Seating Positions and Activities in Highly Automated Cars – A Qualitative Study of Future Automated Driving Scenarios

Sofia Jorlöv, Katarina Bohman, Annika Larsson

Abstract The aim was to identify future seating positions and activities in highly automated cars, and explore attitudes towards extra restraint systems.

In total, 52 users aged 11-63, participated in a Swedish qualitative study. The participant was asked to position four seats within a simplified physical environment representing a highly automated car, visualizing a short drive alone, and a long drive with several occupants. The test included a questionnaire and a structured interview.

In the long drive scenario, the most commonly selected activities included movies, games, or socializing with other occupants. The social scenario called for a "living room" position, with front seats rotated between 90° and 180°. Motivation for not fully rotating the seats was to increase the "drivers'" possibility to gain control of the car, if necessary. In the short drive scenario, users could relax, sleep, surf the internet, work, or read. There was no desire to rotate the seat, but to recline the seat to a more relaxed position. Participants were positive toward extra restraints if they allowed for new seating positions.

This study provides information for future seating positions, which may require new passive restraint systems to address future crash safety.

Keywords Highly automated vehicles, seating position, self-driving car, qualitative study, user experience

INTRODUCTION

Highly automated cars may prove to be the most important innovation of the automotive industry due to their potential benefits: enhanced safety, reduced needs for infrastructural investments, improved fuel economy, and reduced congestion are some suggested benefits [1-4]. Highly automated cars are undergoing rapid development. The Google car has completed more than 2.4 billion kilometers in autonomous driving mode [5], and Volvo Cars are planning for one hundred highly automated cars on public roads during 2017 in their DriveMe project [6].

Highly automated cars have the benefit of freeing time for the driver, since there is no longer the need to drive. This new situation opens up for new spatial orientations, since the driver is no longer forced to sit behind the steering wheel [7]. To adapt the vehicle's interior and safety systems for this new way of "driving", there is a need to understand how users would like to sit in highly automated cars, and what activities they would choose to engage in.

There is limited research published in this area, partially due to difficulties investigating the future [8-9]. Pettersson and Karlsson [10] have conducted research in this area, and have developed new methodology to explore user expectations of highly automated cars. The method, called "Setting the Stage", involves placing the user in a simple prototype of the interior of a highly automated car with the possibility of redesigning its interior during the session. User expectations are also related to the individual's view of different user scenarios [11]. This method includes some important elements to facilitate to access to the participants' views of their future needs in automated cars. The participants were given an active role when re-positioning the chairs, which encourage further reflections, a method referred to as Participatory Design approach [12]. Furthermore, by giving the participant a scenario to relate to, Participatory Design serves as a mediating tool to further access information at a deeper level than the first thoughts that come into participants' minds [8,12]. A minimalistic test set-up is chosen, since studies have shown that detailed design limits the participants' fantasy compared to

Sofia Jorlöv, MSc, conducted her Master Thesis at Chalmers University of Technology in Gothenburg, Sweden and at Autoliv Research. Katarina Bohman, PhD, is a Senior Research Specialist at Autoliv Research (corresponding author, + 46 733 61 43 19, katarina.bohman@autoliv.com. Annika Larsson, PhD, is a Research Specialist at Autoliv Research, Vårgårda, Sweden.

simple and open designs [8, 13].

Various sources recognize that up to 93% of all crashes are fully or partially caused by limitations of human perception and attention, so that injuries could potentially be reduced and lives saved through automated vehicles [14-15]. Reducing the negative effects following what is popularly called human error has the greatest potential for reaching “Vision Zero” which has been adopted by many governments [16]. However, today's automated vehicles are also involved in crashes, and the actual safety benefit is not yet possible to determine due to limited data [17][18]. For a conservative attitude toward the future’s automated vehicles, we therefore assume that crashes might not be the same or with the same frequency as today, but will still occur. As there will be crashes with highly automated vehicles, though their exact type is unclear today, there is a need to understand how people wish to be seated in future automated cars. There is a need to understand if current restraint systems provide adequate safety to these new seating positions, or if improvements are needed. The aim of the study was to explore and identify possible seating positions and desired activities in future highly automated cars. Furthermore, the study aimed to explore attitudes towards extra restraint systems.

METHODS

The study was conducted at Autoliv’s booth at a local fair in Vårgårda, Sweden. The fair was intended for the inhabitants of Vårgårda, and the exhibitors were from local sports associations, companies, and different areas of the municipality. Autoliv was founded in Vårgårda and is the largest employer in the area. Participants were chosen randomly from visitors to the fair. Inclusion criteria were potential users of highly automated cars between the ages of 10 and 65. Participants under 18 were included, since they were thought to provide reflections unrestricted by driving experience. Participants partook in the study alone or in groups of 2-3 persons. The duration for each test session varied between ten and twenty minutes. Prior to each test session, participants were informed of the purpose of the study, and that participation was voluntary and could be aborted at any time. Written information was handed out afterwards.

In this study, highly automated cars were defined as SAE level five (fully automated) on the automation scale by the SAE [19].

Design

Based on Pettersson and Karlsson [10], the study consisted of a semi-structured interview divided into three parts. The first part included structured questions about the participants’ gender, age, driving license, car travel habits, and when they believed highly automated cars would be available on the market. In the second part, participants were asked to enter a minimalistic setting, consisting of four chairs in front of a simple sketch of a Mercedes-Benz F015 with a futuristic view in the windows. The area was, constrained by white marks on the ground (Fig. 1), representing the interior space of a future highly automated car.

Fig. 1. The test environment

In the “car” space, participants were presented with different driving scenarios. They were asked to show how they would prefer to sit in these scenarios, and explain what activities they would like to engage in. Participants were encouraged to reflect freely and redesign the “car interior”. Participants aged 18 or older were given two different scenarios; a shorter drive, where they were encouraged to visualize the last time they drove to work (if regularly) or another shorter and longer drive where they were encouraged to envision a weekend, with the entire family taking a trip to their summer home in Varberg (approximately a two-hour

drive). The scenarios were given in random order. Participants under 18 were only presented with the long scenario. The third part of the study consisted of two questions to explore participant attitudes toward additional restraints in highly automated cars. The questions were formulated as:

1. If you were allowed to rotate your seat, would you mind using an extra seatbelt? (Pictures of a girl using an extra belt of a crisscross and rucksack type were shown as an explanation of an "extra belt".
2. If you were allowed to assume a resting/sleeping position (reclined seat), would you mind buckling up in a way beyond the ordinary belt?

Data collection and analysis

Data was collected in the form of notes from the user narratives and photos of the final seating positions. Data was analyzed by conventional qualitative content analysis [20]. This method supports the question formulations and establishes the themes during data categorization and grouping.

RESULTS

The study included 52 participants, 27 men and 25 women, aged 11-63 years. In 18 of the 31 tests conducted, participation was as part of a group. 24 participants in the study were under 18, and consequently, had no driving licenses. Most participants over 18 had driving licenses (34/38) (see Fig. 2). Only participants over 18 were exposed to the shorter driving scenario, which resulted in 18 tests (data was lost in two tests).

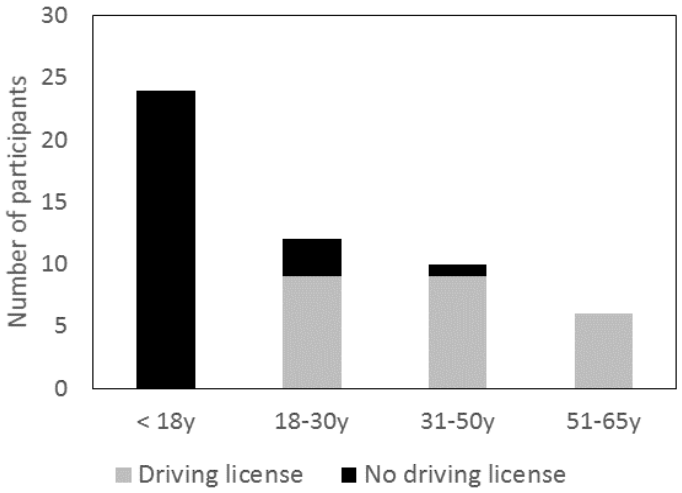

Fig. 2. Age and driver's license distribution of participants

Additional basic facts for participants are summarized in Table 1. 36 of the 52 participants travelled by car daily, but almost all travelled by car at least a few times weekly (50/52). Participants were generally optimistic about the introduction of highly automated cars, and 41 of 52 thought they would be available by 2025.

TABLE 1
FACTS FOR PARTICIPANT CAR TRAVEL HABITS, AND WHEN THEY THOUGHT HIGHLY AUTOMATED CARS WOULD BE ON THE MARKET.

Background data		n
Car travel habits	Daily	36
	2-3/week	14
	2-3/month	2
Highly automated cars on the market	Latest 2020	27
	2021-2025	14
	2026-2030	4
	Far future	7

Seating Positions

In 16 of 18 tests participants chose to sit forward facing during a shorter drive ("For such a short distance it's not worth it to sit rearward-facing."), but for longer drives most participants envisioned the highly automated car as an extended living room. Photos of some seating positions from the longer driving scenario are presented in Fig. 3.

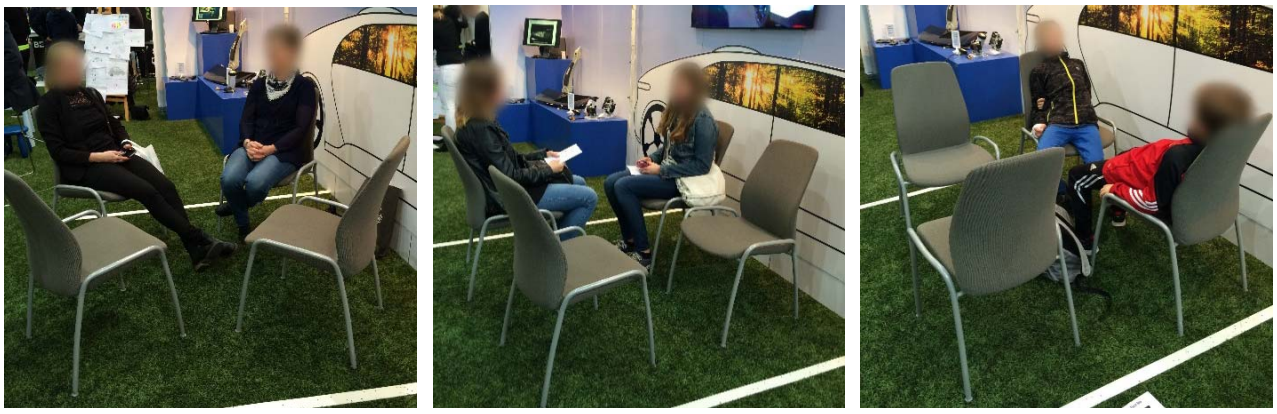

Fig. 3. Photos from the longer driving scenario in three tests. All represent variations of the "living room position".

Primarily five seating positions were mentioned in the study (Fig. 4): the normal forward facing position (A), a conversation position with the front seats rotated inboard (B) and three living room positions where all seats faced each other (C,D,E).

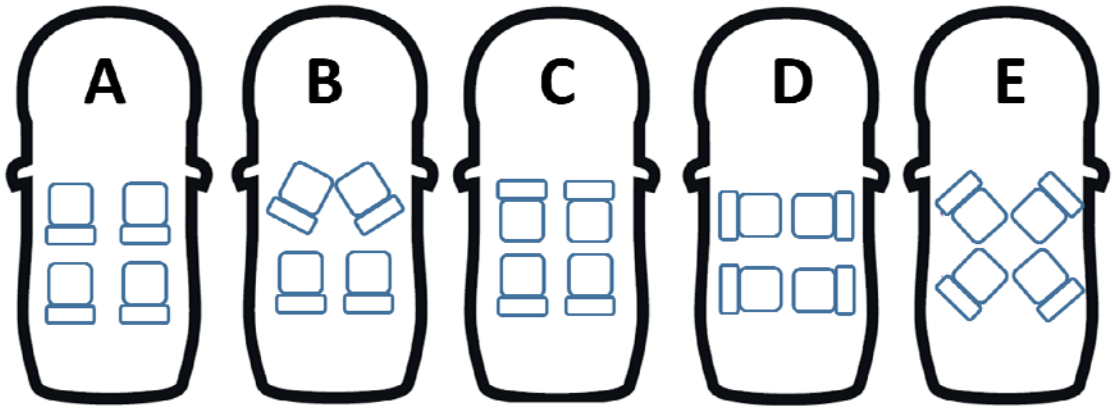

Fig. 4. Top view of five different seating positions from the study.

The most preferred position for longer family drives was the living room position with the front seats rotated 180° (C), followed by the living room positions E and D (12, 6, and 5 tests, respectively). In four tests, participants wanted to sit facing forward (A), and one preferred the conversation position (B). The ability to recline seats for a more comfortable resting or sleeping position were mentioned frequently. 13 wanted to recline the seat during a short drive. During longer drives 20/31 tests participants wanted to recline the seats.

Activities

Participants envisioned how the highly automated car could release time for activities they would not otherwise have time for in their daily lives. "*Oh, imagine being able to watch TV series when travelling to Gothenburg every day. It could be an episode on the way there, and another on the way home*!", "*I would sit rearward facing and play guitar on the way to work*", "*I could rest and be wide awake when arriving home*", "*we would just hang*

out...maybe play board games". During shorter drives, when the "driver" was alone in the car, participants wanted mainly to look out the window, surf the internet, sleep, or rest. When travelling a longer distance with the family, the most popular activities included playing video games (only mentioned by children) and board games, watching movies, and socializing with the other occupants. Fig. 2 presents all activities mentioned.

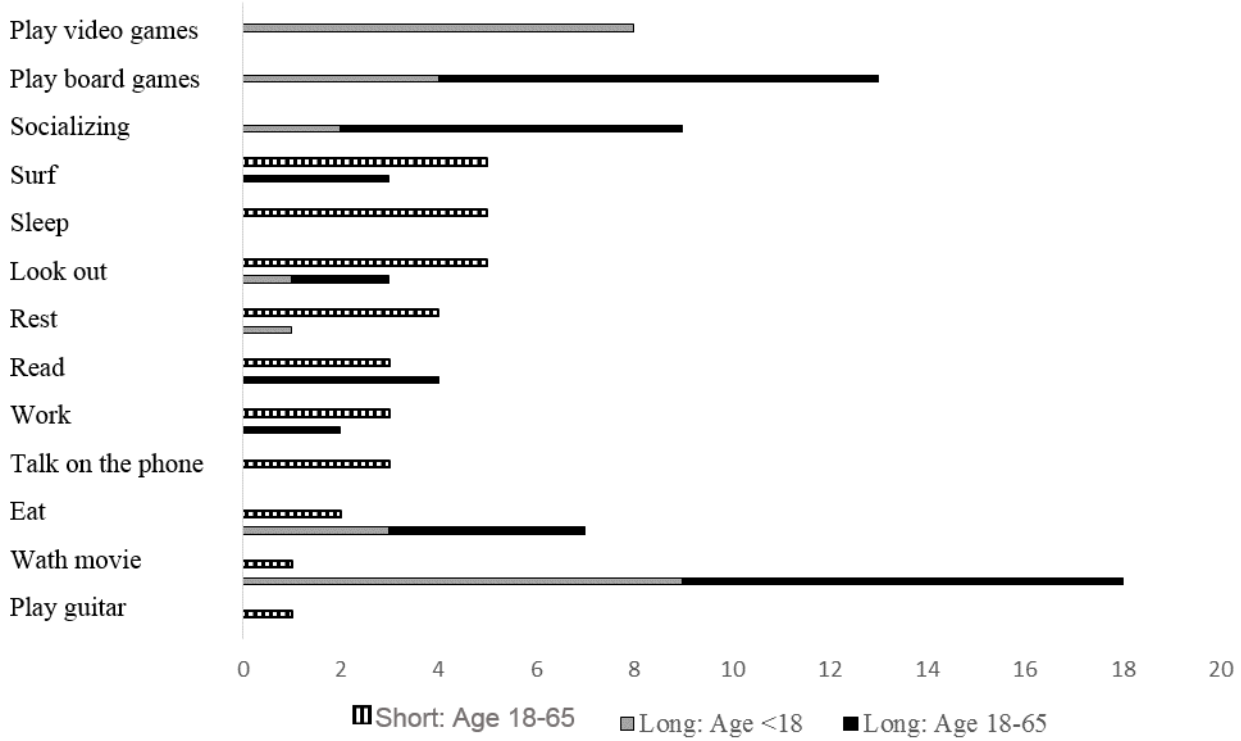

Fig. 5. Activities in a highly automated car: Each test could have more than one activity. Shorter scenario: 18 tests. Longer scenario: 31 tests (11 tests <18 years, 20 tests 18-63 years).

New Interior Design

Participants wanted to redesign the car by more than just rearranging seat positions. 16 tests suggested swivel seats, and 17 of the 23 tested preferring a living room position suggested a table in the middle of the car. All participants under 18 wanted to have in-vehicle screens, while no one above 18 mentioned it. Overall, many participants expressed a vision of the highly automated car as very luxurious. "*It would be a luxurious interior with beverage holders between the seats, a large screen in the rear window, high-quality speakers, voice control of the car, and very comfortable seats - think cinema*!". "*The car would have a "limousine-feeling*!".

Trust in Highly Automated Vehicles

In more than one fifth of the tests (n = 7) participants expressed concerns about trusting the highly automated car; "*the driver must have an eye forward and on the technology*", "*I would have to sit so I can see what's happening*" and "*to begin with, I would like to have a steering wheel*". In two tests participants were concerned about what other drivers would think. One lady expressed this concern: "*It must look like I'm driving, not everyone will have a highly automated car*". Trust concerns for highly automated cars were not restricted to a specific age group.

Attitudes to Additional Restraints

Participants were generally positive to using an extra belt or other additional restraints, if allowed to rotate or recline their seats. 84% of the participants were positive in using an extra belt (question 1) and 87% of the participants was positive in using other additional restraints (question 2), allowing them to rotate the seats. An example of the answers were: "*Yes, absolutely!*", "*Yes, if it's safer!*", "*Yes, it will probably be necessary!*", "*Yes, we should have it today!*", "*Yes, as long as it's comfortable!*", "*Yes, otherwise it would be really dangerous in case of an accident*". Five, and four, respectively, test participants were totally against any additional restraints ("*No, only a lap belt so it´s easier to move*.", "*No, I prefer not to use the seatbelt at all. It can get stuck in case of*

a crash.", "*No, I feel so trapped with a seatbelt, and I get carsick.*"). In three tests, participants were neither positive nor negative about using an extra belt when rotating the seat (question 1). They argued that "*it would have been uncomfortable, but worth it if safer*".

DISCUSSION

A qualitative study was carried out to identify future seating positions, what future users wanted to do while travelling, and to explore attitudes toward additional restraints in future highly automated cars. The participants were placed in a simple environment representing a highly automated car, and were asked to visualize a longer and a shorter driving scenario. Participants were then asked to show how they would prefer to sit in these scenarios, and explain what activities they would like to engage in. The younger participants were positive to the study, and contributed with a wider range of answers. For instance, it was natural for them to have an in-vehicle screen, while no participant over 18 even mentioned it. There was also a different attitude to additional restraints among younger participants. This is important knowledge for designing future highly automated cars.

Seating Positions and Activities

Long scenario: In an internet survey, looking out the window and watching the road was the most popular activity [18]. Other popular activities were texting or talking with family and friends, sleeping, watching movies or TV. It is important to note that the question in the survey stated neither the length of the drive nor the number of occupants in the car. In the current study during longer drives, participants envisioned the car as a place for socializing, watching movies, playing board or video games, or just "hanging out". This reflected the seating positions, and one example, with all seats oriented towards each other in a so-called living room position, was the most popular position, often with the seats in a reclining position. Pettersson and Karlsson [10] reported similar result from the pilot study that was performed during their method development of "Setting the Stage".

Short scenario: Almost all participants wanted to be seated forward-facing during shorter drives, preferably with a reclining seatback. Looking out, sleeping, resting and internet surfing were the most popular activities, similar as a previous study [18]. Automotive manufacturers often promote working in the highly automated car [17]-23]. This was also a desired activity in previous studies [10], but was only mentioned in this study in 3 of 18 short drive scenarios, and 2 of 31 long drive scenarios. The desire to work in the car depended on the type of work and travel time. Many participants in this study had short travel times and physical work, such as a lumberjack or farmer, which explains why working in the car was not a popular suggestion. In larger cities, where people generally spend more time in traffic jams, office work is more common, so working would likely be a common way for city dwellers to spend time in a highly automated car.

Interior Design

Participants envisioned the highly automated car as very luxurious. This was commonly expressed as a "limousine feeling", with a coffee machine, theater seats, and large screens. The luxurious feeling was much more prominent for the longer driving scenario. It was clear that participants envisioned the highly automated car as more than just a means of transportation. However, the participants did not reflect upon that highly automated cars may be part of the public transportation, which normally have limited luxury feeling to their interior design.

Today's cars are parked 96% of the time [24]. This fact has raised a discussion about car ownership and the potential for highly automated cars [2], [25-27]. John Zimmer, co-founder of the transportation network "Lyft", believes highly automated cars will turn transportation into a service. He argues that this service could be more flexible, and could offer a car for every occasion [27]. This could be a way to satisfy the desires mentioned in the study. A more luxurious car could then be the choice for the family weekend, and a cheaper, simpler car could be used for commuting. Changes of transportation mode are already ongoing, the increase of car share companies supports this future vision, of less people owning a car but instead accessing a car when it is needed [28]. Furthermore, with people being frequently connected on social media, also "share-a-ride" solutions have also increased lately. However, there may be a conflict, if people have similar needs, of accessing small vehicles during the week at the same time as well as the need of larger vehicles during the weekend.

Safety Issues and Attitudes

The new seating positions in highly automated cars raises several safety issues. Airbags and seatbelts are in general not adapted for positions other than the upright forward facing position, and might be insufficient when starting to rotate or recline the seat. In a living room position, where occupants are facing each other, interaction between the occupants might be a risk in a crash. Free flying objects are an additional safety hazard arising from devices brought into the car. In this study, gaming consoles, smart phones, coffee cups, laptops, books and tablets were mentioned. These devices could turn into dangerous projectiles in case of a crash, and there is an even bigger issue when occupants face each other in a living room position. The safety systems need to be evaluated for these new seating positions in highly automated cars.

In this study, the attitude towards additional restraints was explored. Additional restraints are one way to handle passive safety when reclining or rotating the seat. Generally, participants were positive to using extra belts or other restraints if allowed to recline the seat for resting or sleeping, or rotate the seat to a living room or conversation position. Children were more positive than adults. It was not strange to them at all to use more restraints than an ordinary seatbelt, as long as they were safer, and they had many suggestions about different restraint solutions. The positive attitude towards additional restraints in highly automated cars might be unique for Sweden. Swedes are known to have high safety awareness in general, and seatbelt usage is high with most children travelling in a child restraint until the age of 9 [29]. The attitude to additional restraints in highly automated cars needs to be explored further in other countries.

Trust

Trust was a concern to all ages in contrast to J.D Powers' study, which found that younger users have more confidence in technology. Other studies have shown that trust in automation is age dependent [30-31]. In this study, some participants explicitly stated concerns with trusting the highly automated car, and several statements also indicated a lack of trust. Position D in Fig. 4, with all seats rotated inboard 90°, was one example. The participants motivated this position due to the ability of the "driver" to keep an eye on the road and control the technology, while providing a better view forward for all occupants. This position has not been seen in other studies, or in any highly automated concept car. In the other living room positions, configuration C and E in Figure 4, the driver was rotated by only 90° in two tests, with the same motivation as above.

Trust was also an issue in the study by Pettersson [11]. Besides similar concerns as expressed in this study, participants in Pettersson [11] also shared another view. They worried about the car's route planning, since a wrong decision could, at worst, lead to an additional hour in congested traffic. That study was performed in Los Angeles, California, where it is likely to raise different concerns from those in a small town in Sweden. It is important to understand the variety of concerns users have, depending on their driving habits, when developing the future's highly automated car.

Motion Sickness

Only a few participants in this study considered motion sickness a potential problem in an highly automated car, similar results were reported by previous studies [7],[10]. These participants probably had recurring bouts of motion sickness. Various studies report that motion sickness could be a problem in highly automated cars, and affect more users than in today's cars [3], [32], [33]. The reason is partially that the users of future cars could no longer control the direction of movement, and that the new seating positions and activities lead to a non-forward gaze. Different initiatives to decrease the frequency and severity of motion sickness have been found: active suspension [3], augmented reality [34], new interior design, and specific in-vehicle screens [32].

Method

The method "Setting the Stage" developed by Pettersson and Karlsson [10] was used in this study. In the pilot study [10], participants were in a group, and had a shorter session, but in a later study [11] the single participants were exposed to longer session. In this study, the test session was relatively short, 10-20 minutes, due to the constraints of a fair. Some participants were in a group of 2-3 persons, and some were alone, depending on how they visited the fair. In this study it was beneficial to have the participants in smaller groups. Discussions began spontaneously, and limited intervention was needed from the test leader. Participants argued back and forth between options, inspiring each other with various ideas. In all tests the group ended up with a consensus, even if there were different opinions from the beginning. This also resulted in groups having a

constructive test session.

Limitations

This study was limited to a minimal test set-up, by only giving the interior constraints in terms of white lines on the floor, offering the participant to re-design the interior by moving the simple chairs. However, the participants were encouraged to describe in words, what other future expectations and desired they had on the interior. So, even though the simple chairs did not offer the possibility to recline them, the participants described that desire as well as other interior details such as luxury comfortable seats reminding them of cinema seats, tables and built-in screens. No restraints were included in the set-up, however some attitude questions regarding restraints were asked, resulting in participant discussing the need of restraints in highly automated vehicles and especially the need of comfortable restraints.

This study did not investigate the effect on ingress or egress in the various configurations. This needs to be addressed in future studies.

This study had only two driving scenarios: one with the occupant travelling alone, and one where the entire family travelled together. A scenario with two occupants in the car was not included, which explains why the conversation position hardly appeared in the study. The conversation position is mainly for two occupants, and has been seen in various concept solutions [35-36].

This study was performed in a small town in Sweden and should not be generalized to the population at large. Other studies are needed to understand if and how the desires and attitudes differ culturally and geographically.

This study was limited to static sitting limited in time, to further understand if various seating configurations are desired and work well during drive, dynamic testing and testing over a longer period of time is needed as well. Especially to understand the influence of motion sickness. Given the limitations of exploring seating positions in vehicles that are not yet available to the public, “Setting the Stage” was still found to be useful. Mainly, the dynamic focus group-like setting and the discussions focused to specific driving scenarios were found to set participants in a futuristic but real mind-set. The focus on the expectations of the general public are also a benefit to future studies, where safe ways to explore seating positions can be based on these results.

CONCLUSIONS

This study has provided important knowledge about user desires and attitudes to seating positions and activities in highly automated cars. During long drives, with several occupants in the car, there is a desire to rotate the seat to a living room position. During shorter drives alone, users would prefer to maintain the forward facing position, but with the seat reclined to a more relaxed position. The new seating positions with rotated and reclined seats will challenge today´s safety systems, but participants were positive to extra restraints if that allowed for more freedom when choosing a seating position. The authors conclude that the “Setting the Stage” method used provided a convenient and rewarding approach for a first exploration of seating positions in highly automated vehicles. The seating positions and design solutions in this study should however only be regarded as indicators of user expectations, and further studies are needed.

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