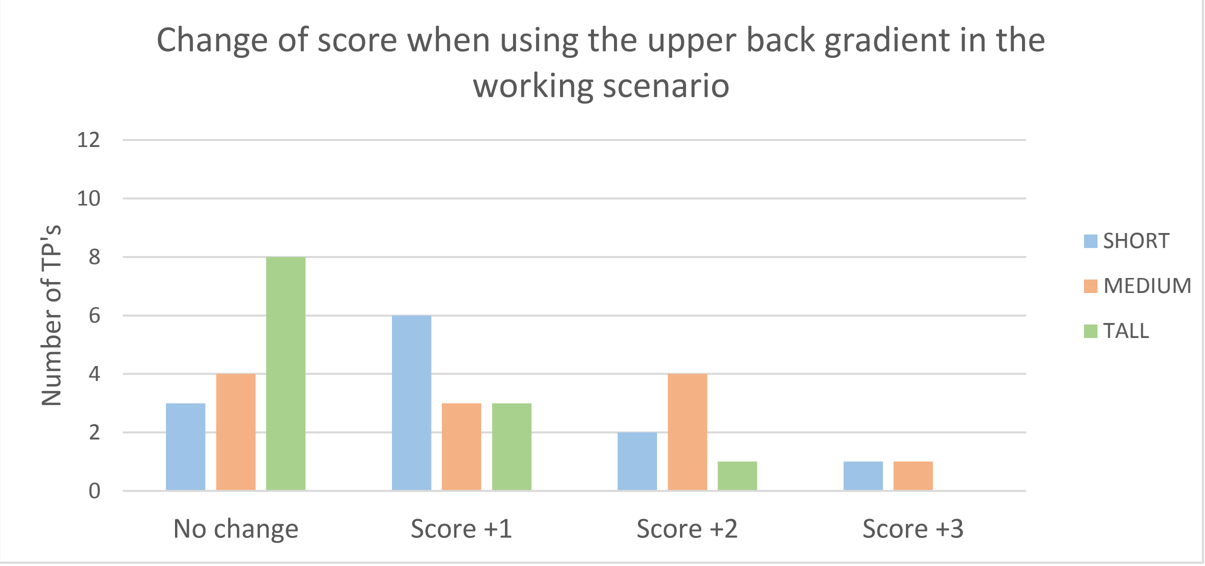


12.6 F - User test two, part two, distribution change

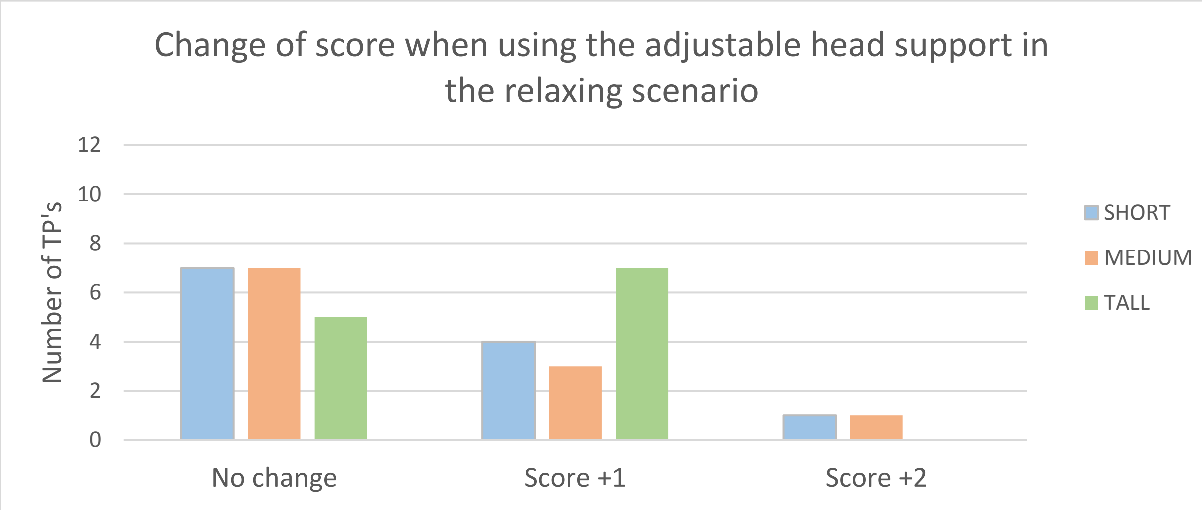
ONLY ARTICULATION IN THE BACK

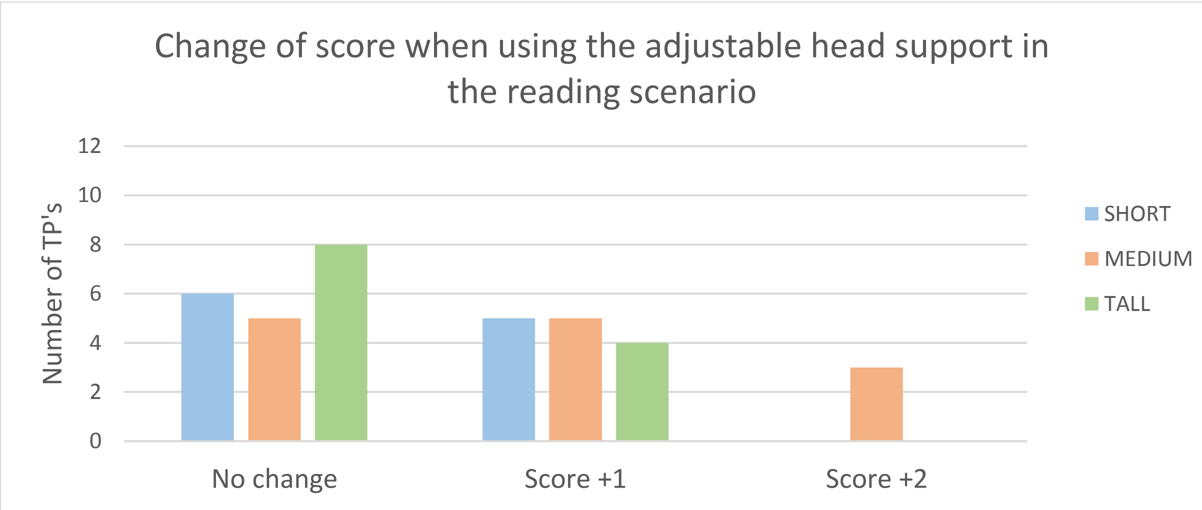


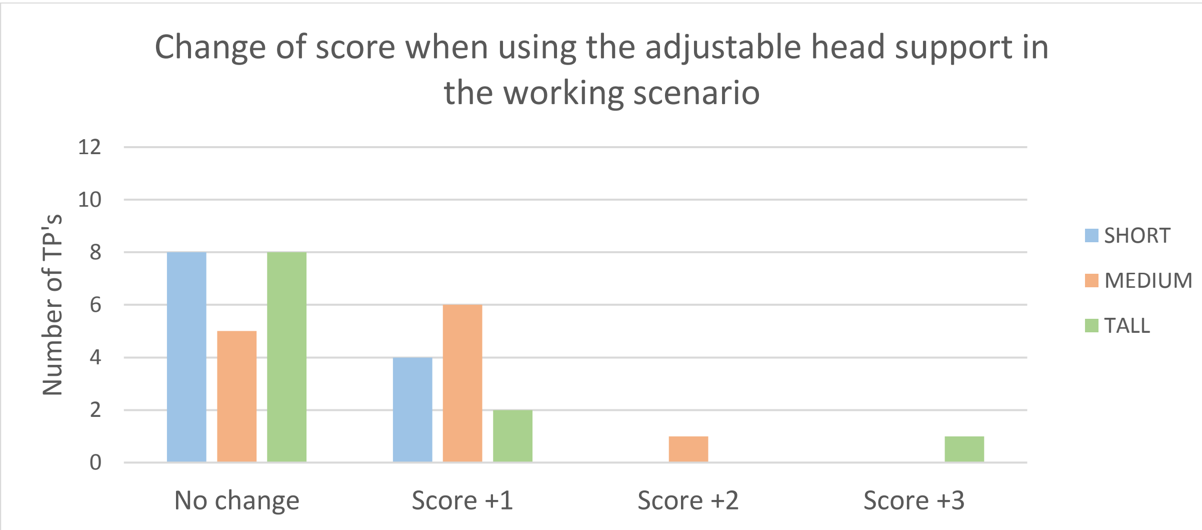




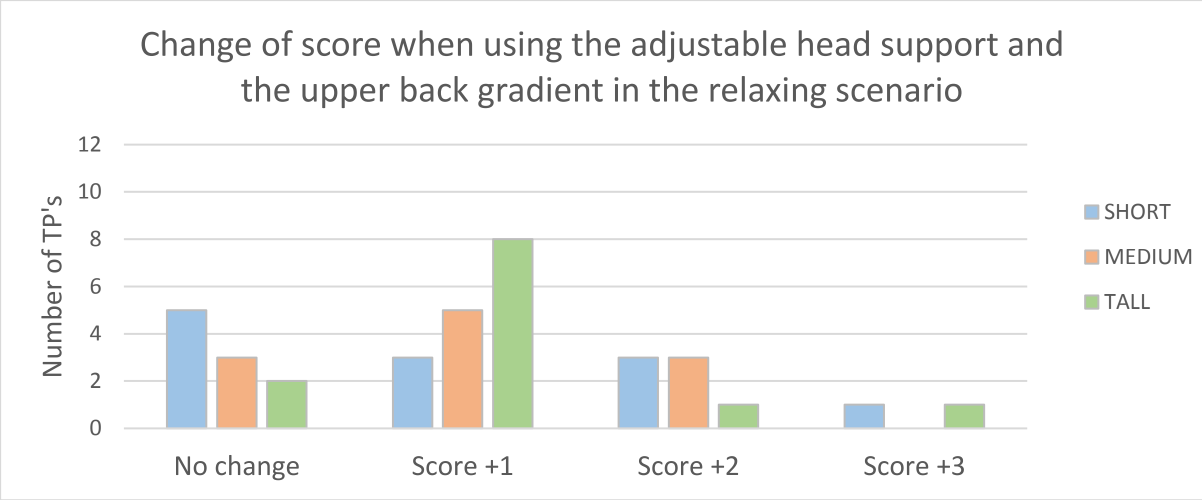
ONLY ADJUSTABLE HEAD SUPPORT

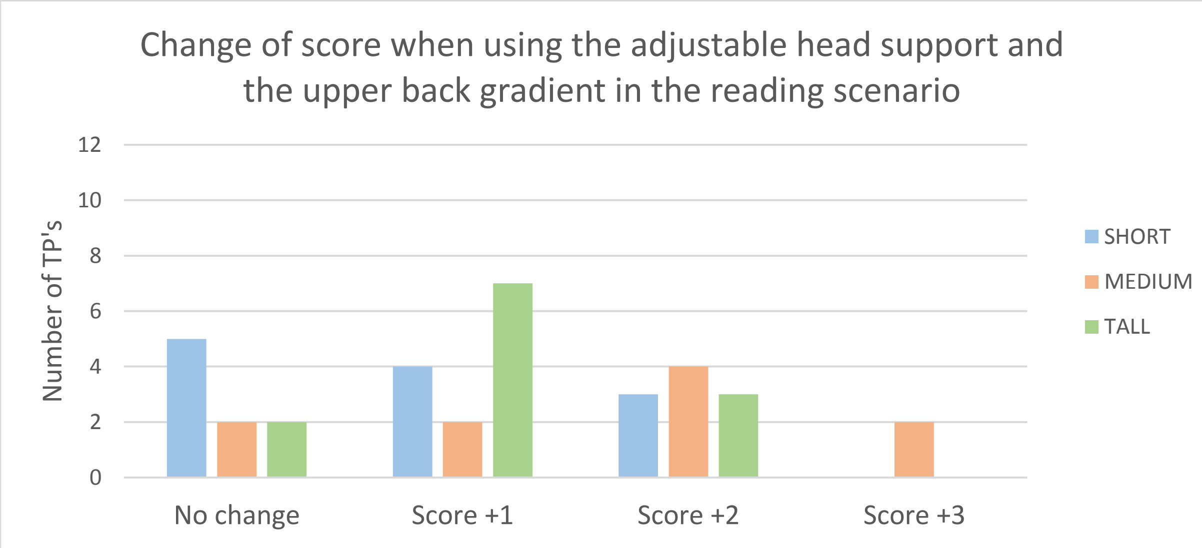


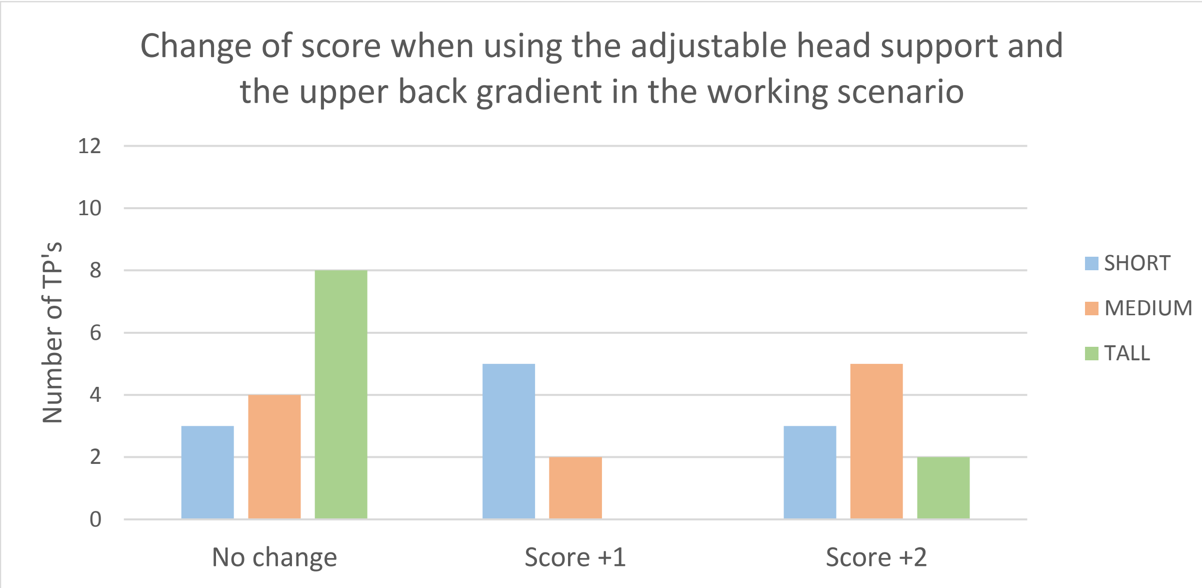




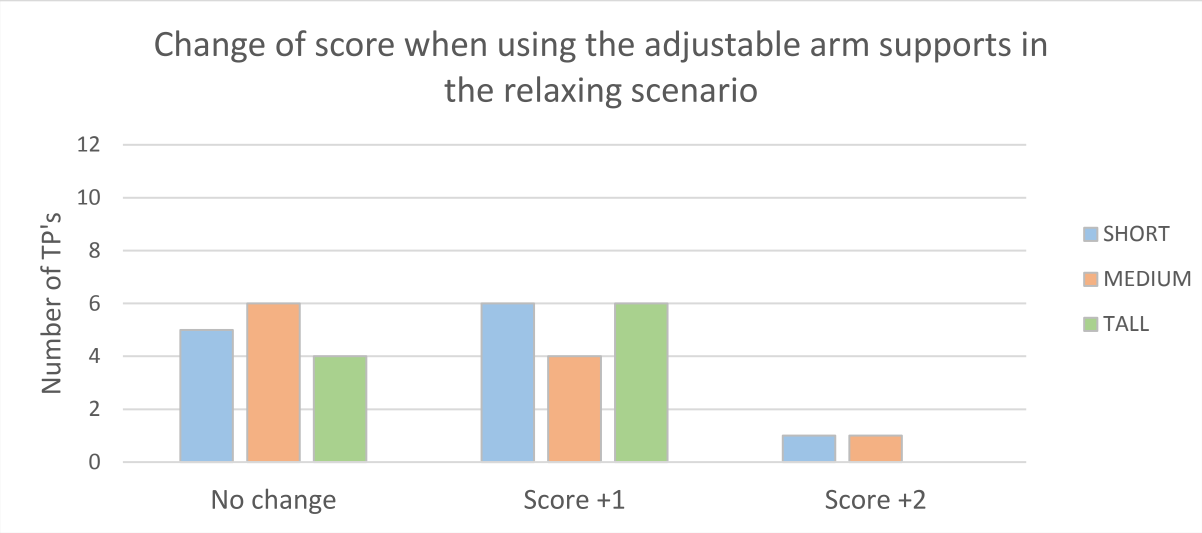
ARTICULATION IN THE BACK SUPPORT AND ADJUSTABLE HEAD SUPPORT

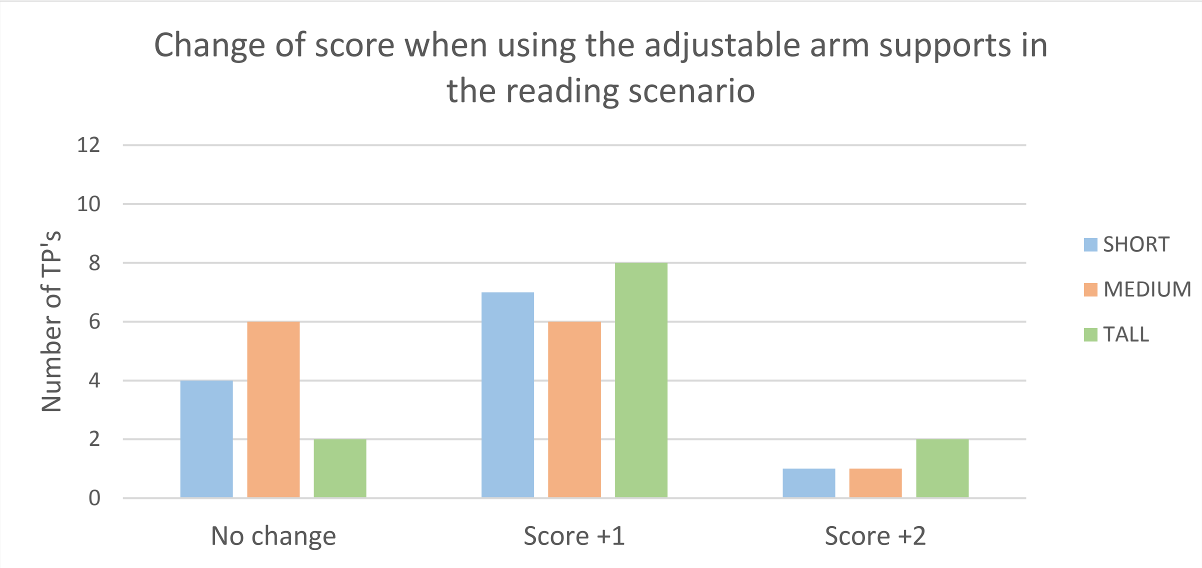


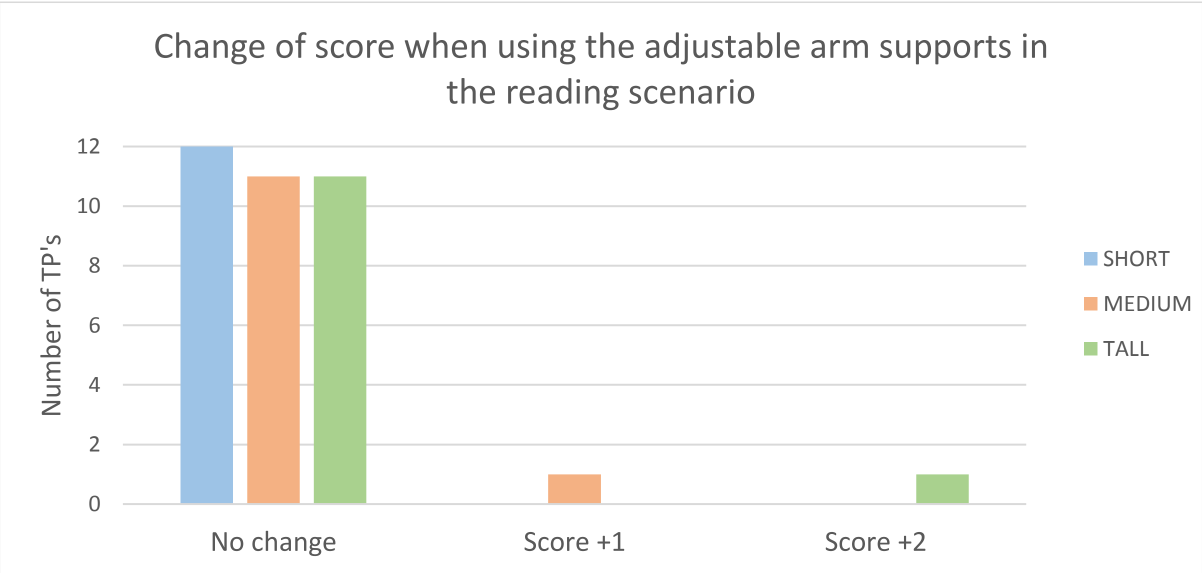




ONLY ADJUSTABLE ARM SUPPORTS

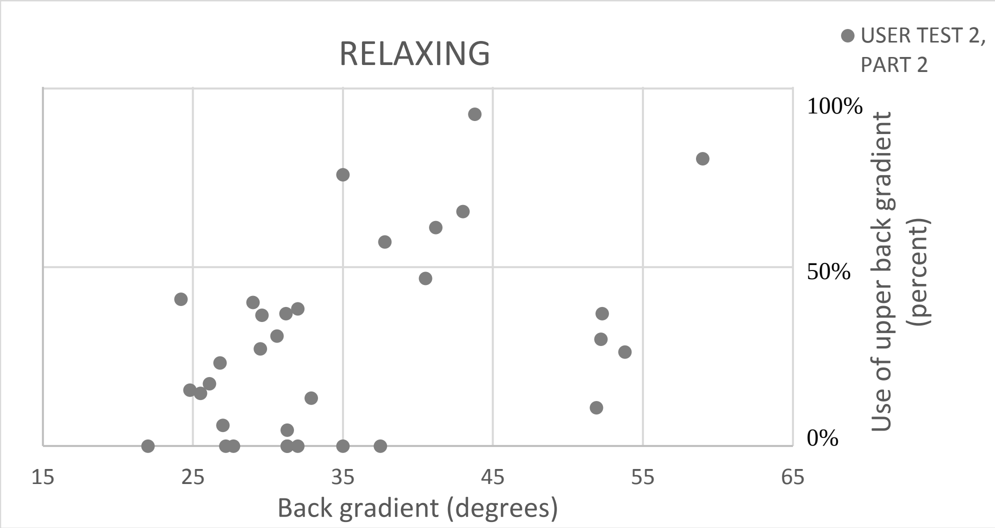


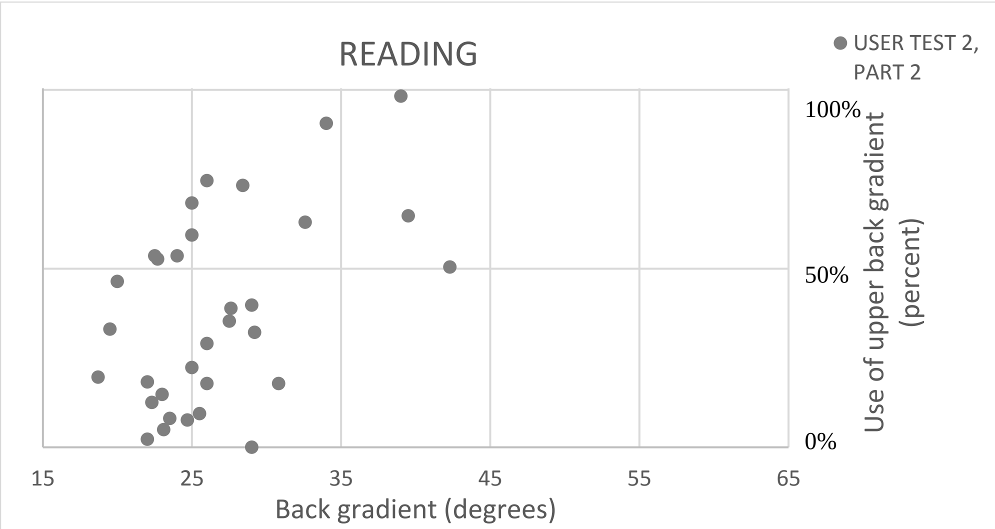


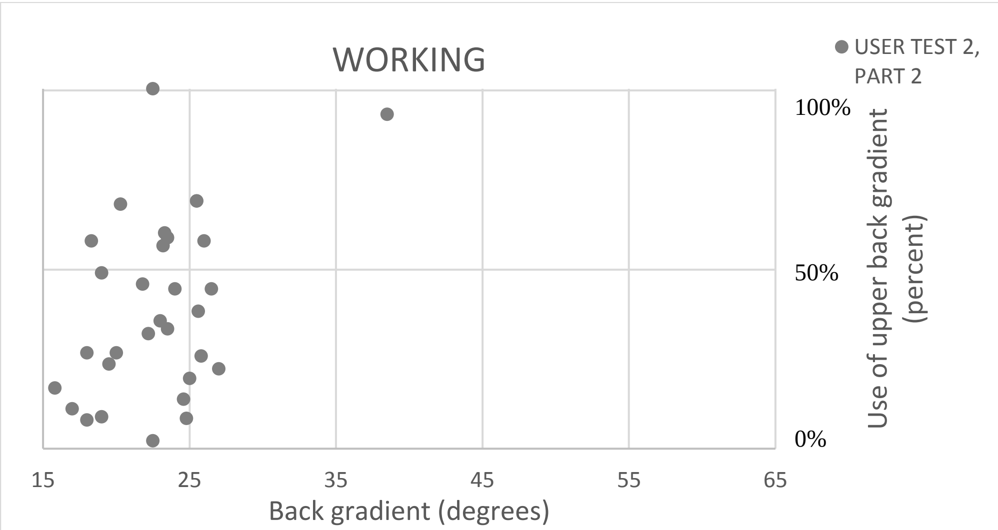


12.7 G – User test two, part two, position

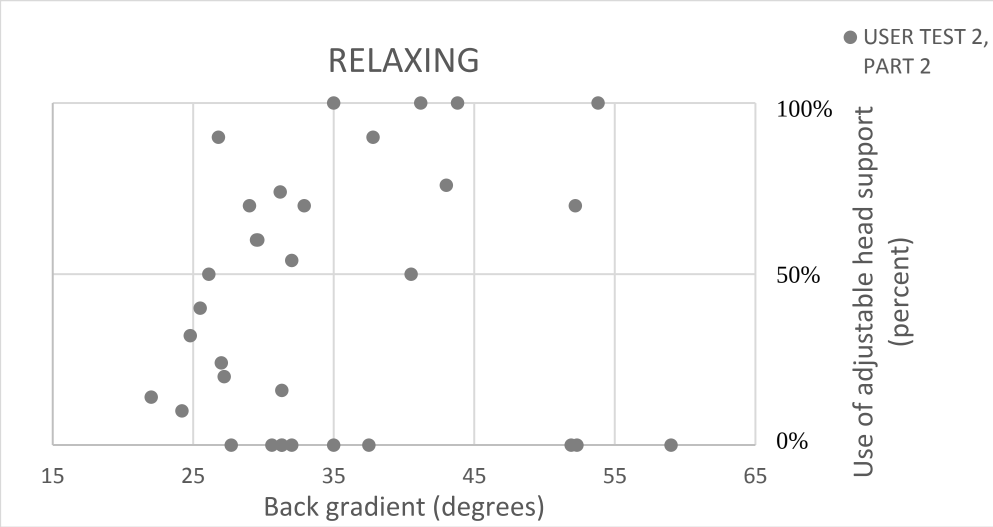
Only using the articulation in the back

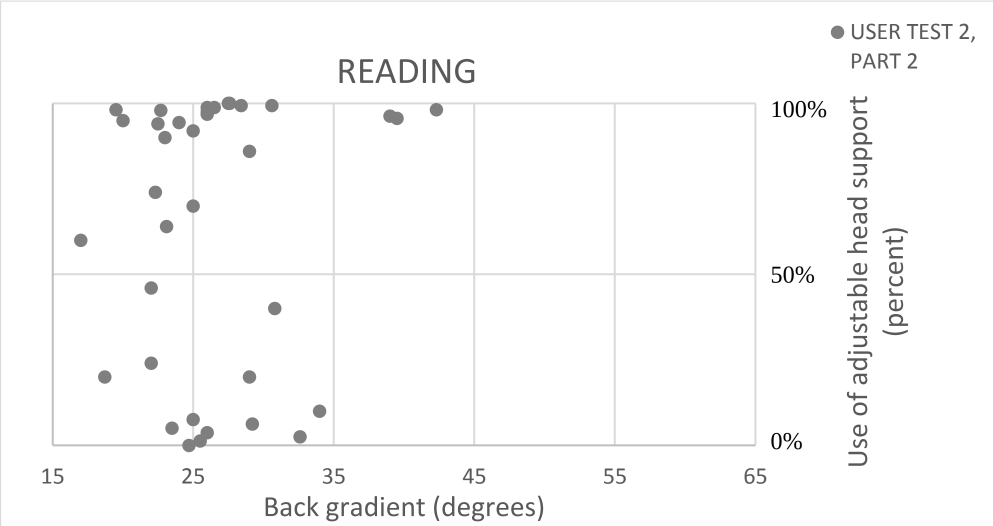


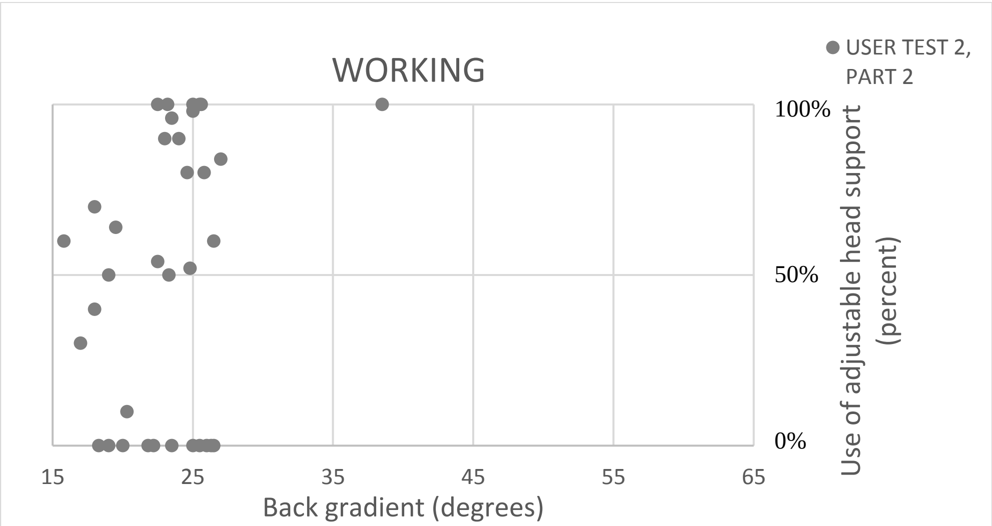




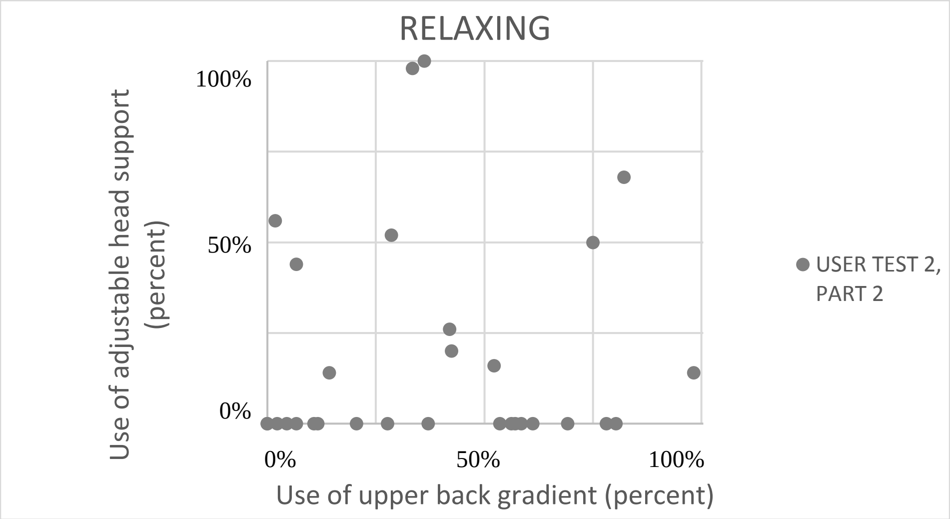
Only using the adjustable head support

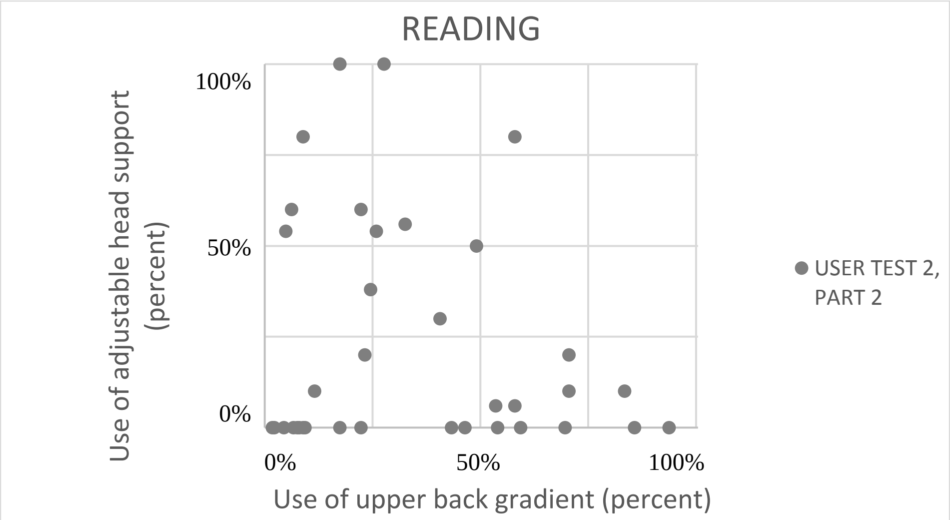


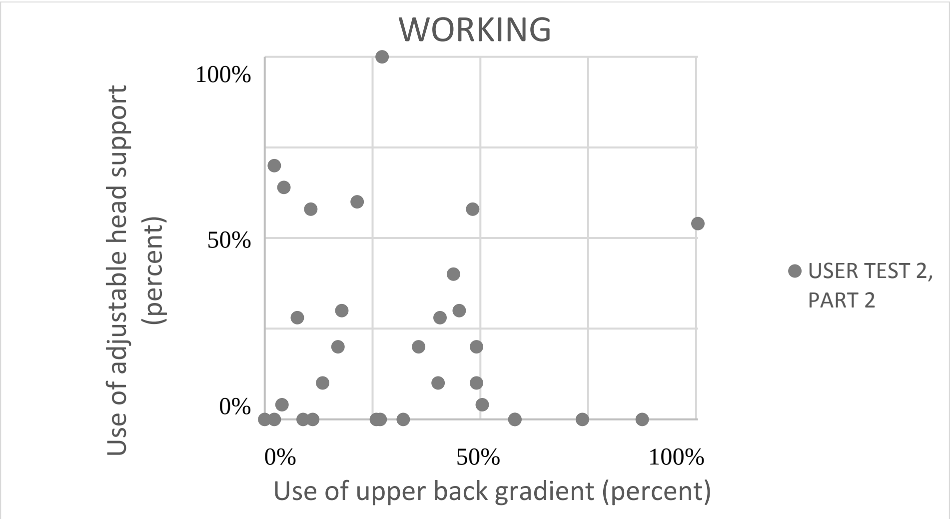




Using both the articulation in the back and the adjustable head support







12.8 H - User test three interview form

Relaxing

Hur upplever du din sittposition/komfort (ett helhetsperspektiv)?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Hur upplever du din huvudposition/komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Hur upplever du din ryggposition/komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Hur upplever du din position/komfort vid dynan?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Hur upplever du din ben- & fotposition/komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Hur upplever du din armposition/komfort?

1	2	3	4	5	6	7	8	9	10
Very Bad				OK				Very Good	

Har bra stöd för kroppen	
Bekväm stol	
Bra justeringsmöjlighet	
Blir avslappnad	
Bältet är i vägen	
Viktigt med kontroll	
Vill kunna se ut	
Skönt att blunda	

Har stöd för huvudet	
Bra med justeringsmöjligheter	
Bra mjuk/hårdhet	
Bra vinkel för huvudet	

Bra med stöd på sidan av nackstödet	
Vill ha stöd i själva nacken	
Nackstödet kommer för högt upp	
Vill ha mer stöd på sidan av huvudstödet	
Nackstödet är för långt ner	
Vill ha mer justering	
Huvudstödet är för hårt	
Får en tryckpunkt högt upp på huvudet	

Får bra stöd för ryggen	
Kan sitta avslappnat	
Får stöd över axlar och skuldror	
Bra hårdhet	
Bra support för svanken	
Bra stöd i sidled	
Saknar svankstöd	

Bra stöd från dynan	
Bra med justeringsmöjligheter	
Bra mjukhet/hårdhet	
Bra stöd i sidled	
Bra med dynförlängning	
Vill ha mer dynförlängning	
För hård	
Med stöd i sidled	

Finns gott om utrymme	
Bra med stöd för vänster fot	
Pedalerna är i vägen	
Vill ha bredare utrymme	
För lite utrymme för benen	
Saknar fotstöd på höger sida	
Vill ha ett ben/vad stöd	

Skönt med armstöd blir mer avslappnad	
Får bra stöd för armarna	
Armstöden sitter för brett isär	
Armstöden är för smala	
Armstöden är för korta	
Armstöden är för höga	
Blir trångt vid b-stolpen	
Bolstren är i vägen	

Upprepa samma sak för Reading och Working

12.9 I - User test three signing form

Medgivande för användartest

Undersökning av positionering och komfort av förarstol vid Autonom körning. Jag har läst och förstått informationen om forskningsstudien och förstår vad som förväntas av mig. Jag har även fått möjlighet att ställa frågor och få svar på det som varit oklart. Jag samtycker härmed till att delta i ovanstående forskningsstudie. Jag lovar att inte avslöja något om testets utformning, mätutrustning eller resultat till någon annan person.

Jag tillåter att det under studien kommer att filmas och tas stillbilder och att dessa används vid analys av studien.

□ **Ja** □ **Nej**

Jag tillåter även att insamlad data inklusive stillbilder återanvänds i framtida forskningsprojekt med likartad inriktning där Volvo Car Group ingår.

□ **Ja** □ **Nej**

Jag samtycker även till att stillbilder av mig publiceras eller visas offentligt i olika sammanhang, t ex i forskningsrapporter, och konferenser.

□ **Ja** □ **Nej**

Ort: ________________________________ Datum: ____-__-__ (ÅÅÅÅ-MM-DD)

Underskrift: ____

Namnförtydligande: ____

<u>För Volvo Car Group</u>:

Göteborg ____-__-__ (ÅÅÅÅ-MM-DD)

Underskrift: ____

Kontaktpersoner

Har du några frågor eller kommentarer, vänligen kontakta Josefine

Josefine Rysjö

Ergonomics 91230

0709 61 33 43

12.10 J - User test three information regarding the test

Information inför användartest på Hällered Proving Ground

Välkommen till vårt användartest. Här är lite information om testet och insamling av data.

Studiens upplägg

I denna studie undersöker vi vad som bidrar till komfort vid olika scenarios för självkörande bilar. Du kommer att få testa två olika stolar i två olika bilar under olika förutsättningar som kommer beskrivas av testledaren. Under testets gång kommer du även att få svara på frågor som testledaren ställer till dig. Testet är dynamiskt vilket innebär att bilen kommer köras på Hällered där du kommer åka med som passagerare under hela testet. Under studiens gång kommer data samlas in i form av videoupptagning, ljudupptagning samt notering av stolspositionering, där samtliga kommer användas för att analysera testresultatet. Testledaren kommer hela tiden finnas på plats om du har frågor och du som testperson behöver inte prestera något, utan endast åka med och uttrycka dina åsikter.

Anonymitet & rätt att avbryta

All insamlad information kommer att behandlas konfidentiellt på Ergonomics 91230- inom provningsteamet och i enlighet med personuppgiftslagen (PUL). När studien avslutats kommer det därför inte vara möjligt att spåra informationen till någon enskild person. Studien skall inte ses som något personligt test, dvs. ingen kommer att bedömas på något sätt. Vi analyserar hur en hel grupp varierar, inte hur en viss person beter sig. Det finns alltså inget bästa eller sämsta utförande.

Du har när som helst möjlighet att avbryta mätningen, t.ex. om det känns obehagligt eller påfrestande. Du behöver inte motivera avbrottet på något sätt, säg bara att du vill avbryta så gör vi det. Du har även möjlighet att avböja din medverkan efter utfört prov.

Sekretess

Studiens syfte, mätutrustning och utförande är strikt konfidentiellt. Vi ber dig därför respektera detta och inte berätta för någon annan person om den information du fått hittills, eller eventuellt kommer att få framöver.

Frågor

Om du har frågor under testets gång är det bara att du frågar testledaren. Skulle du ha några frågor efter testet så är du välkommen att kontakta Josefine Rysjö, 0709 61 33 43.