

OCCUPANT ACTIVITIES AND SITTING POSITIONS IN AUTOMATED VEHICLES IN CHINA AND SWEDEN

Martin Östling

Autoliv Research
Sweden

Annika Larsson

Veoneer Research
Sweden

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ABSTRACT

To save lives in future traffic crashes, we need to understand what people will be doing in fully automated vehicles during various types of trips, and shape the restraint systems to protect for the resulting postures. This paper describes how participants of our study in China wished to sit and what they wanted to do as occupants during different trip scenarios, and how they compare to participants in a previous study in Sweden.

Both studies used the “Setting the stage” method to explore these future situations. The “stage” consisted of a space with four chairs, designated as a vehicle. This minimalistic setup has been claimed to stimulate the imagination to a greater extent than more developed designs, because it allowed participants to play a more dynamic role when designing and expressing their expectations of a fully automated vehicle, within the constraints of the trip scenarios posed to them.

The fully automated vehicle was described as a car that doesn’t need to be driven at all; upon entering, the occupant only has to dial in a destination. Three trip scenarios were presented to the participants in China. After each presentation, participants were encouraged to discuss among themselves what they imagined they would do during such a trip, and how they would like to be seated. Participants could redesign the “vehicle” interior as they wished by manipulating the position of the chairs as they were speaking. An observer took notes and photos as participants were discussing.

For a short trip, to or from school or work, participants in China saw themselves seated in a traditional forward-facing, upright position. For weekend rides or longer trips with family, the traditional seating position and a living-room style position with participants facing each other were most commonly mentioned. Participants also suggested a 45- or 90-degree rotated version of the living room position and being able to sleep in a horizontal position. Activities mentioned include relaxing, watching movies and working.

Participants in both China and Sweden expected fully automated vehicles to allow for more varied sitting and more comfortable seats. Reclined seats were frequently mentioned, as were swivel seats. Both groups expected the fully automated vehicle, more than vehicles today, to support activities normally not done when driving. Participants in China also wished to lie down during longer trips. The requests for new sitting positions will require novel restraint systems—for example, new seatbelt concepts (such as belt-in-seat) and new types of airbags—as well as new tools to assess the systems’ safety.

INTRODUCTION

To keep occupants safe in the future as well as today, we need to understand what people are doing during various types of trips. Factors such as the length of the journey, the vehicle interior, and who will be in the vehicle are likely to have an impact on occupants’ behaviours and desires. For a fully automated vehicle, seating configurations will be influenced by the operational design domain (ODD) it is designed for. The ODD will very likely be different for different types of trips, as a commute may be different than visiting family or going on holiday. These trips are likely to involve different speeds as well as different road layouts and traffic environments; thus the likelihood of various types of crashes changes. Fully automated vehicles allow vehicle occupants to interact more, as there is no need for one person to focus on driving. The passenger car industry is adapting, trying to understand and predict how occupants in such vehicles will behave. This has been expressed in different types of concept vehicles [1-3].

To understand how occupants may wish to be seated in the future, we performed two studies: one in a small town in Sweden and one in a mega-city in China. The first study took place in Vårgårda, Sweden, a town with 5000 residents where the traffic environment consists mainly of rural traffic for daily commutes and highway driving in the countryside for longer weekend journeys. The study in Sweden was conducted in 2016 and described by Jorlöv in 2017 [4]. The second study was performed in 2017 in Shanghai, China, a city of roughly 24 million residents with mega-city daily-commuter traffic during the week and highway traffic for longer weekend journeys. This paper presents results from the participatory observation study conducted in Shanghai, China describing how people expect to be seated during trips of varying lengths in fully automated vehicles and discusses these results in relation to the previous participatory observation in Vårgårda, Sweden.

METHOD

The study used the “Setting the stage” method [5], allowing participants to play a dynamic role, using their imaginations when designing and expressing their expectations for a fully automated vehicle within the constraints of the trip scenarios posed to them. “The method’s ambition is to move the participants into a tomorrow, different from today, but importantly still situated in their own life” [6]. The “stage” consisted of a space with four chairs, set up as a contemporary vehicle (Fig.1). The minimalist setup has been claimed to stimulate the imagination to a greater extent than more developed designs [6]. Two stages were set up at a shopping mall in Shanghai, similar to the setup used at the local fair in Vårgårda [4]. A convenience sample was selected by randomly choosing participants from visitors at the mall. The inclusion criterion for participants was an age between 10 and 65 years, to include drivers of the future as well as the older driving population, who may have different needs and preferences. Participants entered the study alone, in pairs, or in larger groups of up to four people (Fig.2). The duration of each test session was 10-20 minutes. Participants were informed that participation was voluntary and that they could abort at any time without stating a reason. For their participation, they were given a coffee voucher.

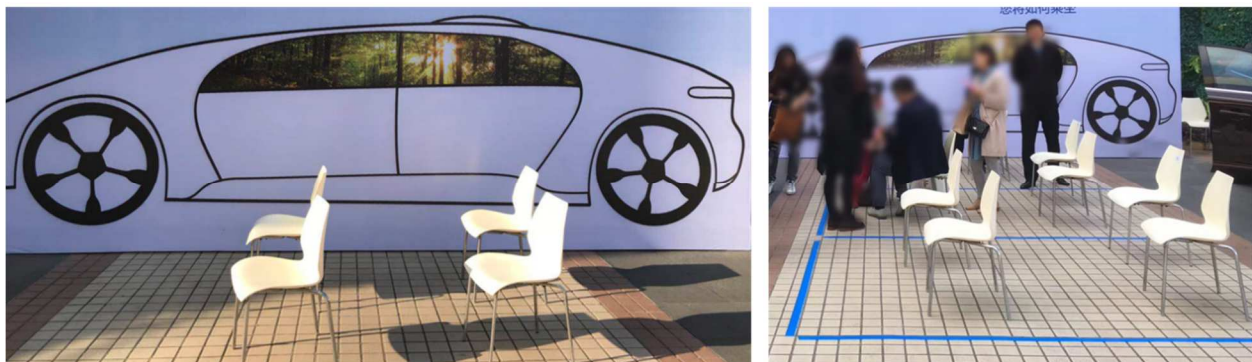


Figure 1. Photos from the minimalist setup of a vehicle interior



Figure 2. Photos from participant interviews

Procedure

In accordance with Pettersson and Karlsson [5] and the study in Sweden [4], the study in China was conducted in three parts, starting with a background questionnaire with structured questions about gender, age, habits related to car travel, and possession of a driving license. Participants were then given a description of the vehicle automation level targeted in the study and were presented with three trip scenarios, one at a time. Finally, the participants were asked about the use of extra restraints.

The fully automated vehicle was described as a car that doesn't need to be driven at all; upon entering, the occupant only has to dial in a destination—Level 5 automation, according to the Society of Automotive Engineers (SAE) [7].

In total, three trip scenarios were presented to the participants in China: riding to work or school, a weekend trip with family, and a longer vacation trip with family. In Sweden, two trip scenarios were presented, corresponding to scenario one: a shorter journey to work alone, and scenario three: a longer vacation journey with family [4]. After each presentation, the participants were encouraged to discuss among themselves using the “vehicle” interior what they would imagine they would do during such a trip, and how they would like to be seated. Participants could redesign the “vehicle” interior as they wished and manipulate the position of the chairs as they were speaking. By this procedure, both body and mind of the participants were involved in the reflective process.

In the end of the session, after the third trip scenario, the participants were asked two questions to explore their attitudes toward use of additional restraints in fully automated vehicles. The questions were formulated as:

1. If you were allowed to have a resting/sleeping position, would you mind fasten you in any additional way beyond the ordinary seat belt?
2. If you were allowed to rotate the seat, would you mind using an extra seat belt?

Data collection and analysis

Two observers per participant group collected data by taking notes and photos as participants discussed among themselves for all three scenarios. The data were analysed by conventional qualitative content analysis [8], which supports the question formulations and establishes the themes during data categorization and grouping. For ease of use, the observers' notes consisted of both free-form entries and a set of illustrated seating configurations based on the study in Sweden [4].

Participants

In China, 100 participants took part in all three trip scenarios used in the study. In Sweden, 18 participants were part of the study for the shorter trip scenario, and 31 participants for the longer trip scenario [4].

RESULTS

We present participant information, suggested seating positions, preferred activities, and further comments—and finally, participant attitudes toward additional restraints.

Participant information

Of the 100 participants in China, 51 were men and 49 were women; 77% were holders of a driving license. The ages varied from 10 to 59 years; 6% were younger than 18, 34% were between 18 and 30, 52% were between 30 and 50, and 8% were more than 50 years old. The majority of the participants, 67%, travelled daily by car, 18% travelled two to three times per week, and 15% travelled only two to three times per month. In general, the participants were optimistic about introduction of fully automated vehicles in China with 80% believing that it would happen before 2030.

Participants' suggested seating positions are reported per trip scenario:

Trip scenario 1 – Ride to work or school

In the trip scenario 1: Ride to work or school, most participants (56%) preferred the traditional forward-facing seating configuration A) (Fig.3) while 16% selected the “Face-to-Face” seating configuration B), also called the living room position. Another 5% selected C), with the front seats rotated slightly inboard. Variants of B) were suggested by 4% (four participants), with all seats rotated toward the centre, configuration D), or all seats rotated 90 degrees inboard. Another 4% wanted to be able to merge two seats into a bed, E). The remaining 15% proposed different layouts, with

variations in the number of seats, which seats were rotated (and how), or simply having all seats rotatable to any angle. One such proposal was rotating the seats outward to better see out of the windows.

Trip scenario 2 – Weekend ride with the family

In the trip scenario 2: Weekend ride with the family, 32% of the participants elected to sit in the traditional forward-facing seat configuration A). A similar number, 27%, chose the “Face-to-Face” seating configuration B) while 8% opted to rotate the front seats slightly inboard, like configuration C). Another 15% suggested variants of B): either all seats rotated toward the centre, as in D), or all seats rotated 90- degrees inboard. Two participants (2%) wanted to be able to merge two seats into a bed, E). The remaining 16% proposed other seat configurations with variations in the number of seats, which seats were rotated (and how), or simply having all seats rotatable to any angle. One example was simply rotating the front passenger seat 180 degrees.

Trip scenario 3 – Longer trip, going on vacation with family

For Trip scenario 3: Longer trip - going on vacation with family, 29 % of the participants selected the traditional forward-facing seat configuration A), and 30% the “Face-to-Face” seating configuration B). Three participants (3%) suggested rotating the front seats inboard, configuration C), and 20% selected to have all seats rotated toward the centre as a variant of B), either as D) or with all seats rotated 90 degrees inboard. For this longer trip, 8% wanted to be able to merge two seats into a bed, E). The remaining 10% suggested some other type of configuration, with variations in the number of seats, which seats were rotated (and how), or simply having all seats rotatable to any angle.

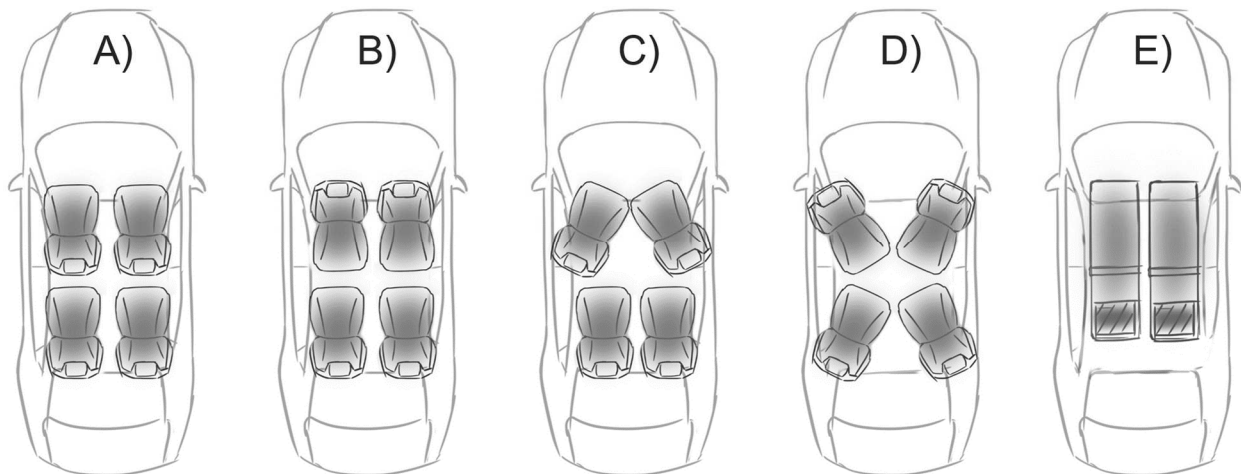


Figure 3. Variants of seat configuration: A) represents the traditional forward-facing seat configuration, B) the “Face-to-Face” living room position, C) inboard rotated front seats, D) all seats rotated toward the centre, and E) front and rear seats merged into two beds.

Activities

For Trip scenario 1, a short trip to work or school, the activities mentioned most often were relaxing (35%), playing on their phone (35%), watching a movie (22%), or working (20%). For Trip scenario 2, a weekend trip with family, chatting (30%), relaxing (28%), watching movies (25%), eating (22%), or playing on their phone (19%) were the preferred activities. For the third trip scenario, a longer vacation trip with family, activities such as relaxing (52%), watching movies (40%), eating (28%), and sightseeing (19%), were mentioned most often.

Other activities stated less often in the various trip scenarios were doing yoga, listening to music, taking phone calls, and playing board games or cards.

Interior design

Participants imagined that the interior design had features such as screens, a table, comfortable seats with the possibility of reclining, panoramic windows, and glass-transparency adjustment. Other suggestions included interior mood lighting, a conferencing system, rotatable seats, beds, a TV, an air purifier, a freezer, a coffee maker, and a karaoke machine.

Attitudes to additional restraints

When asked about the use of additional restraints, 63% of the participants were positive about using an extra seatbelt for a rotating seat, with the argument that safety is very important. Some of the participants pointed out that they would always use the extra seatbelt and that it was especially needed when they were resting, but it had to be comfortable. Other participants, on the other hand, pointed out that the extra belt (and even the traditional seatbelt) would hinder them from doing what they wanted to do. Most participants who did not want to wear an extra seatbelt considered it unnecessary and uncomfortable. Notably, the comfort aspect of the extra belt was indicated as important in both the positive and the negative responses. Two of the participants requested that the extra seatbelt have an automatic unlocking function, since an additional seatbelt could make it harder to escape from the car in the case of an accident.

DISCUSSION

A qualitative study was carried out to identify future seating positions and potential activities in fully automated vehicles. In both Shanghai, China and Vårgårda, Sweden, participants were placed in a minimalist setting, conceived to spark their imaginations regarding the design of fully automated vehicles and to direct their thinking as little as possible. Participants were asked to visualize three scenarios with different trip lengths. The test leaders encouraged participants to explain what activities they imagined themselves doing, and how they would prefer to sit, during each trip scenario.

The results from the study in China are first summarised, before a comparison to the study in Sweden is made.

Results from the study in China:

The results from the study in China are from a larger group than the results from the study in Sweden, which from a qualitative standpoint does not mean they are more or less valuable. Generally, qualitative results tend to converge after seven participants from one user group [9].

Seating positions and activities

For the trip scenario with shorter traveling time, more than half of the participants wanted to be seated traditionally forward-facing. For the longer traveling time this was reduced to one third with the living room layout being as common. If all versions of “face-to-face” layout were summaries for the longer traveling time, B) and D), those summarised to almost half of the participants.

Activities that came up for all three trip scenarios were either the socializing kind (chatting, playing cards or boardgames, taking phone calls), or the relaxing kind (playing games on their phones, reading, watching movies, listening to music or just doing nothing). Other activities mentioned were working, eating, sightseeing, and yoga.

Interior design

Participants envisioned the fully automated vehicles as having a setup more like an airplane than a conventional vehicle, with a functional chair and a table for other activities. The desired functions of the chair include reclining, providing massage, and being able to flatten out horizontally. Vehicle width would be affected by the occupants’ desire to have chairs that can be rotated. The features desired are fairly luxurious, with a focus on comfort and privacy (such as extra soft or ergonomic seats and the ability to adjust window transparency). Other desired services are more common in homes than in vehicles—like screens, coffee makers, air purifiers, freezers, and karaoke machines.

Results from the study in China compared to results from the study in Sweden

The preferred seating positions were similar for Shanghai and Vårgårda, despite the differences in traffic and community size.

Seating positions and activities

The authors of the study in Sweden [4] suggested that people in mega-cities may wish to work in their cars more than people in small rural communities. The results of the study in China do not support this hypothesis. Working does come up as an activity in the shorter commute to work, but relaxing or playing on one's phone are far more commonly mentioned. Participants' occupations were not recorded, so it is difficult to know whether this preference is attributable to occupational requirements or personal preference.

Participants in both studies mention relaxing or sleeping as preferred activities for all trips, but for longer trips the participants in Sweden did not mention this as frequently. Instead, at least for the longer trips, their most frequently-mentioned activities were watching movies and TV series.

Phones or screens are important for in-vehicle activities in both China and Sweden, both as part of the longer, more social trip and the shorter, more individual one.

The ability to recline seats, even fully horizontal, was important for participants in both China and Sweden.

Interior design

The participants in both countries envision fully automated vehicles as luxurious, with features that cannot be found in public transport vehicles or mass-market cars. In Sweden, participants even mentioned a limousine feeling, whereas in China participants focussed on a multitude of comfort features. At the same time, both sets of participants appeared to see their daily commutes as similar to those of today, with seats in their traditional forward-facing position. During longer trips, however, the socializing part of travel may become more prominent, with participants in both studies wishing to face their co-passengers.

Safety implications and need of novel restraints in fully automated vehicles

It has been claimed that fully automated vehicles have the potential to reduce the number of crashes [10], but avoiding all crashes in mixed traffic with human drivers is impossible for several reasons: hardware failure, software failure, sensing mistake from the fully automated vehicle, or irrational human behaviour with too little time for the fully automated vehicle to react [11]. Occupant restraints (i.e. belts and airbags) and crash-safety evaluation therefore remain important. Actually, crash-safety evaluation might be even more challenging in the future than it is today, due to the new sitting positions and interior designs that are expected. The voluntary guide from NHTSA [12] encourages the crash-safety evaluation of any alternative planned seating configuration. However, current restraint systems are only tested in the traditional sitting position in homologation and consumer testing, in either pure frontal or pure side crashes. Improved restraints would most likely be needed to provide equal protection for occupants in any future alternative seating or interior configurations.

Restraints—and their evaluation methods—need to evolve in a world of fully automated vehicles. If the seats are allowed to rotate, translate, or recline more than they do today, we foresee the need for a new type of restraint, adapted to the seat position (e.g., seat-integrated belts and airbags). If, for example, the seat back is reclined, the risk that the lap belt will slip over the iliac wing and submarine into the abdomen increases [13]. Improved pre-tensioning of the lap belt, in combination with an inflatable seat pan structure, has been proposed to reduce the risk of submarining in reclined positions up to 45 degrees [13]. To improve the restraint function of the belt even further, an additional shoulder belt running across the opposite shoulder (criss-cross belt) can be beneficial, as the load from the seatbelt is more widely distributed than it is with a standard 3-point belt [14-15]. If the seat is rotated, the extra belt would also help keep the occupant from sliding out of the belt, which might happen with a standard 3-point belt [16]. Both the study in China and the study in Sweden showed positive attitudes towards an extra belt and encourage further efforts towards fleet-wide implementation. Another example of the possible evolution of the 3-point belt is the inflatable belt, proposed to protect the occupant from sliding out of the seat belt in a 45 degree angled impact [17]. An example of how the airbag could evolve is described in [18]; an airbag in the seatback which has the potential to protect the occupant in any seating position. As a further challenge, the restraint system also might need to protect the occupant from free-flying objects such as laptops and tablets in seating configurations B) and D) (Fig.3) as in those seating configurations such object might become free-flying with the risk to hit the persons sitting in the opposite position.

Protection is needed for all occupants, whatever their characteristics (stature, sex, age, etc; a diverse population). Therefore, we encourage the use of human body models (HBM) that could be morphed to better represent the full diversity of the human population than current crash test dummies, which are currently limited to three sizes: the 5th percentile female, 50th percentile male and 95th percentile male. Additionally, current crash test dummies are only validated for pure frontal or pure side impact in defined sitting positions. Since passengers of fully automated vehicles are likely to sit in rotated and/or reclined seats, assessment tools that are designed and valid for omnidirectional loading will be required. Further refinement of HBMs is necessary to accurately represent kinematics and predict injuries in new sitting positions with oblique loading.

Motion sickness

Motion sickness can occur when humans are exposed to motion that they seldom experience. The symptoms (sweating, pallor, flatulence, burping, salivation, apathy, etc.) vary between people in the order of occurrence and in their magnitude [19]. When travelling in a moving vehicle, a person can develop motion sickness if there is a conflict between visually perceived movement and the vestibular sense of body movement. Typically, this can happen when a person in a moving vehicle does not watch the road ahead [20]. The problem normally increases if the person does not control the motion; vehicle passengers experience motion sickness more frequently than drivers do [21]. In fully automated vehicles, everyone will become a passenger, which will lead to an increased risk of motion sickness [19]. Further, travelling facing backwards was found to lead to a significant increase in motion sickness symptoms [22].

In summary, although positions other than forward-facing and activities not focussing on the road are more likely to induce motion sickness [19-20, 22], the participants in the two studies did not always want to face forward. Moreover, they expect to be able to read, watch movies, play games and perform similar activities which divert the gaze from the road. Providing a solution to motion sickness in fully automated vehicles will be necessary to fulfil their expectations.

Limitations

The study in China was performed one year after the study in Sweden, and research on vehicle automation has evolved and new systems have been released during that time. This time lapse may have influenced the results, as participants' views may have shifted. However, the activities imagined by participants in China and Sweden were slightly (but not very) different; we can assume that participants primarily extrapolated from their current activities, which are unlikely to have shifted much in a year.

The trip scenarios in the two studies were somewhat different. This discrepancy makes it somewhat difficult to compare the trip scenarios between countries. The reason for providing different trip scenarios was to allow participants to consider a wide range of activities.

The "Setting the stage" method [5-6] has its own limitations (which are, at the same time, its strengths). The method provides a way for participants to visualize the future of mobility for themselves, without the constraints of a life-sized set on their imaginations. Further, since the study is conducted in a static setting, the limitations imposed by a moving vehicle, possibly on bumpy roads, and the risk for motion sickness, were not considered. Performing a study in a more realistic setting, such as on the road, may provide more information, but at the same time such a study would be difficult to perform from a safety perspective.

CONCLUSIONS

We have presented a study of future seating positions in fully automated vehicles using the "Setting the stage" method [5-6] with participants in Shanghai, China, and compared these results with previous results from Vårgårda, Sweden [4]. This comparison demonstrates that user expectations are similar, they expect fully automated vehicles to allow reclined sitting, versions of a living room setup, and more comfortable seats with screens and tables for various activities. New sitting positions will require the development of novel restraints for in-crash protection. Seatbelts and airbags need to adapt to new interiors; we have discussed some promising solutions such as seat integrated belt, additional shoulder belt, inflatable belt and seat integrated airbags.

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