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Crash or hug? – A study on how pedestrians perceive safety of autonomous cars in parking garages

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

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Department of Industrial and Materials Science
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Abstract

The car industry is a line of business that constantly advances. The new technology has made it possible to let vehicles have driver support features to help the driver or overtake the steering. Automated Valet Parking (AVP) is an automated driving feature for autonomous vehicles, whose technique implements an automatic self-driving drive-up and park service in parking garages. The pedestrian-vehicle interaction har poorly been explored, especially in the context of a parking garage where the vehicle's speed is slow.

For this reason, this master's thesis project has been to conduct a study about the interaction between pedestrians and self-driving vehicles in parking garages. The aim has been to investigate how autonomous vehicles' behaviour should be managed and perceived safety for pedestrians with the aim to deliver driving guidelines to autonomous vehicles in parking garages to maintain a perceived safety for pedestrians.

The project developed several user tests in a parking garage, applied with a Wizard of Oz approach to illustrate a self-driving vehicle. The participants were acting pedestrians, and the experience of interacting with an automated vehicle was gathered with the emotional tool Self-Assessment Manikin and interviews. To evaluate the findings from the user tests, a validation test was performed, containing a sequence of similar situations as the user tests, but with another group of participants.

The results showed that pedestrians have a perception of space they prefer to keep to a vehicle in slow speeds in order to perceived safety. That space has been identified as a comfort zone concerning both lateral and longitudinal distances to the vehicle. Additionally, the study found a body language of the car that increased the pedestrians understanding of what the car's behaviour intended to do.

The findings got sum up to a final concept with guidelines to an autonomous vehicle with the autonomous feature Automated Valet Parking.

Keywords: Autonomous vehicle, automated valet parking, pedestrian, interaction, emotional experience, perceived safety, body languish, comfort zone, autonomous vehicles.

Acknowledgements

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Finally, we would like to thank our participants in the user study. Thank you very much for your contribution with commitment, time and comments to the test situations. Without your involvement, this project would not have been possible.

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1 Introduction

This chapter is an introduction to the master's thesis about the interaction between pedestrian and automated vehicles in parking garages. This chapter contains the context and background of why the master thesis is written. It also presents the project's purpose, objectives and the report structure.

1.1 Context

The car industry is a line of business that continually advances. Development in technology, such as communications, controls, and embedded systems, open up to new solutions for new features. The new technology has made it possible to let vehicles have driver support features to help the driver to handle, for instance, decision making, deceleration, and acceleration. The industry predicts progress, where the cars will act even more independent. Advanced technology as automated driving features is in development, which allows the vehicles to be more self-driving and fully autonomous. The development of autonomous cars leads to significant benefits, for instance, increasing safety, lower fuel economy and lower emissions. However, to achieve the benefits, the new technology has to be accepted and adopted by the users (Pettersson & Karlsson, 2015).

Automated Valet Parking (AVP) is an automated driving feature for autonomous vehicles and is a solution that implements an automatic drive-up and park service in parking garages (Bosch, 2019). AVP allows the car to ride driverless indoor in a parking garage. A user scenario of an AVP can be that a driver leaves the autonomous vehicle at a drop-off area in connection with a parking garage and the car, in turn, park on its own. The driver should be able to control and monitor the vehicle until the parking task is accomplished by its smartphone (Huang, Lu, Lin, & Shen, 2018). Hence, the car should be able to self-drive from the drop-off area to an empty parking spot and interact with other parking garage users like pedestrians or other vehicles.

The AVP technology makes it easier and less stressful for users to quickly get rid of the car when other cars want to pass and make the garage experience more comfortable when it is tight to open the door (Göteborgs stads parkering, 2017). The new technique facilitates the driver to avoid spending time to find a parking spot, and the vehicles can park much closer, up to 20 % parking spaces can be saved with AVP (Bosch, 2019).

1.2 Problem description

Now the technology has been developed and progressed. Focus for many companies, in the car industry, is to develop autonomous cars with a vision to avoid injuries and fatalities. Within a few years, there will be more automated driving functions, and several car brands are currently developing AVP systems for their vehicles. Bosch and Daimler have, for instance, in late 2018

released an Automated Valet Parking in the multi-storey car park at the Mercedes-Benz Museum in Stuttgart, to show visitors about the new function (Mercedes-benz, 2019).
A self-driving car in a parking garage will need to interact with other manual vehicles and pedestrians. Previous research has mainly focused on the driver's relation to trust and perceived safety in an autonomous vehicle. There is shown that a particular extent of trust in the car is especially necessary since driving is a risky endeavour and mistakes may result in fatal consequences and that it becomes necessary for the driver to accept the occasional autonomy of the car (Rodel, Stadler, Meschtscherjakov & Tscheligi, 2014).

However, pedestrians do also perceive vehicles, and there is a gap in previous research showing how an automated vehicle should relate to people to maintain a safe experience, for those who are outside the car. The human perception of space (proxemics) has poorly been explored when applied to vehicles. Hence, concepts of personal space in the vehicle environment are low. The research gap is even more significant regarding pedestrian interaction with autonomous vehicles without any external devices (eHMI) on the car. Therefore, the purpose of this report is to keep the main focus on pedestrians without any external devices on the car, such as lights. Also, the study is about to investigate how a pedestrian should feel safe when interacting with an autonomous vehicle in a parking garage and, to find reasonable distances that an autonomous vehicle needs to keep to be perceived as safe.

1.3 Project

This Master's thesis project was commissioned by the company CEVT (China Euro Vehicle Technology AB) in Gothenburg, Sweden, in spring 2019. CEVT is an innovation and development centre for future mobility and C-Segment cars in the Zhejiang Geely Holding Group. Their business operations are made up of research, development, and design for automotive applications (CEVT, 2017).

External stakeholder in the project has been RISE (Research Institutes of Sweden) who has provided with insights during performed user tests.

1.4 Purpose

This project aims to investigate how autonomous vehicles' behaviour should be managed and perceived safety for pedestrians in a parking garage. The intention is to investigate whether there are lateral and longitudinal distances between pedestrians and a vehicle that are perceived safety at low speeds (comfort zones). Furthermore, the purpose is to investigate whether it is possible to develop safe driving behaviour (body language), which increases the pedestrians' understanding of the vehicle.

1.5 Goal

The project should deliver guidelines to autonomous vehicles in parking garages to maintain a perceived safety for pedestrians. The guidelines should focus on social behaviour and perceived safety. The guidelines should be based on distances between pedestrians and autonomous vehicles, which for the pedestrians, is perceived as safe. The distance the vehicle should keep to the pedestrian will work as a body language. The project should also investigate whether there are other intentions except for distances that the autonomous vehicle could use as expressions for its body language to reinforce perceived safety.

1.6 Report structure

This project has been a master of science thesis in the master degree program, Industrial Design Engineering. It resulted in an investigation on the interaction between a pedestrian and an autonomous vehicle in a parking garage. The user study has been the main part of the project, where the participants' contribution to conducted user tests has been the most valuable inputs to the project. The process of the project is described more in detail in chapter *4 Method*.

The structure of the report begins with a brief presentation of the results of the recommended guidelines, in chapter *2 Final Result (Short)*. It is to facilitate the understanding of the remaining chapters in the report.

The information collected from theories and literature has taken place throughout the whole project. Most of the theories were, however, obtained during the project's first phase. Therefore, all collected data and theories are assembled in one chapter, chapter *3 Theory*, including theories about used methods. In chapter *4 Method*, it is described how the project has been implemented, which approach and methods that have been used.

The result is divided into two parts, Needfinding and Design of Use. The result in chapter *5 Result Needfinding* presents the findings from the project's first phase, Needfinding. The findings are results from a questionnaire, observations, ideation and evaluation. The chapter, *6 Result Design of Use,* contains results from the projects greatest phase, Design of Use. The findings are mainly from the three user tests, concerning lateral and longitudinal distances between pedestrians and vehicles in a parking garage. The chapter also includes an evaluation by a validation test.

The final concept is a recommendation of driving behaviour for how an autonomous vehicle should act when interacting to pedestrians in parking garages and is presented in chapter *7 Final Concept (Guidelines)*. The last part of the report is chapter *8 Discussion* which discusses the results, method, limitations, ethical and future work. The report ends up with the conclusion in chapter *9 Conclusion.*

2 Final Concept (Short)

The project's final concepts are recommendation guidelines about how a self-driving vehicle should act to retain and increase the pedestrians' perceived safety. The recommendation guidelines contain a body language that will increase the understanding of the intention of the car. Comfort zones of lateral and longitudinal distances were implemented in the guidelines to maintain the perceived safety and understanding to the vehicle.

There are guidelines where the pedestrian is located with lateral distances to a passing vehicle. In the guideline, the vehicle will adapt its speed depending on the lateral distance to the pedestrian, see figure 1. There are also guidelines where the pedestrian is located longitudinally to an approaching vehicle. In the guideline, the vehicle will change its speed depending on the distance to the pedestrian, until the vehicle is on a distance where it should stop, see figure 2. The last recommendation guideline refers to when a pedestrian walks behind a parked idling car. It contains a comfort zone the car should not enter when a pedestrian is behind the car, see figure 3. The guidelines and the result is described more in detail in chapter *7 Final Concept (Guidelines)*.

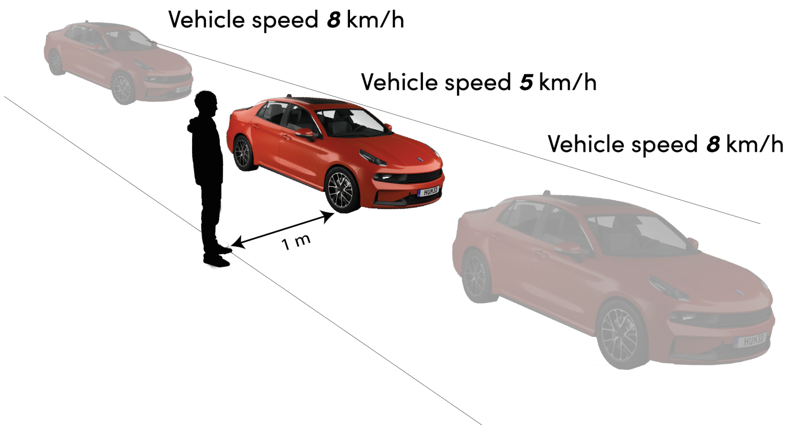


Figure 1. Lateral distances to a pedestrian for perceived safety.

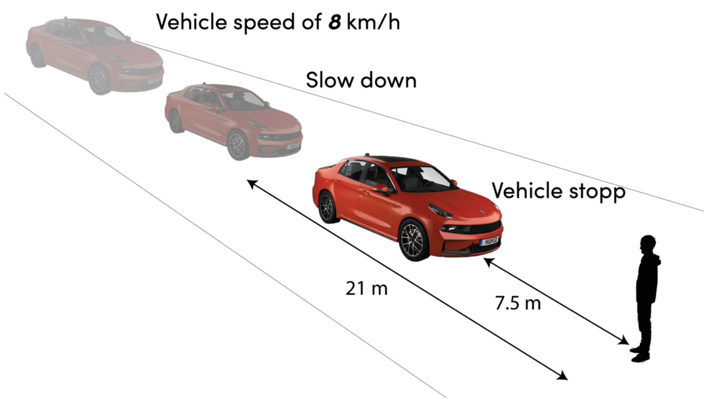


Figure 2. Longitudinal distances to a pedestrian for perceived safety.

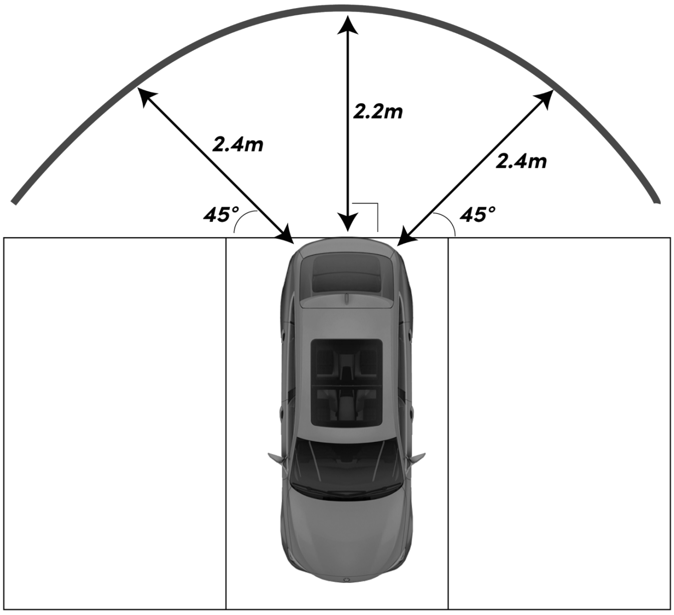


Figure 3. Comfort zone for pedestrians, when walking behind a driverless vehicle with a running vehicle.

3 Theory

The information collection has going on during the whole project, and this chapter presents theories and data that has been important to the project.

3.1 Autonomous vehicles

In order to understand the scope of vehicle-pedestrian interaction, it is essential to know what defines autonomous cars and what kind of safety aspects concerning slow speeds and traffic indoors.

3.1.1 Levels of automation

An autonomous car is using artificial eyes to navigate and detect obstacles along its trajectory. Common supports to detect the surrounding are, for instance: cameras, ultrasonic sensors, lidars, and radars (Fridman, 2019). Six different levels describe levels of driving automation. It is defined by the standard SAE J3016TM levels of driving automation from SAE International (SEA, 2018). Level 0,1 and 2 includes driver support features, meaning a human is driving the vehicle when the features are engaged. Level 3, 4 and 5 have automated driving features, and the driver does not drive the car when the features are committed (Dyble, 2018). Table 1 below shows the standard of SEA (2018).

Table 1

SEA International, levels of driving automation (SEA, 2018)

<table>
<tr><td>Level 0</td><td>Level 0 is the majority of the vehicles today, and the driving is manually controlled.</td><td rowspan="3">Driver support features. The driver <u>is</u> driving when the features are engaged.</td></tr>
<tr><td>Level 1</td><td>The vehicle has a single aspect of automation that assists the driver with Advanced Driver-Assistance Systems (ADAS). E.g. provide the steering, acceleration, or braking control.</td></tr>
<tr><td>Level 2</td><td>More than one feature of ADAS aspect is provided. The driver has complete control of the vehicle.</td></tr>
<tr><td>Level 3</td><td>Features let the vehicle make informed decisions as overtaking slow-moving vehicles or act like a traffic jam chauffeur. Human override is required when the system fails.</td><td rowspan="3">Automated driving features. The driver <u>is not</u> driving. The vehicle is in full control.</td></tr>
<tr><td>Level 4</td><td>The vehicle can intervene if things go wrong or the system fails. Human intervention is not needed in most of the situations.</td></tr>
<tr><td>Level 5</td><td>The features do not require individual attention nor standard driving controls like pedals or steering wheel. The system can handle all conditions.</td></tr>
</table>

3.1.1 Safety aspects to autonomous vehicles in a parking garage

A car with Automated Valet Parking (AVP) feature can be classified as SEA Level 4 of driving automation since no driver interaction is needed, but the environment where the vehicle operates is limited, only in a parking garage. The function of AVP always requires safety mechanisms to get the car into a safe state. Hence, a full stop at a secure location where the vehicle is no hazard for anyone in the parking garage (Schönemann et al., 2019).

The driver is not in charge of the automated vehicle when using the AVP function, which differs from a manually driven car. Therefore, the safety of the passenger is playing no role as there are no passengers on board. The most significant safety challenge for a self-driving vehicle is lack of a safety driver since it is not possible to transfer control to a driver (Reschka, 2016). A still standing vehicle could have hidden risks in several situations as the car cannot be moved immediately under manual control. The vehicle can also be a dangerous obstacle for other vehicles, block emergency vehicles and emergency escape paths, which is illegal. It is according to Reschka (2016) conceivable that in the event of a fault, the control of the vehicle is transferred to a remote operator, who then drives the car to a safe location, using a remote control. It requires, however, a communications channel to the vehicle for reporting problems, and the remote control. The requirements and the operating risk is lower at a parking lot compared to other traffic situations, since the vehicle's low speeds and the comparatively low levels of traffic (Reschka, 2016).

3.2 Earlier research on the subject

Autonomous vehicles' interaction with pedestrians has been studied for several years. The studies presented here has been important to the project since it shows essential founding and identifications on the behaviour of autonomous cars and also behaviours that pedestrians appreciate more or less to perceive safety.

3.2.1 Body language among vehicles

An observation study by Dey & Terken (2017) was about pedestrians and how they were crossing the street. The participants in the study were crossing a road at different locations, at a pedestrian crossing and in the middle of the road. The findings indicated that specific communication methods like eye contact and gestures were not as important or essential as it might suggest. At the pedestrian crossing, the pedestrian decided whether to cross the road just after a momentary glance at an oncoming vehicle. What the car was doing or intended to do was more important compared to who the driver was. They predicted an approaching vehicle behaviour through its movement patterns and body language and by that understood the car's intent, for example, whether the car was slowing down or not. Thus, the knowledge about the intention of the car played a central role in pedestrians' crossing decision. In the other case when the participants should cross the road without a pedestrian crossing, the strategy for the pedestrians was to wait until there was an enough large gap in the traffic, or walk around sparse traffic, and then cross the road as quickly as they were able to. In those rare occurrences of when a car actually stopped, the pedestrian stepped on the road just after the car had stopped.

The eye contact might be more essential for manually driven cars, which in turn can lead to positive consciousness to pedestrians. Ren, Jiang & Wang (2016) stated in their study about drivers and pedestrians (no crossing) that eye contact had a great impact on the drivers' behaviour when the drivers were passing pedestrians. The eye contact decreased the speed of the cars and also made the deceleration process smoother, which can significantly increase the time to collision to protect the pedestrians (Ren et al., 2016). It did not appear if the pedestrians felt safer with eye contact. It might instead just affect the car's behaviour.

Pedestrians seem to want an autonomous car to behave and appear as a normal car. Yang (2017) showed in a study that pedestrians were less sure about their safety when crossing the street in front of a car with an amounted display than crossing in front of a normal car. The pedestrians experience autonomous vehicles with and without external information display, with unusual driver behaviours, as, gesticulating driver, sleeping driver, phone call and a black window. The results showed that distracted driver behaviours in the conditionally autonomous driving context had a negative impact on pedestrians' crossing experience and emotional state. The gestures gave the most negative feeling among the pedestrians. They thought it was strange or got confused, as well as sleeping drivers, phone call or a black window neither generated a positive emotion. The amounted display, however, got a more negative result than the situations without it. Additionally, the eye contact got the most positive result, and the author suggested the reason could be that pedestrians felt safe when seeing that the driver behaved normally, and the car looked normal.

3.2.2 Robot's navigation decision and proxemics

A study about social robotics community by Rios-Martinez, Spalanzani, & Laugier (2015) stated that human management of space is a complex dynamic system including special factors for different situations, such as if there is one person, a group of people interacting or humans interacting with objects and robots. Their findings are similar to what Yang (2017) found, that an automated car should act normally. They found that context plays a vital role in detecting social situations. The robot navigation decision should be similar to a human, who make navigate decisions by considering the meaning of the space associated with discomfort or disturbance to others, and not only based on safety (risk of collision).

Personal spaces are the most popular proxemics (human perception of space) model used in robotics, but few have tried to take into account proxemics factors such as speed, appearance, the direction of approach (Rios-Martine et al., 2015). Edward Hall introduced the term proxemics to designate interrelated observations and theories of one's use of space as a specialised elaboration of culture. Human has zones of personal space and it differs greatly from culture to culture. The United States keeps longer distances to people, Arabs keep shorter while Northern Europeans and Asians share a distaste for indiscriminate contact. A small study of upper-middle-class eastern professionals categorised distances as intimate, personal, social or public. Since the study was small, the distances are not set in stone (Griffin, Ledbetter, and Sparks, 2019).

- *Intimate distance* (0–0.45 m) This distance refers to a close relationship, a gap between people who like each other, distance for whispers and hugs.
- *Personal distance* (0.45 m – 1.2 m) When a person stands within this range, it shows the closeness of the relationship.
- *Social distance* (1.2 m – 3.6 m) Impersonal transaction, a common distance for people who are acquainted.
- *Public distance* (3.6 m –7.6 m) At this distance, the eye can take in the whole body in a glance, used in public speaking situations.

A study from Neggers, Cuijpers and Ruijten (2018), about automated robots in close distances to people, measured perceived comfort of varying passing distances between a robot and human in a corridor indoor. Their results showed that the level of comfort increased with a distance up to 0.8 m and then it remained constant. The side of the distance did not affect the perceived comfort.

3.2.3 Comfort zone surrounding the car

Lubbe and Davidsson (2015), and Lubbe and Rosén (2014) proposed that a comfort zone surrounding the individual can be equally applied to cars and that there are spaces around the car defined by comfort boundaries for the driver. The reason can be to avoid collision to other road users in the trajectory. In their studies, drivers were supposed to push the brakes whenever other road users intrude or were about to intrude the comfort zone. The tests included a vehicle and a pedestrian crossing in front of the vehicle. The test participants were driving the car and did not expect the pedestrian crossing in front of them. Measures of the time to collision were taken when they hit the brake. Measured distances were lateral distances between pedestrian and centre of the driving lane, and longitudinal distance between the pedestrian and the front of the car. The result showed that a higher speed of the pedestrian led to a later brake. Pedestrian's speed was found to have a significant influence on brake onset for the driver (Lubbe and Davidsson, 2015). For a pedestrian speeds of 1 m/s, 90% of drivers at 30 km/h braked before 2.6 s time to collision, and for 2 m/s the value was 2.2 s which corresponded to 21 m longitudinal distance for 1 m/s pedestrian speed and 19 m for 2 m/s. 2.7 m lateral distances for 1 m/s pedestrian speed and 4.6 m for 2 m/s. Lubbe and Rosén (2014) showed a comparable result, the difference was small for lateral distance, both in meters and seconds. The longitudinal distance between break onset and pedestrian median for 30 km/h was 26 m, while for 50 km/h the median was 43 m. Lateral distance from car centre to the pedestrian in meters at brake onset had a median value of 3.2 m for 30 km/h and 2.9 m for 50 km/h).

Further research did also confirm that human perception of space can be applied to vehicles. Ferrier-Barbut, Vaufreydaz, David, Lussereau, & Spalanzani, (2018) performed a study about shared space between pedestrians and autonomous cars in an urban centre. However, the test subjects were seated in the car and were not acting pedestrians. The participants (19 volunteers) was delegated the control to an autonomous system while remaining seated in the driver's seat and viewed 360° videos using a Virtual Reality headset. They evaluated their feeling about the human perception of space of the pedestrian to the car and at several distances and speeds. 0 km/h (static car), 7.5 km/h or 15 km/h, in a straight-line motion, distance from the car was either 0.2 m, 1.2 m or 3.6 m, measured from the side of the car. Their results indicated that there is the existence of a comfort zone around the car in which intrusion lead to discomfort. The discomfort among the passengers was related to the distance between the car and pedestrians. The subjects significantly indicated a feeling of discomfort when the proximity was too great. The passenger felt a higher degree of discomfort when a pedestrian walked past the car at a distance of 0.2 m than if the distances were 1.2 m or 3.6 m, even though there was no risk of collision and the passenger from the car was not supposed to take any decision related to the driving. The speed had also a discomforting effect, a car in motion had a higher discomfort than if it was static.

3.3 Parameters – Vehicles and pedestrians in parking garage

With parameters, the system becomes tuneable i.e. it becomes easily change behaviour, and by specifying their requirements through parameters, the system becomes measurable and easy to verify. This chapter is about pedestrians and vehicles in the parking garage.

3.3.1 Reaction time

The reaction time is mainly used for determining the required visibility distances (stopping distances) (TFK, 1991). The reaction time is varied, but when the driver is focused it is usually between 0.5 and 1.0 seconds (Sveriges trafikskolors riksförbund, 2009).

3.3.2 Parking garage

The design of the parking garage occurs in different constructions. The autonomous vehicle parking system may, therefore, appear in several types of contexts since there are different parking garage architectures. For instance, a multi-level parking garage with several floors. Additionally, there are several different ramp systems such as half-level ramps, single-threaded helix ramps with sloping floors, spiral ramps with bidirectional or one-way traffic, or double spiral ramps (TFK, 1991).

Economic parking modules are based on 2.4 m wide parking spots and parking angle of 70° for one-way traffic and 90° for a bi-directional roadway (TFK, 1991). Figure 4, shows different common angles of parking lots.

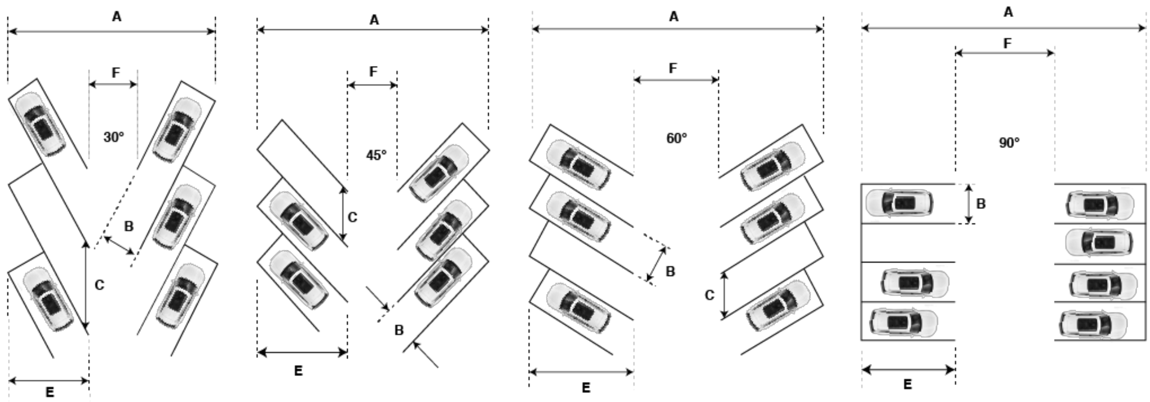


Figure 4. Different angels of parking lots.

3.3.3 Pedestrians in parking garage

The parking garage should contain as much open areas as possible to maintain safety and security for pedestrians. Openness in the garage improves sightlines, elimination of hiding places and enhance perceived security. The open space should also be combined with full light. Proper lighting enhances user comfort and perception of safety. In a pedestrian perspective, the lighted area will improve the signage visibility, readability and it will also permit safe movement for pedestrians and vehicles (Horn & Walker, 2016). Areas that especially need to be lighted are spaces for elevators, staircases and places for evacuation. If the parking garage is above ground, there are opportunities to use glass to increase visibility as a compliment to the lamps (Henriksson, 2001).

When it is lighted in the garage, it is easier for pedestrians to recognize cars in time which promote the reduction of hazards. To maintain full safety for pedestrian, Schönemann et al., (2018) stated, that a safe state is a complete stop at a safe location where a safe location is a place in which the vehicle is no hazard for other actors in the parking garage. Possible hazards have to be identified to establish safety mechanisms to prevent any harm for other participants. A full lighted parking garage is a source that allows the autonomous vehicle to use all the sensors in the system that is used to detect obstacles which in turn helps to avoid hazards (Fridman, 2019). The visitors to the parking garage might be used to the parking garage but not used to behave as a driver or a pedestrian in a traffic situation indoors (TFK, 1991).

3.4 Human-Machine Interaction

This section is about human-machine interaction (HMI) which is the interplay between human and machines. The HMI that has been taken into account are interaction and decision making. It was used to understand the participants' experience in the user tests and how they experience the interplay with the test vehicle, that simulated an autonomous car.

3.4.1 Cognitive Process

By cognition, new knowledge can be obtained. It is a process that happens through experiences, senses and thoughts. The first step for cognitive processes as (Wickens & Flach, 1988) states, starts with receiving stimuli by senses. Then, the information will be represented in the short-term sensory store, see figure 5. The information will then be processed in the pattern recognition state where the information from the sensory store will be integrated into meaningful elements. From this point and to the last step when some sort of response will be made, the attention resource will work in parallel, figure 5. The memory will work as well, but only to the step when a decision and a selection should be made.

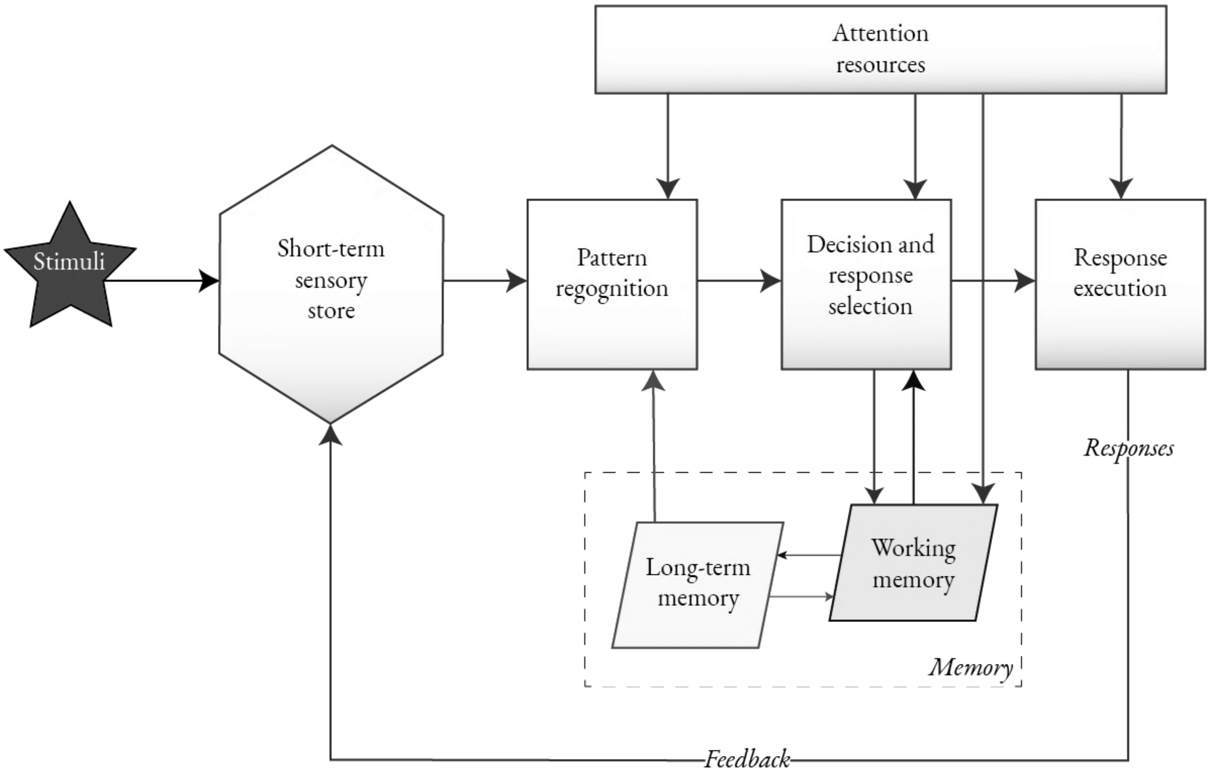


Figure 5. A model of information processing (Wickens & Flach, 1988).

3.4.2 Bottom-up and Top-down processing

Bottom-up and top-down processing concerning how information and impressions are processed in order to be perceived. Which type of processing that is in use depends on the quality of the income stimuli. When the stimuli are unfamiliar, the bottom-up processing is in use. Also, when the income stimuli are indistinct in its shapes or expressions. During the bottom-up processing, the human senses are the source to interpret income stimuli to make it understandable (Wickens, 2004).

When the stimuli are of a more familiar nature, the top-down is the process that recognizes the stimuli. The top-down processing helps to recognize what should be expected to be in the context, and things that could be desired to be in the context. Top-down processing is knowledge-based and analyses the stimuli by past experiences (Wickens, 2004).

3.4.3 Rasmussen's SRK

Rasmussen's SRK is about what previous grounds that are behind behaviours and decisions making in a human-machine environment. Rasmussen's SRK is based on three levels, skill-based, rule-based and knowledge-based (Rasmussen, 1986).

Skill-based are deep in learned tasks which do not require any effort to accomplish. Decisions are done by routine automatically. It facilitates short-term memory and helps the problem solver to spend time on different things at the same time. The rule-based level is when actions are made by rules and explicit knowledge, such as traffic rules which have been learned and must be followed. The knowledge-based levels are characterized by solving problems in new and unfamiliar situations. There are no stored rules for the task which force new rules to be developed. Knowledge-based is a slow active problem-solving and for the knowledge-based problems, the skill- and the ruled-based solving will be used to some extent (Rasmussen, 1986).

A knowledge-based task based on a physical environmental problem solving will be broken down into smaller frames of the whole context. The frames will then be analysed and categorized to known and unknown elements. The unknown elements will then be analysed step by step by the skilled based level or the ruled based level. Depending on how well familiar a person is to the environment, the time will vary to understand the whole context (Rasmussen, 1986).

For a human-machine context, the problem solving will follow in an iterative process. Like the environmental problem, the human-machine context will break down into frames. Where a knowledge-based way is to identify the frames into known elements. Those elements will then be categorized into two points of view, the functional- and the physical properties of the human-machine (Rasmussen, 1986).

3.4.4 Mental Models

Mental models are about how people interact with the world in their surroundings. It can be seen as internal representations of external reality and they are individually constructed based on perceptions, experiences and understanding of the world. Mental models can describe people's behaviours and are used to make decisions, and interpretations. Mental models give insights about people's perceived responses when they affect a specific system, this will give some understanding about how people comprehend a system and how they might intervene. It can be used to predicting people's interactions, and because of the mental models' similarities in structure for a represented area, it is opportunities to map it up. Then, it is possibilities to understand it better and compare mental models for a larger group of people and explore the similarities and differences to improve an overall understanding of people's behaviour for a given system (Jones, Ross, Lynam, Perez, & Leitch, 2011).

3.4.5 Emotions and decision making

Emotions can impact perception, attention, and decision making, and may affect how pedestrians perceive interaction with an autonomous vehicle. Emotion can be defined in two parts, valence and magnitude. The valence is the type of emotion describing positive and negative feelings, for instance, joy, satisfaction or sadness and anger. The magnitude is emotion when arousal increase caused by an emotion, regardless of its valence. Small shifts in information processing can be caused by minor emotions, while extreme emotions can cause a fundamental change in decisions (Resnick, 2012).

Positive emotions can increase efficient decision making, creativity and flexibility. It has been shown that positive emotion can lead to people overestimate positive outcome and so, underestimate a negative outcome. Depending on the context, it can also lead to risk-seeking behaviour and increase optimism. Negative emotions can cause a reduction in people's attention, and sadness and fear can lead to pessimistic predictions, which can lead to higher risk perception. Anger can, in turn, increase the speed of making a decision and risk tolerance (Resnick, 2012).

Arousal can decrease attention, cause mental exhaustion and reduce decision accuracy. On the other hand, emotional intensity leads to a rapid selection of intuitive responses. Thus, emotional arousal can lead to the identification of new and better solutions (Resnick, 2012).

3.5 Theory about used methods.

During the project has several different methods been used to collect important data for the project, generate ideas and perform user test scenarios. The methods the project has used is presented below, and the theory they are based on.

3.5.1 Observations

Observation is a fundamental research method which for design purpose and can be categorized into three different observation formats, semi-structured, structured and pre-structured. The semi-structured observations are related to the collection of information in a new environment and are often used in the exploration phase and should be performed with an open mind to get design inspirations. The structured observation is ideal when the context and behavioural elements are defined, which are often built by data from the semi-structured observations. The pre-structure are iterated observations that are used when researching predetermined types of interactions or behavioural categories, which can be used during user tests when participant interacts with an interface or product prototype (Martin & Hanington, 2012).

3.5.2 Questionnaires

A questionnaire is an instrument used to collecting information about people's behaviour, beliefs, knowledge and attitudes. It is often used as research questions for a part of a larger study, and it can be used for collecting both qualitative- and quantitative data. A questionnaire can also be used within a mixed methodology study like, supplementary questions for a user test or to extend and quantify data from an earlier stage in research (Boynton & Greenhalgh, 2004).

3.5.3 KJ-Analysis

KJ analysis is a method used for sorting data. The collected data are often data obtained from interviews, observations and questionnaire responses. By the KJ analysis, it is possible to structure the data to categorized headlines. The headings are developed during the analysis and can be into specific themes or relationships depending on what the context to the issue is. The collected data will then be sorted out to a related headline. The analysis will then work as a flow-down information chart where requirements to the context issue can be developed (Martin & Hanington, 2012).

3.5.4 Brainwriting 6-3-5

The ideation method 6-3-5 is an iteration way of ideation where the participants get five minutes to sketch three ideas which are defined by a question of an issue. When the ideas are presented a new session of five minutes will start, but this time, the participants change sketches with each other, and there will be a redesign of the already created ideas. It is advantageously if the participants are familiar or briefed with the subject to get more qualified ideation (Michanek & Breiler, 2007).

3.5.5 Brainstorming

Brainstorming is a group activity which promotes creativity. The purpose of brainstorming is to generate concepts and ideas regarding a specific challenge. The creativity activity advocates free thinking where it is no right or wrong. It provides a judgment-free zone to create an “outside the box thinking” (Martin & Hanington, 2012).

One way of brainstorming is to create flow diagrams where participants can document ideas to a system or a process. It is particularly suitable to create a sequence of events where it usually has a clear beginning and an end. But it can also be used to create cycles with a closed loop (Martin & Hanington, 2012).

3.5.6 Self-Assessment Manikin (SAM)

Self-Assessment Manikin (SAM) is a tool that is useful when measuring generalize emotional states, and not specific experienced emotions that a system provokes (Desmet, Hekkert, & Jacobs, 2000). By SAM, there is an opportunity to measuring perceived valence, arousal and dominance related to a system, through a predetermined scale, see figure 6. The dominance category could also express the feeling of control. The SAM method is a none word method but gives an indication of a person's emotional response to a large amount of stimuli (Bradley & Lang, 1994). Each feeling is rated from 1 to 9, the feeling is expressed with symbols, see figure 6.

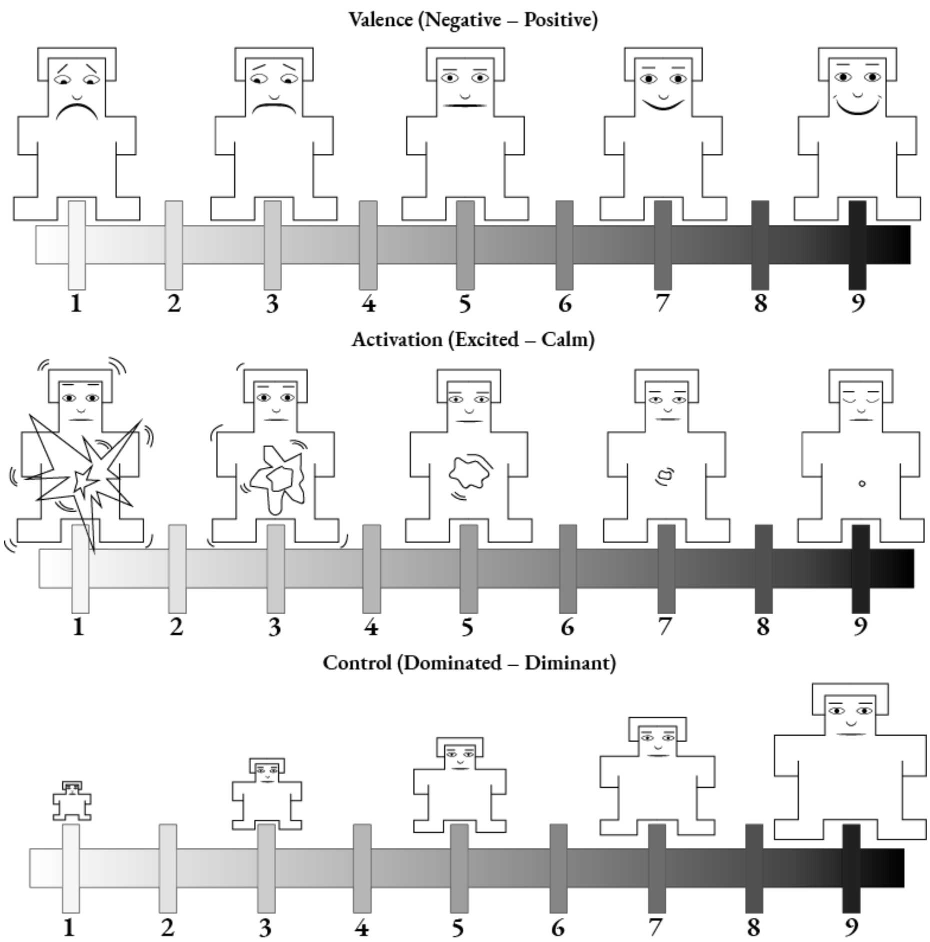


Figure 6. Self-Assessment Manikin (Bradley & Lang, 1994).

3.5.7 Interviews

An interview is a way to get first-hand information and direct contact from an interviewee about opinions, experience, perceptions and attitudes. It is a survey research method which is most suitable conducted in person to get data of personal expression and body language, but an interview can also be completed through a phone. Questions in an interview can follow a structured or an unstructured script. The unstructured format is suitable for exploration purposes. When there is a more rigorous purpose and consequence comparable data are required by the participants, a structured format is needed, and the questions need to be read exactly as scripted by the researchers. Interviews are often used as a research compliment together with questionnaires or observations (Martin & Hanington, 2012).

3.5.8 Wizard of Oz

Wizard of Oz is an experimental method where the outcome is to try out an interaction between a product or a system to a participant. The testing phase is a simulation where the product or the system will be controlled and responded by a hiding human, the wizard, while the participant interacts with it. By this, it is possible with a low technical mock-up, simulate how an advance system would work to a user (Martin & Hanington, 2012).

4 Methods

The process of the project, how the conducted project was performed, is not identical to the format of the report. The project was oriented from the process method ACD^3 (Bligård, 2015). The ACD^3 framework is a development process from a human-machine perspective and is based on an iterative way of methodology and has originally seven process phases. The method was however adapted to this project, but only the two first phases, called Needfinding and Design of Use, have been used, see figure 7.

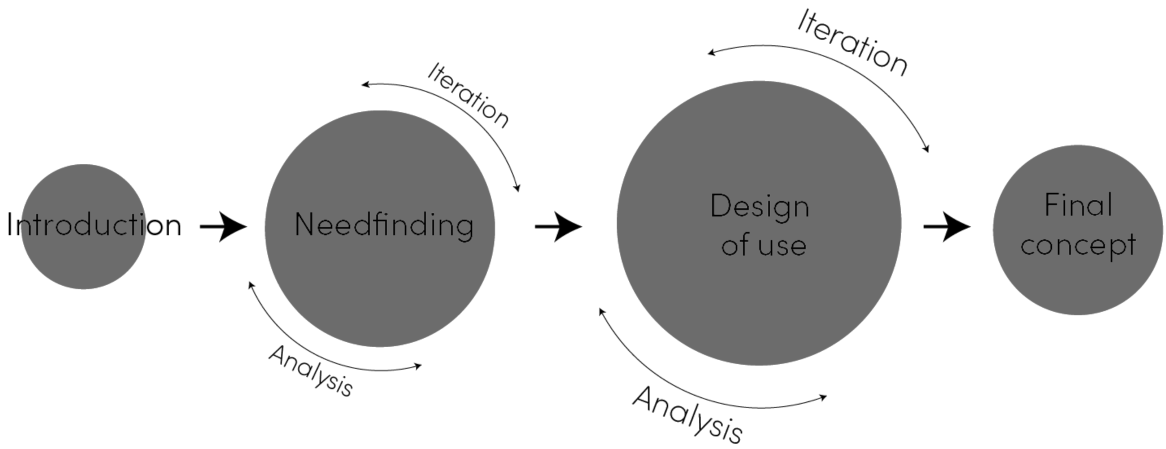


Figure 7. The process of the project.

Throughout the work, the project has been frequently planned, and the data collection has been ongoing throughout the whole project. Questions that helped as a guide to reaching the project's purpose and goal has been:

- What is the appropriate lateral and longitudinal distance between a pedestrian and an autonomous vehicle at the speed of 5 km/h and 8km/h?
- What is explicit driving behaviour without any external devices?
- Which factors affect the perceived safety among pedestrians in a parking garage?

The project started with initial planning, an introduction, which framed the project, see table 2. Next phase was the Needfinding, which, in this case, meant to familiarise with the topic, identify the main problems, users and context, and explore what had been done in prior research. In the meantime, observations were made in parking garages to see how both vehicles and pedestrians behaved in such an environment. A digital survey was also made to get specific answers about experiences in parking garages among pedestrians and drivers. Brainstorming was made to generate possible scenarios that could happen in a parking garage. Findings from the ideation were then consulted with the client. Within the Needfinding, the process was mainly iterated when it comes to scenarios from the idea generation and adding needful theory.

The project now had the foundation to start doing user tests to find answers to the purpose. The Design of Use phase began with new ideation concerning how the user tests should be designed, by using the brainwriting method 6-3-5. The result was then evaluated together with the client. The project did three pilot tests to arrive at the correct approach to the design of the user tests; a pilot test within the project group was conducted, a pilot test with the client, and a pilot test with an independent test participant. With the developed test methods, three different tests were performed to find out how pedestrians perceive different longitudinal and lateral distances to a vehicle. The tests were analysed, and a new validation test was developed to evaluate and analyse the results of the previous tests. Based on the test data, a final concept was formed consisting of recommendations of driving behaviours for an autonomous car in a parking garage.

Table 2

Describing the structure of the project

Introduction – Initial planning, to choose approach and methods to conduct the project.
1. Needfinding – What's the effect and the need? ● Theory – Main problem, users, context, prior research ● Observations – vehicles and pedestrians in several parking garages ● Digital survey – safety aspects in parking garages ● Brainstorming – Scenarios in parking garages ● Evaluation – Consultation with the client
2. Design of Use – How is it used and what are the user requirements? ● Theory – aspects of human-machine interaction ● Brainwriting 3-6-5 – Design of User tests ● Pilot tests – evaluations of user tests ● Running user tests – longitudinal and lateral distances between pedestrian and vehicle ● Analysing of findings ● Evaluation – Validation test and analysing
Final concept – Based on findings from theory, observations, survey and user tests

4.1 Needfinding

There has been used several methods during the iteration phase Needfinding. The outcome has been to learn about the project's scope and to investigate the field to reach the goal. The used methods for this phase are presented in this subchapter.

4.1.1 Literature and theory

The literature study was performed in Needfinding as a pre-study, but it has also followed throughout the whole project. Papers and previous master theses have been the main information source. But also, online searches for the latest findings in the automotive industry was used. By the literature studies, there were possibilities to do researches of explored areas.

4.1.2 Observation

Observations in the context parking garage gave insights about people's behaviour and pedestrians trajectories. The observations were made in four different parking garages in the morning and in the afternoon. Visited parking garages were P-hus Nordstan, Svenska mässan, P-city and Mölndals galleria. The mental models were taken into consideration for the observations in the parking garage to mapping up common walking trajectory by pedestrians. It was made to get a better understanding of where they walk and what activities a pedestrian actually do in a parking garage. The insight was research material used in several approaches, such as the questionnaire, ideation process, brainwriting and in the creation of the user tests and validation test.

4.1.3 Questionnaire

A survey made in Google Forms was spread via social media with the purpose to receive thoughts and opinions regarding parking garage experiences. The aim was to see if there were anything that concerned parking garage users. The questions were based on findings from a literature study to confirm how people generally feel about safety and how they behave in a parking garage.

The questionnaire was held in Swedish and received 108 answers in total and 86 answered a free text question. The participants were evenly distributed between an age range of 18 to 65 years old and 55 % were women, 44 % were men and 1 % had unknown gender. Of the participants did 81 % say that they drive a vehicle regularly, 17 % sometimes and 2 % of the participants did not use to drive. A majority of the participants, 60 % stated they used parking garages more rarely, while 24 % had a monthly use and 8 % said weekly and 8 % daily.

4.1.4 KJ analysis

The KJ analysis was used to categorize the results of the answers from the questionnaire. It allowed the project to easier structure the answers and get the insights of the participants' opinions about their experiences of parking garages.

4.1.5 Brainwriting 6-3-5

The 6-3-5 method was redesign during the ideation phase. It was done to get a method that could fit the process in a better way. The ideation method was performed to generate potential scenarios in a parking garage and was based on the collected data of the observations and questionnaire.

4.1.6 Evaluation with client

The ideas were outcomes from the brainwriting 6-3-5 method and included situation scenarios in a parking garage with respect to the lateral and longitudinal side of a vehicle. All ideas were set up in a document with an explained description. By discussion with the client from CEVT, there were some of the ideas that were of interest to work further with as potential scenarios for user tests.

4.2 Design of Use

In the Design of Use phase, there has been used methods which practically used the base of information earned in Needfinding to develop user tests. In this chapter, the user tests are also a part of the method which later led to the final concept.

4.2.1 Brainstorming

Brainstorming was used to process the potential data for scenarios that had been examined by the evaluation with the client. Through the process, all user tests were developed, which made them ready to be exposed to the pilot tests.

4.2.2 Evaluation of scenarios

Three pilot tests made the evaluation of the user test. The first step was an intern test within the project group which helped to get to know the test in such a way that it was practically feasible, how long duration of time it would need and to practice. Next step was together with the client from CEVT, which was done to check off that all desirable elements for relevant outcome data existed in the tests. The last pilot test was done with a test participant who had no previous insights into the project, and it worked as a confirmation that the tests were in a condition for sharp tests.

4.2.3 Conducting user tests

User test was conducted to investigate how pedestrians perceive an autonomous vehicle in different situations in a parking garage. Three different tests were conducted to investigate and collect data of the participants' emotional states when they experienced different speeds and distances of a vehicle at lateral and longitudinal approaches and to investigate what an appropriate walking distance behind a car is in a parking garage.

In total, there were 22 participants in the tests. Though, two participants have been removed from the results due to too much previous experience of autonomous vehicles and incorrect measurements. The results present data from 20 participants, 10 female and 10 male.

The participants were principally students from the Chalmers University of Technology and had an age range of 22 to 31 years old. The majority had Scandinavian origins. Three out of 20 participants had no driving licence and the average time of how long the rest had had a driving licence was seven years. The majority had no previous experience of autonomous functions related to cars, except for two persons who had used back assist and pilot assist.

For longitudinal distances when the participant's emotional experience appeared, the testing vehicle braked down and stopped. Then, the distance between the vehicle and the participant was measured. To calculate where the real distance of the testing vehicle was when the participant's emotional experiences to the car appeared a general formula was used for the stopping distance (Körkortonline.se, 2017).

How the user tests were performed can be found in Appendix A: User tests methods. The user test led to an amount of raw data with responses from twenty test participants. The user test itself contained three methods, Wizard of Oz, Self-Assessment Manikin and interviews.

4.2.4 Wizard of Oz

The driver in the test vehicle was dressed up as a driving seat. The front passenger seat was dressed in the same upholstery to disguise the driver in the driving seat even more. It was not possible for the participants to see the driver or get any eye contact. Even if Dey & Terken (2017) stated in their study that eye contact seemed to be less important for pedestrians and what the car is doing is more important, the eye contact should be eliminated and also the view of the driver to stage-manage an autonomous vehicle. The Wizard of Oz was a tool to force the participants to not look inside the car and instead focus on the vehicle's behaviour. Wizard of Oz helped to get a more credible qualitative- and quantitative data.

The same Wizard of Oz approach was also performed in an observational study by Rothenbücher, Li, Sirkin, Mok & Ju (2016). Then, the Wizard of Oz approach appeared to work well and seemed to be valuable for research, involving pedestrians and other road users, since people will react to a driverless car in a real-world setting.

4.2.5 Self-Assessment Manikin

The method Self-Assessment Manikin (SAM) was used in user test 1, user test 2. The method of SAM gave opportunities to analyse the emotional states between participants and became the major quantitative input of data collection together with distance measurements.

4.2.6 Interview

Interview questions were asked after all tests in the user tests to get information about the participants' holistic experience and emotions. The interview questions were also useful as information data for the creation of the validation test.

4.2.7 Evaluation of the user tests

The evaluation from the user test was made in spreadsheets. The evaluation was made regarding the comparison between the tests including, distances, the defined speeds in the tests, emotional states, interviews, gender, technical interest and adventurous. The result of the evaluation became data input to a new test, the validation test, that should further evaluate the user tests.

Full description of the validation test can be found in Appendix B: Validation test method. The validation test had the same approach as the user tests, but this time, the project was looking for a confirmation of previous tests. Therefore, the same method was used over again, such as Wizard of Oz, method SAM and interviews.

The flow chart diagram was the way of brainstorming to define the sequences of the validation test. The challenge was to come up with a real scenario that could be related to an actual sequence of events that could occur in a parking garage. Based on the previous user tests, the solution became a sequence with three tests that should be repeated twice — one sequence with the most appreciated distances and one with the least appreciated.

There were 12 new participants in the validation test, and they had not experienced the previous tests. The participants were principally also students from the Chalmers University of Technology, six males and six females in a range of ages from 22 to 35. The majority had Scandinavian origins even in these tests. All persons in the test group had a driving licence for about eight years on average. The majority had no previous experience of autonomous functions, except for four persons who had used: adaptive cruise control, pilot assist and parking assist.

After the validation test was performed, there was an interview session with profound questions with four categories such as perceived safety, trust, understanding and control. By the interview questions, there was an opportunity to follow up and compare positive and negative comments.

By comparing the least and the most appreciated test results, the project group could confirm the results and findings from the conducted user tests. The verified information was what later led to the final concept in combination with the qualitative data from the interviews.

4.3 Final Concept

The final concept's recommendation guidelines are related to the validation test scenarios and the user tests, which were based on situations with lateral and longitudinal distances. The pedestrians in the final concept were located in the same directions to the autonomous vehicle as they were to the testing vehicle in the performed tests.

An analysis was made where the qualitative data from the interviews were compared with the quantitative data from the SAM analysis and the distance measurements. By the process, it was possible to put the quantitative and the qualitative data in relation to each other and thus strengthen the results. The results were the data used for the development of the comfort zones, which was implemented in the guidelines.

The vehicles behaviour in the recommended guidelines is implemented by findings of the vehicle's intentions that the participants perceived as safe. To create a functional interaction between the pedestrian and the autonomous car, the theory of human-machine interaction (HMI) was as well used for the development of the vehicle's behaviour in the guidelines. The findings of the perceived safety and the theory of human-machine interaction helped to create adaptations of the vehicle's behaviour depending on how the pedestrians changed their lateral distance to the car or moved away from the vehicle's longitudinal direction.

5 Result Needfinding

This chapter presents the results of the project's first phase, Needfinding. The chapter includes results from four observations in parking garages. It also contains results from a questionnaire about finding out if there are things that generally lead to low perceived safety in parking garages, for pedestrians. All information led to an understanding that user tests were needed to achieve the purpose of the project. Therefore, an idea generation is presented here about possible situations that could happen in parking garages as a start to creating user tests. At last, an evaluation of the events from the ideation was made with the client before the project entered the next phase, Design of Use.

5.1 Observations

Findings from the observations in four different parking garages did not bring that many new insights to the project. It might be due to the low traffic situation in the parking garages or that an interview was not conducted. The finding is divided into pedestrians and manually driven vehicles:

Pedestrians

- The pedestrians' gait is goal-oriented, they are heading for a destination.
- Some pedestrians go slowly, nonchalantly against the cars.
- Mobile phones distract pedestrians' attention to traffic.
- Road markings help pedestrians to not go where the cars are driving.
- No queue at the parking meters.

Manually driven vehicles

- Drivers often park their cars next to the exit. Hence, they do not have to walk around in the parking garage.
- Aggressive driving styles in a parking garage.
- Many drivers are not looking at the direction of travel when driving, maybe they are looking for free parking spots.
- High speed, concerning the situation.

5.2 Questionnaire

The questionnaire gave insights about general thoughts to perceived safety in a parking garage. Some findings confirm the findings from the observations, for instance, that drivers often did not look at their driving trajectory while they were searching for a parking spot and by that increase the insecurity among pedestrians.

The result showed that pedestrians experience a higher probability by being discovered by a driver when walking in a parking garage then what they experience the possibility of discovering a pedestrian when sitting in the car. The pedestrians rated on two scales from 1 to 5 whether they experienced the possibility of discovering a pedestrian as a driver and the probability of being discovered by a driver as a pedestrian. 37 % believed there was no problem or almost no problem (answers 4 and 5 in total, see figure 8) to discover pedestrians where 49 % (answers 4 and 5 in total, see figure 9) believed there was a high probability or nearly high probability of being discovered by a vehicle.

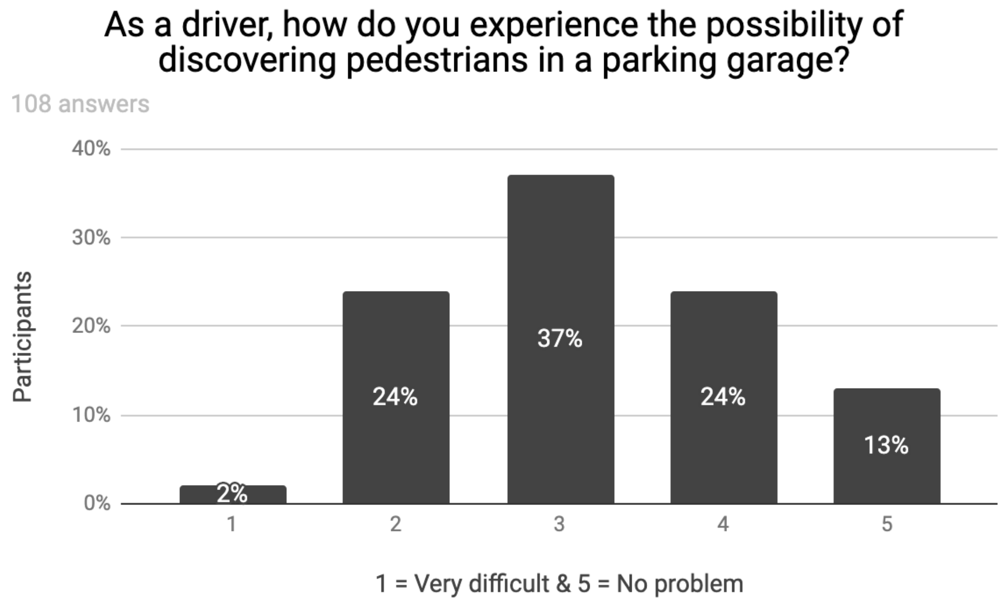


Figure 8. The response of experienced possibility of discovering pedestrians as a driver.

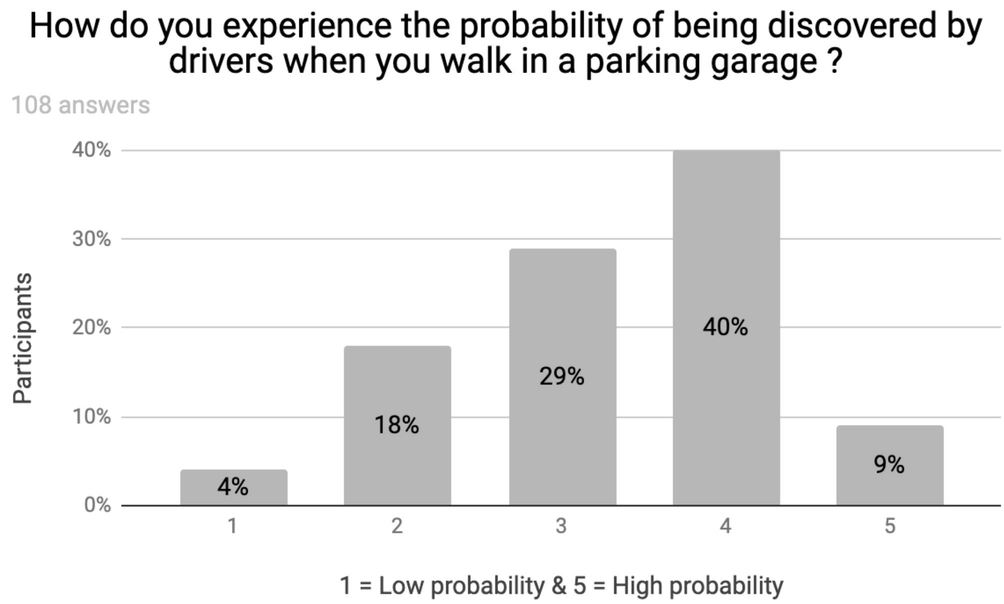


Figure 9. The response of experienced possibility of being discovered of drivers as a pedestrian.

The results also showed that 64 % of the questionnaire participants had never experienced an occasion where they believed they were too close to a participant. However, 34 % answered that they had, and the estimated distance they thought had driven next to a pedestrian varied. Figure 10 shows how close they estimated the distance to a participant when they experienced the distance as too close. The findings give hints of how a close distance to a pedestrian might be. The results do not say if the distances are lateral or longitudinal distances between pedestrians and vehicles.

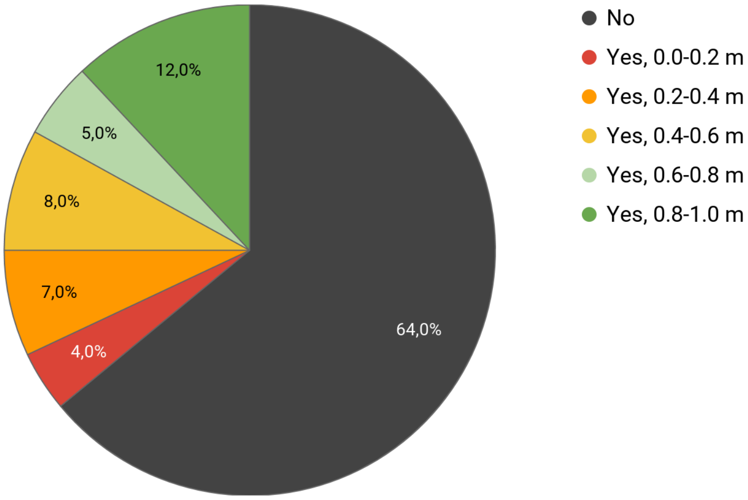


Figure 10. 108 answers from the question "Are there occasions when you, as a driver, experienced that you were driving too close to a pedestrian in a parking garage, if so how close?".

The KJ analysis found several legit reasons to participants experience the environment insecure by letting the participants answer in own words the question: *Have you ever felt insecure when you have walked as a pedestrian in the parking garage? If so, why and what is the reason that you felt insecure?* The results showed that 17 % of the 86 participants never felt insecure as a pedestrian in a parking garage while 83 % felt some kind of insecurity, see in figure 11.

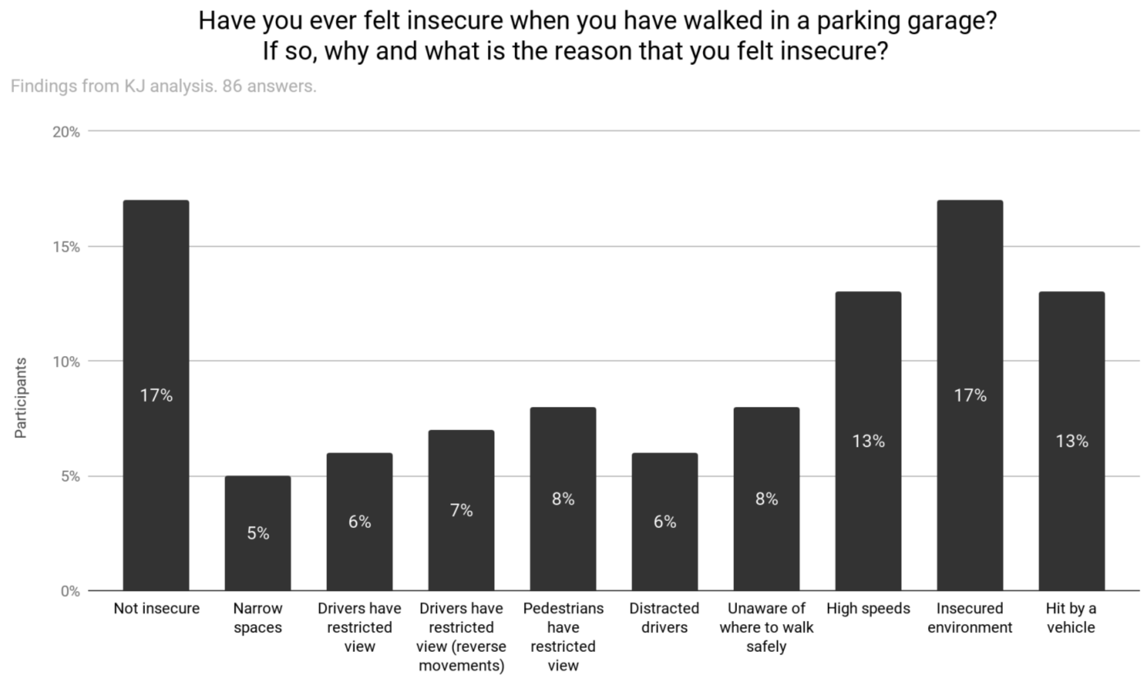


Figure 11. Reasons for insecurity in parking garages for pedestrians, findings from the questionnaire.

Some feel a fear of being hit by a vehicle, which is an overall factor that can have many causes. According to the questionnaire, some never feel insecure in a parking garage and some do, people, interpret and perceive experiences differently. Narrow spaces in the parking garage increased the insecurity among some of the participants, even small distances between pedestrians and vehicles.

The driver's sight view affects pedestrians' sense of feeling safe which may be due to narrow spaces or poor lighting. Additionally, some said that they feel insecure when they cannot get eye contact with the driver. Hence, the uncertainty of whether the driver has seen the pedestrian or not can cause a feeling of insecurity. Another insecurity seen in the questionnaire is that some people are not sure that they have been discovered by a reverse car.

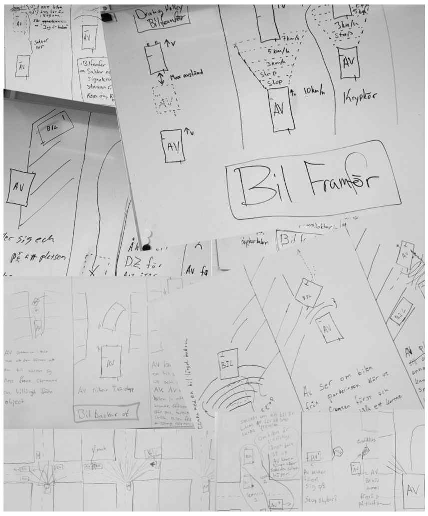
High speeds do also increase the insecurity among pedestrians. Some do not feel safe when vehicles drive fast because they believe that the driver has less control of the surroundings. The parking garage can be perceived as an insecure environment, according to the survey is it due to the risk of being assaulted, robbed or violence. Poor lighting, deserted garage or the time of the day are also factors that come into play.

5.3 Ideation, brainwriting 6-3-5

To gain knowledge and insights to clarify perceived safety for pedestrians, the project group had understood that the behaviour of vehicles should be tested in some way. As a beginning to find out how and what driving behaviour should be tested were scenarios that could occur in a parking garage brainstormed. It was brainstormed to figure out how the tests should be performed and designed. The project generated different themes of possible events that can occur in a parking garage and several scenarios that could occur during every theme, see table 3. Those descriptions of situations are however omitted from the report because of its long length and that it is not needed to understand the process nor the project's mindset.

Table 3

Results from the ideations of events and scenarios that may occur in a parking garage

Possible events that may occur in a parking garage	**Brainwriting scenarios that could occur in a parking garage (omitted from the report).**
What behaviour should an autonomous vehicle have if: ● the vehicle drives straight ahead ○ has a car in front ○ has a car behind ○ car in front takes a parking lot ○ oncoming car occurs (single file) ● car drive out from a parking spot ● if it has to turn in a parking garage ● at a 2-way four-way crossing ● it will park the car ● it should go reverse ● there is a queue to the drop off zone ● to pedestrians	

5.3.1 Evaluation – Consultation with client

The result from the consultation with the client gave in-depth discussions about the presented scenarios and insights to further work to develop user tests. The project decided to iterate the scenarios between pedestrians and vehicles and design tests concerning to find lateral and longitudinal distances to pedestrians that could be perceived as safe. Which means that the project from this point, just trying to find distance pedestrians perceive safety without covering all possible scenarios that could happen in a parking garage.

5.4 Summary Needfinding

From the questionnaire could there been seen that the driving behaviour of an autonomous vehicle should be easy to understand for all kind of people. The behaviour should let people know what the vehicle is up to and it should not do sudden movements, which in turn can lead to that pedestrians have to do sudden adaptations. Additionally, some pedestrians feel insecure when they cannot get eye contact with the driver. Hence, the uncertainty of whether the driver has seen the pedestrian or not can cause a feeling of insecurity. Thus, the autonomous vehicle needs to be able to perceive people moving in the parking garage regardless of narrow spaces, lighting, size of people to make people feel safer. The behaviour needs to be explicit to confirm in some way that it has detected a person.

The ideation and especially the evaluation led to insights that the project should put more effort into the user tests and increase focus on the pedestrians rather than all scenarios that could happen in a parking garage.

6 Result Design of Use

The results of the ideation, user tests and the validation tests are presented in this chapter, which all was a part of the second phase Design of Use. The results of the user tests and the validation tests were used for the set of conclusions for the tests. The conclusions and the result data were the information that the final concept's guidelines were developed.

6.1 Ideation and evaluation of user tests

In connection to the phase, Needfinding started an investigation on how the user tests should be designed and performed. The ideation was completed to find how the tests could be done by trying to let the user tests answer the following questions:

- How does the vehicle speed of 8 km/h and 5 km/h affect the pedestrians?
- What lateral and longitudinal distance to the car is a comfortable distance?
- When does the distance between pedestrian and vehicle experience close and too close?
- At which distances is one's personal comfort zone?
- From which distance does a pedestrian's integrity begin?
- How close do pedestrians want to walk too a vehicle that is about to leave a parking spot?

The test suggestions from the ideation got iterated three times until the project had found measurement techniques regarding how distances should be measured and analysed. The result became a method for user tests and can be found in Appendix A: User tests methods. The user tests became three individual tests that got tested consecutively, in random order and was divided into lateral and longitudinal distances between pedestrian and vehicle and into an appropriate walking distance behind a car.

6.1.1 User test 1 – Lateral distance between pedestrian and vehicle

The purpose of user test 1 was to get a deeper understanding of how the lateral distance in combination with the speed impact pedestrians when a vehicle is passing by at a speed of about 5 and 8 km/h. The aim was to find an appropriate distance between a pedestrian and a passing car where the pedestrian perceived safety, see figure 12.

In order to find an appreciated lateral distance between participants should the participants chose their own distance to the passing vehicle. However, the project group did also want to investigate the distances seen in the theory. The chosen distance was 0.45 m which is referred to the shortest *personal distance* of personal proxemics, in chapter 3.2.2. A distance of 0.8 m was found as a distance for perceived comfort to automated robots, in chapter 3.2.2. That distance was found interesting to implement to cars and got chosen to see if that distance could be perceived similar in these tests.

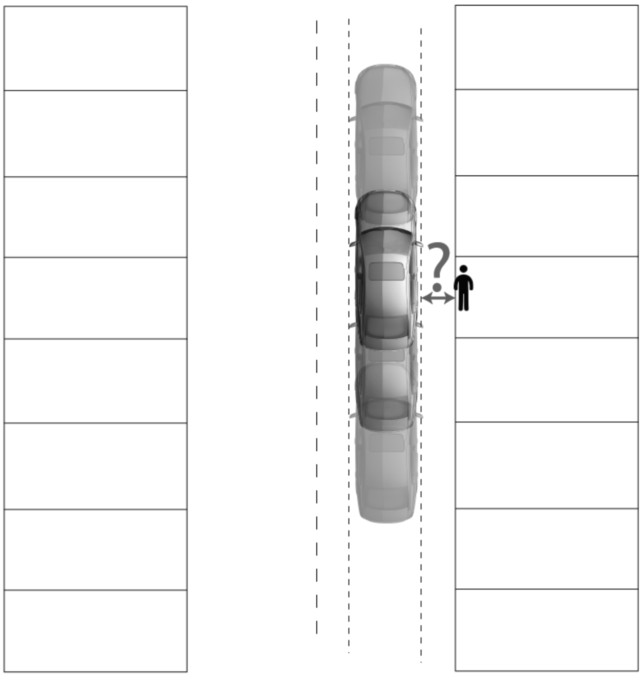


Figure 12. User test 1.

6.1.2 User test 2 – Longitudinal distance

The purpose of user test 2 was to get a more profound knowledge of how the longitudinal distance in combination with the speed impact pedestrians when a vehicle is approaching at a speed of about 5 and 8 km/h. The aim was to find an appropriate longitudinal distance between a pedestrian and the front of the car where the pedestrian felt safe and secure and to get information about (figure 13) :

- When a pedestrian starts to keep the attention to an approaching vehicle.
- Which longitudinal distance that perceives as a close distance.
- When a pedestrian wishes the car to decrease its speed.
- When a pedestrian wishes the car to stop.

The distances got chosen in order to investigate when pedestrians start to interact with a vehicle, when they want it to stop and how they want the car's behaviour to be until it has no speed.

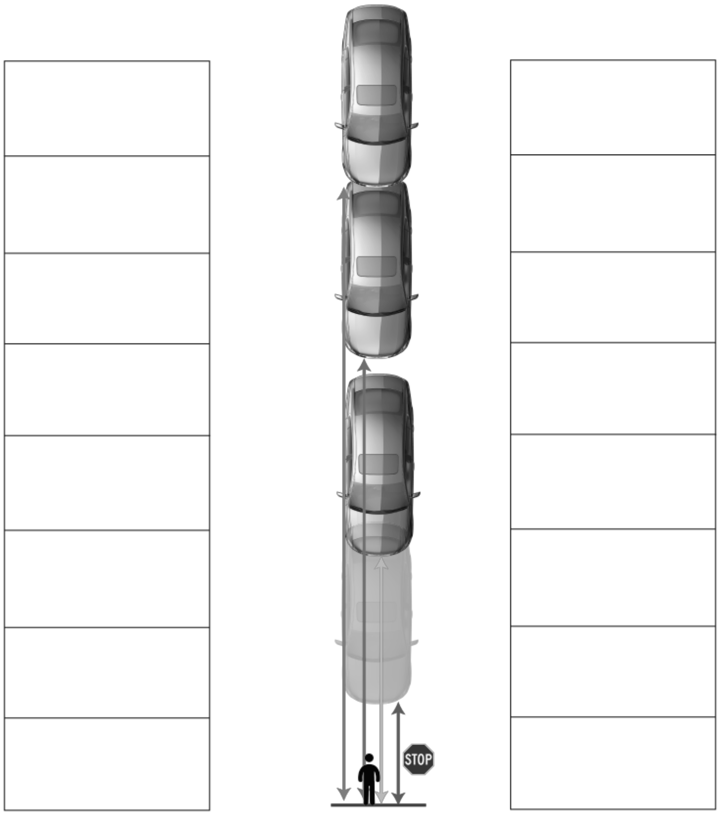


Figure 13. User test 2.

6.1.3 User test 3 – Trajectory behind a car

The purpose was to see how close a pedestrian was willing to walk behind a car, that has a running engine, in a parking spot, and knowing the car can start to drive any time. The goal was to map up to the participants' walking distances and find how great distance they preferred to a vehicle that anytime could leave the parking spot, see figure 14.

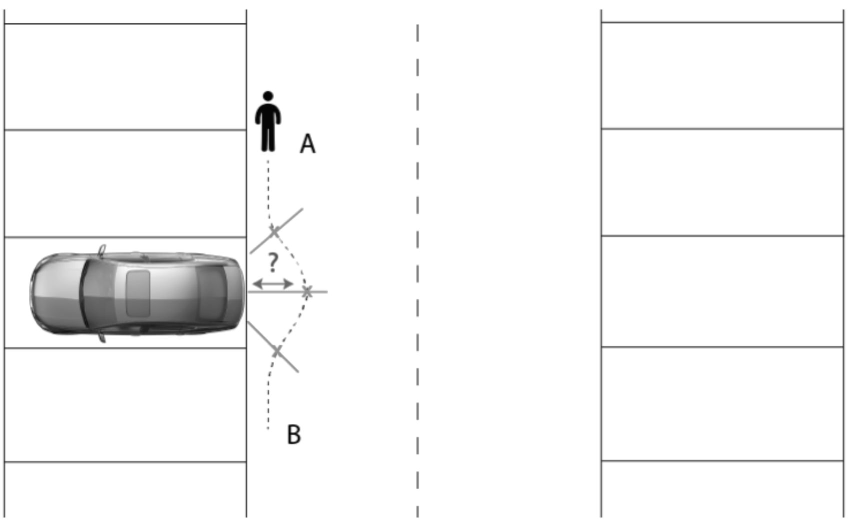


Figure 14. User test 3.

6.2 User tests 1 – Lateral distance between pedestrian and vehicle

User test 1 was conducted out of six tests (1A, 1B, 1C, 1D, 1E and 1F) and tested lateral distances between pedestrians and the test vehicle in slow speeds, 5 km/h and 8 km/h, see figure 15. At test 1A and Test 1B, the participants had the opportunity to decide their own lateral distance to the car. Test 1C-1F had fixed distances at 0.45 m and 0.80 m. All distances were experienced twice at different speeds, see table 4.

Figure 15. Photo from user test 1.

The results from user tests 1 is shown in table 4. According to the results, the lateral distance to the vehicle experienced better the longer the distance was and also the slower the speed was of the vehicle. The SAM analyses showed that the participants had a more negative state of emotions in the tests where they stood closer to the car than in test 1A and 1B where they chose their own distances.

Table 4

Results of tests 1C - 1F, result from SAM analyses

Lateral distances to vehicle. Participants' own choice of distance, 0.45m and 0.80m VS 5 km/h and 8 km/h						
	Test 1A	**Test 1B**	**Test 1C**	**Test 1D**	**Test 1E**	**Test 1F**
Speed of vehicle	5 km/h	8 km/h	5 km/h		8 km/h	
Median distance to Car	0.97 m Participants' choice	1.03 m Participants' choice	0.47 m	0.81m	0.49 m	0.81 m
SAM: Unpleasant – Pleasant (1-9)	7.5	6.5	5.0	5.0	4.0	5.5
SAM: Active – Calm (1-9)	7.5	7.0	6.0	7.0	5.0	6.5
SAM: No Control – Full control (1-9)	8	7.0	5.5	6.5	5.0	7.0

Table 5 shows in per cent how many of the participants that perceived the situation as good and how many that perceived it as uncertain. The results come from interviews with the participants. *The situation felt good* is a combination of answers such as, if they felt secure, safe, calm or did not want to take a step back etc. *Perceived uncertainty* is a gathering name for states as: Has the car seen me? I want to take a step back, distance is too close or the speed is too high etc.

Table 5

Results from interviews user test 1

Test	**Test 1A**	**Test 1B**	**Test 1C**	**Test 1D**	**Test 1E**	**Test 1F**
Distance Speed	0.97 m 5 km/h	1.03 m 8 km/h	0.47m 5 km/h	0.81m 5 km/h	0.49m 8 km/h	0.80m 8 km/h
The situation felt good	90 %	80 %	35 %	65 %	0 %	52 %
Perceived uncertainty	10 %	20 %	65 %	35 %	100%	48 %

Tests 1A and 1B – Self-chosen lateral distance to a vehicle at speed of 5 km/h or 8 km/h. When the participants chose their own distance to a passing vehicle in the parking garage, the result showed that the participants slightly chose the same distance to the car either if the speed was 5 km/h or 8 km/h. The median of chose distance to the car was about 1 m in both cases. The distance range in test 1A was between 0.55 and 2.73 m, and in test 1B between 0.39 m and 2.61m, see Appendix A2: Calculations.

However, the emotional reaction to the situations decreased when the car had a higher speed, but not that radically, see table 6. The emotion states of pleasure, calm and control were rated positive and very similar. The majority experienced the situations as good in both situations according to the SAM scales.

Table 6

Result of tests 1A and 1B

	Test 1A	**Test 1B**
Speed of vehicle	5 km/h	8 km/h
Median distance to the car	**0.97 m** **Participants' choice**	**1.03 m** **Participants' choice**
SAM: Unpleasant – Pleasant (1-9)	7.5	6.5
SAM: Active – Calm (1-9)	7.5	7
SAM: No Control – Full control (1-9)	8	7
The situation felt good	90 %	80 %
Perceived uncertainty	10 %	20 %

In test 1A did the majority, 90 %, of the participants experience the passing car as safe, see table 6. They expressed, that it felt safe and secure and none expressed the chosen distance was too close nor that the car's speed was too fast in relation to their lateral distances. The negative feelings concerned the slow speed, one participant stated, "a lower speed of the vehicle at this distance makes it more unpleasant, it feels like the car is intended to do something, than if it had run faster".

Some participants commented that the speed was faster in test 1B and 20 % of the participants experienced the situation less secure. Comments were for instance: "The faster speed made it scarier", "The car is coming faster, but it felt OK". But, most of the participants experienced the situation secure.

Tests 1C and 1E – Lateral distance of 0.45 m and vehicle's speed of 5 km/h or 8 km/h. Test 1C and 1E got the worse results according to the SAM analyses and the interviews. The lateral distance to the vehicle and the participant was about 0.45 m for both speeds, see table 7. The emotion of having control of the traffic situation was almost identical in both cases, 5.5 respectively 5.0 which were the lowest results seen in these tests. They were not particularly emotionally calm either. Test 1E also received the lowest ranking on how pleasant the participants experienced the situation. Hence, the lateral distance of 0.45 m and the vehicle's speed of 8 km/h or 5 km/h did not seem to be a good combination. At the speed of 5 km/h had 66 % of the participants perceived uncertainty where 100 % of the test group perceived uncertainty in some way at 8 km/h, see table 7.

Table 7

Results of tests 1C and 1E

	Test 1C	**Test 1E**
Speed of vehicle	5 km/h	8 km/h
Median distance to car	**0.47 m**	**0.49 m**
SAM: Unpleasant – Pleasant (1-9)	5.0	4.0
SAM: Active – Calm (1-9)	6.0	5.0
SAM: No Control – Full control (1-9)	5.5	5.0
The situation felt good	35 %	0 %
Perceived uncertainty	65 %	100%

According to the interviews, the distance of 0.45 m was not appreciated, 5 km/h seemed to be better than 8 km/h. Participants who stated the distance of 0.45 and speed of 5 km/h as good commented for instance: "there's no problem, I feel safe" and " It felt OK, I'm used to this distance when I'm waiting for the bus". Among the test group did 66 % not experience the distance that good, but the distance seemed to be the critical factor and not the speed. The comments were: "The distance didn't feel safe, I wanted to take a step back", "The speed felt ok, but would never have been that close to an unknown car. Others said "The car drove straight, which made me feel safe, but I had probably wanted to take a step back", "Slow speed meant that I didn't feel like a target, but still wanted to back off".

The speed of 8 km/h and a distance of 0.45 m did none express the situation felt okay nor safe. The distance was experienced as too close and the speed seemed to be too high in combination with the distance. Comments from participants expressed nervousness "I felt the nervousness in the stomach and throughout the whole body, this distance was far too close". Another felt insecure due to the lack of getting an overview of the approaching car "Very close, I wanted to take a step back. I did not see the whole car, no overview!". Further comments expressed irritations "It felt very unpleasant. The driver is an idiot, I get angry! Way too close but the speed was okay", "Not comfortable, it was too fast and too close" and "I would not have been able to take a step back in time if the car had changed the direction of the route".

Tests 1D and 1F – Lateral distance of 0.80 m and vehicle's speed of 5 km/h or 8 km/h.
In tests 1D and 1F, table 8, was the lateral distance between participants and vehicle about 0.80 m, and the speeds of the car were either 5 km/h or 8 km/h. The SAM method showed very similar results of both tests but the interviews showed more clear indications. According to the interviews did 35 % of the participants perceived uncertainty at the speed of 5km/h and 48 % perceived uncertainty at the speed of 8 km/h.

Table 8
Result of tests 1D and 1F

	Test 1D	**Test 1F**
Speed of vehicle	5 km/h	8 km/h
Median distance to the car	**0.81m**	**0.81 m**
SAM: Unpleasant – Pleasant (1-9)	5.0	5.5
SAM: Active – Calm (1-9)	7.0	6.5
SAM: No Control – Full control (1-9)	6.5	7.0
The situation felt good	65 %	52 %
Perceived uncertainty	35 %	48 %

The participants experienced the speed of 5 km/h better than 8 km/h, even though some wanted to take a step back. " I felt calm when the front wheel had passed, I was most worried until the front wheel had passed me", "It felt safe, but I had taken a step back", "It was a safe distance, I experienced as calmly and controlled".

At the speed of 8 km/h and at the distance of 0.80 m the comments were positive, some still thought the distance was too close and some did not, "Good distance, I have control", "No dangerous speed. Had probably taken a step back even though I think that the distance to the car is okay, the longer distance feels safer", "The speed feels good, I feel calm to stay at this distance".

All tests, 1A-1F
Generally, during the tests, the pedestrians in some way wanted the vehicle to confirm that it had seen them, in order to increase the feeling of perceived safety. Some felt even safer because the car was driving in a straight trajectory. It led to they trusted the car's course, but they never knew if the

car had seen them or not. As some participants expressed it: “I want a reaction from the car”, “I want the car to signal that it has seen me”, “Its straight route felt safe and calm” and "I did not expect any unforeseen movements”.

There was a difference between the genders in test 1A and 1B. The men's median lateral distance to the vehicle was shorter than the female's, but the results from the SAM analyses did not differ between the genders. Test 1 A had the men a median distance of 0.85 m and the women 1.13 m. In test 1B, had the males and median distance of 1.11 m and women 0.96 m.

No other significant differences could be seen in the other tests between the genders except for in results 1F where the male felt more pleasure compared to the women. The men rated the emotional state of pleasure to a median of 7.0 where the women only rated 4.5.

6.3 User tests 2 – Longitudinal distance between pedestrian and vehicle

User tests 2 was about to find out a desirable vehicle behaviour in a longitudinal perspective to increase the perceived safety, see figure 16. In user tests 2 there were six tests at the speed of 5 km/h and 8 km/h. These test had the focus to find out which distances the participants started to pay attention to the vehicle when they felt the distance was close and when they wanted the car to increase its speed. The tests were tested twice at a speed of 5 km/h or 8 km/h. The last two tests were to examine when the vehicle should stop when the initial speed was slow, about 2 km/h. For more information on how the tests were performed, see Appendix A: User tests method.

Figure 16. Photo from user tests 2.

Test 2A and 2B – Longitudinal distance – Attention

From table 9, it is shown that the distance from when the participants paid attention to the car did not change if the vehicle drove in a speed of 8 km/h nor 5 km/h. The differences were low and negligible. However, the speed did not seem to play a crucial role, it could be because of the small speed differences that might be hard to distinguish, at a median distance of 38 meters for both tests. Test 2A had a range of distance between 13.7 m and 50.1 m and test 2B between 14.0 m and 45.0 m, see Appendix A2: Calculations. The results of the SAM analyses were similar.

Table 9

Results from tests 2A and 2B

Attention	**Test 2A**	**Test 2B**
Speed of vehicle	8 km/h	5 km/h
Median distance when participants put attention to the car	**38.3 m**	**38.1 m**
SAM: Unpleasant – Pleasant (1-9)	7.0	7.0
SAM: Active – Calm (1-9)	7.0	8.0
SAM: No Control – Full control (1-9)	8.0	8.0

In test 2A, two participants said that they had left the roadway from the distance where they first started to pay attention to the car, in test 2B there was only one. Overall there were pleasant responses to when the first attention is paid to the vehicle, in terms of feeling calm and safety. The things that the participants paid attention to were the headlights, the sound of the engine speed and the movement of the car.

The median distance difference in a gender perspective was 40.1 m for women and 33.5 m for men at a speed of 8 km/h. For speed of 5km/h, the median was 40.0 m for women and 36.0 m for men.

Test 2C and Test 2D – Longitudinal distance – Closeness

When the participants experienced the car close, were very similar for both speeds. The difference in median distances for 5 km/h and 8 km/h when the participants perceived the car was close were 1.4 m, see table 10. The results from the SAM analyses were similar in both tests as well. The range of distances in test 2C was between 7.8 m and 39.2 m and 11.5 m and 34.4 m in test 2D, see Appendix A2: Calculations.

Table 10

Results from tests 2C and 2D

Closeness	**Test 2C**	**Test 2D**
Speed of vehicle	8 km/h	5 km/h
Median distance to the car when the participants perceive that the car is close	**18.9 m**	**17.5 m**
SAM: Unpleasant – Pleasant (1-9)	6.0	6.0
SAM: Active – Calm (1-9)	7.0	6.0
SAM: No Control – Full control (1-9)	7.0	6.0

From the interview, there were more positive comments than negative in test 2C, and the same amount of positive and negative comments in test 2D. The comments' content in both tests were however similar, and some positive were, "It feels ok in relation to speed", "Feel safe and I can get away if I want to". The most common negative comments were both confused about what the car's intention and safety aspects. Examples of the comments were, "What should the car do? Want to know what it is going to do" and "Close distance less control, less time to move ".

Test 2E and Test 2F – Longitudinal distance – Slow down

The median distance from when the participants wanted the car to slow down was 23.3 m (distance range between 16.1 m and 31.9 m) at a speed of 8km/h and 20.7 m (distance range between 12.4 m and 32.9 m) at a speed of 5 km/h, see Appendix A2: Calculations. The difference between the median distances was 2.6 m, see table 11. The test results might indicate that a higher speed admits that the car should slow down earlier, even for low-speed differences. There were no significant differences in the participants' emotional states between the tests. However, one significant finding was that the participants wanted the car to decrease its speed before they perceived the car close (as tested in tests 2C and 2D).

Table 11

Results of test 2E and test 2F

Slow down	**Test 2E**	**Test 2F**
Speed of vehicle	8 km/h	5 km/h
Median distance to car when participants want it to slow down	**23.3 m**	**20.7 m**
SAM: Unpleasant – Pleasant (1-9)	7.0	6.5
SAM: Active – Calm (1-9)	6.5	7.0
SAM: No Control – Full control (1-9)	7.0	8.0

According to the interview, it was split opinions about test 2E. There were more who experienced it as calm or safe, but there were a high amount of participants who felt that the speed was too high. Comments like "this go faster, the car should run slowly. I rely less on the car at that speed". But, it was still participants who were fine with the higher speed with a comment like, "it drove faster, but it felt good, good gut feeling, a good time to stop". In test 2F several participants wanted to have a response that the car had indicated them.

In both test 2E and test 2F, women wanted the car to start to slow down from a closer distance then what the participants of men wanted. The women wanted a decrease of speed at 23.0 m and the men at 24.1 m at the speed of 8km/h, and a distance of 20.3 m for women and 22.4 m for men at the speed of 5km/h.

Test 2G and Test 2H – Longitudinal distance – Stop

During both test 2G and test 2H, the car stopped from a slow speed (about 2 km/h). The difference in distances between the tests was 0.9 m. There were no differences in test 2G, and 2H and the SAM analyses also showed similar results, see table 12. Test 2G had a distance range between 3.3 m and 13.6 m and test 2F had a distance range between 2.5 m and 11.3 m, see Appendix A2: Calculations.

Table 12

Results of tests 2G and 2H

Stop	**Test 2G**	**Test 2H**
Speed of vehicle	Slow speed (~ 2 km/h)	Slow speed (~ 2 km/h)
Median distance to car	**8.0 m**	**7.1 m**
SAM: Unpleasant – Pleasant (1-9)	6.5	6.0
SAM: Active – Calm (1-9)	6.5	6.0
SAM: No Control – Full control (1-9)	6.0	7.0

Most of the participants told that the distance to the stopped car was safely or feel calm. From comments during the tests, it was found that the participants wanted to have more response from the vehicle.

The distance to a stopped car was very similar between the genders, which implies that there is no different when they want the car to stop, related to a gender perspective. However, the men felt more pleasant and more control than the women at the same distance in both tests.

6.4 User test 3 – Trajectory behind a car

The purpose of user test 3 was to see how close pedestrians were willing to walk behind a car that has a running engine in a parking spot with the knowledge that the car can start to go reverse. As the participants walked behind, their trajectory was marked up on the floor at three lines, see figure 17. Findings gave indications that the participants walk either with an increased or a decreased trajectory away from the car.

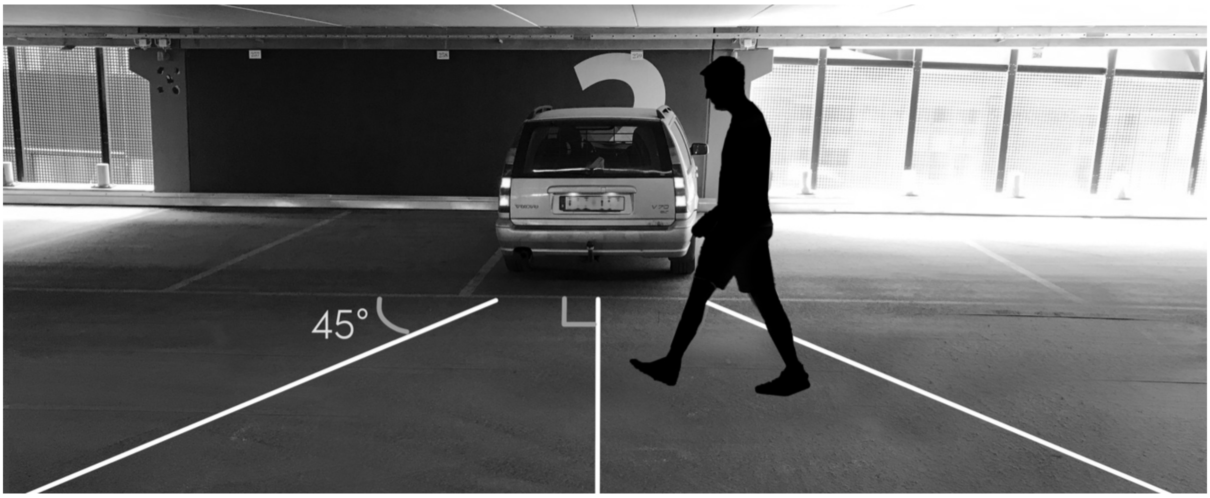


Figure 17. Test 3, with line 1, 2 and 3.

In user test 3, the participants gave decisive insights into their walking path behind the parked car. Two differences separated the participants from each other. 65 % of the participants had a walking distance from the car, which decreased when they had passed the middle of the car. The other group, 35 % of the participants' walking distance from the car increased when they had passed the middle of the car, see table 13.

Table 13

Results from user test 3

Test 3 Trajectory behind a car	**Median All Participants**
Distance to line 1	2.4 m
Distance to line 2	2.2 m
Distance to line 3	2.1 m
Decreasing walking distance	65 % (13 participants)
Increasing walking distance	35% (7 participants)

The closest and the longest distance from the parked car differed. At line 1, the closest distance where 0.95 m and the farthest distance was 4.32 (median 2.4 m). At line 2, the closest distance was 0.93 m and the most far distance was 3.69 m (median 2.2 m). At line 3, the closest distance was 0.85 m and the most far distance was 4.17 m (median 2.1 m). The closest and the longest distance path was made separately by two participants, see Appendix A2: Calculations.

Findings from the interviews indicated that there were the trust and safety to the car that determined how far from the car the participants wanted to go. Comments after the participants had walked behind the car and their trajectory had been marked up, were for instance, “I watch the car but feel less safe closer than the walked line, I do not fully trust the car”, “I feel more uncertain inside the mapped line, has the car seen me?”, “Within the mapped line it feels unsafe, outside safe”. Thus, some responses that the car has indicated the participants seem to be appreciated.

No significant differences could be seen in relation to the participants’ technical interest nor adventurousness in the user tests, neither in user test 1, user test 2 or user test 3.

6.5 Evaluation

As the user tests 1, 2 and 3 were completed and analysed the last test called validation test was set up to validate the previous data. Its purpose was to validate previous tests. The goal was to see if the tests received the same result as in previous tests. Therefore, the test environment and stimulus material as the Wizard of Oz costume were identical as in user tests 1, 2 and 3 in Appendix A: User tests method.

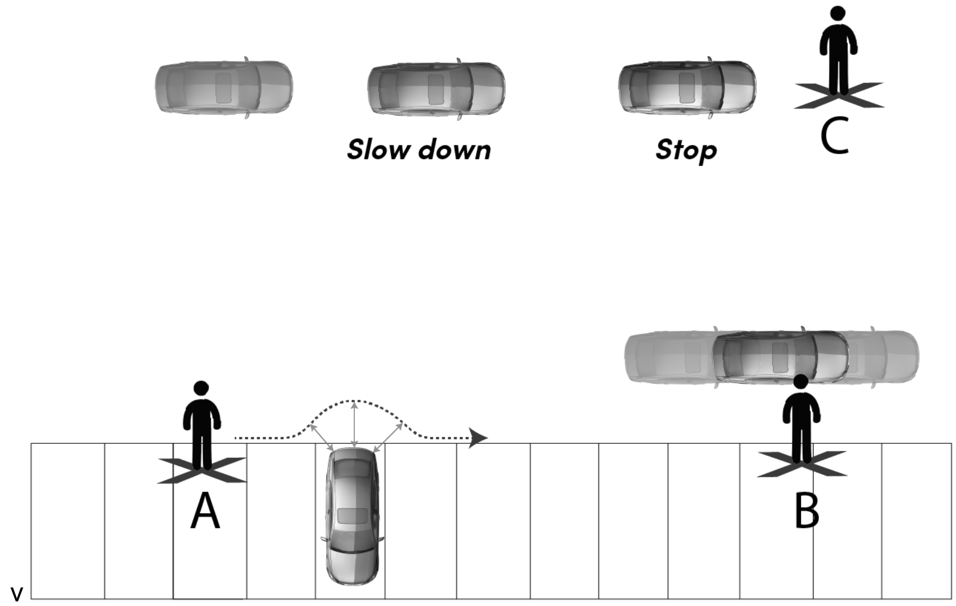


Figure 18. Validation test, two scenarios, six different tests.

The validation test consisted of two scenarios, 1 and 2, with three tests in each scenario A, B and C, see figure 18. The participant experience first either scenario 1 or scenario 2, randomly, and then the other. Before it started, they got informed about the procedure and filled in a questionnaire with questions, as in the previous tests. They were only informed about one step at the time, that is to say, first, they got the scenario about test A, then B and at last test C. After every test within the scenarios, the participants were asked to fill in the SAM survey and answer how it felt and why. Both scenarios were experienced consecutively. After both of the scenarios, an interview was conducted.

6.5.1 Validation test – Trajectory behind a car

In tests A1 and A2, see table 14, the participants were asked to walk along two different paths behind a vehicle with a running engine and parked in a parking spot, see figure 19 and 20. The distance of the line was similar to the median results from the user test 3, and it referred to confirm or deny the previous result. After the performed test, the participant rated their emotional experience by using the SAM method, and after completed scenarios was an interview session conducted.

Table 14

Validation tests trajectories, test A1 and test A2

Trajectory behind a car	**Test A1**	**Test A2**
Walk behind the vehicle	Increasing distance Distance to car 2.1 m → 2.2 m → 2.4 m	Decreasing distance Distance to car 2.4 m → 2.2 m → 2.1 m
Line	Blue	Green

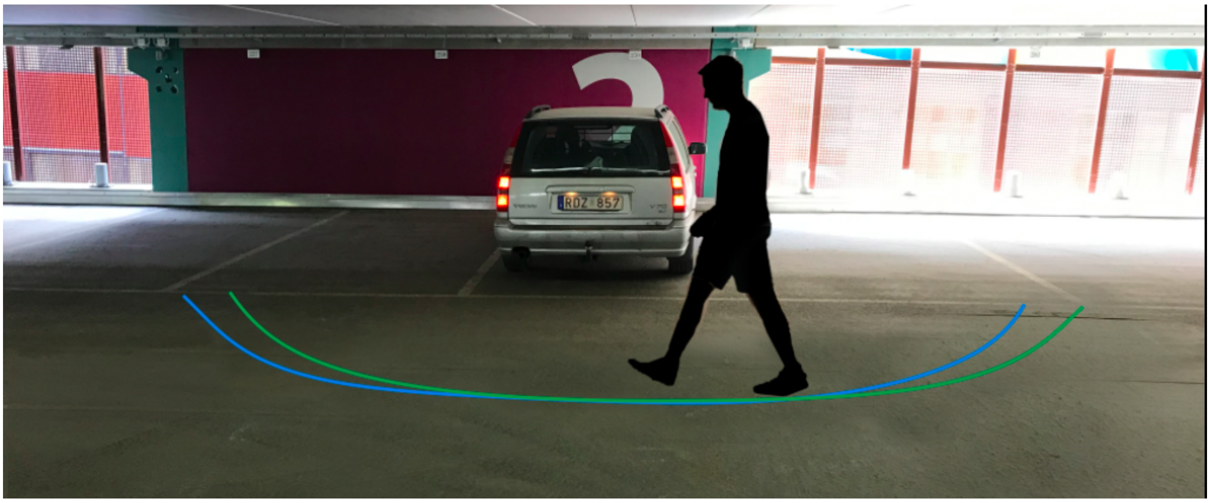


Figure 19. Validation test, trajectory behind a car. The blue line was test A1 and the green line wastest A2.

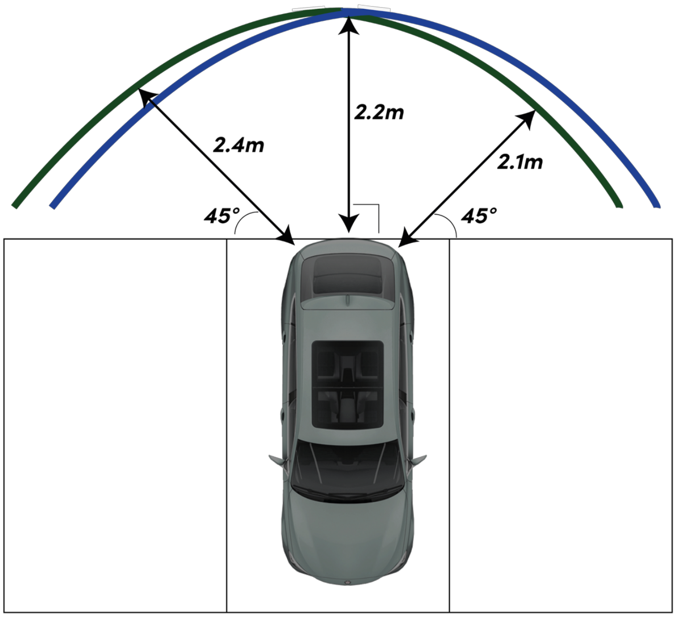


Figure 20. Two different paths behind a vehicle with a running engine.

According to the interviews after performed tests, the majority of the participants were pleased with the distance to the car, and those who were not pleased had a more hesitant attitude to the distance and said like "a bit too close" and "not closer than this". Additionally, findings of the test were that some of the participants did not feel any different from the two trajectories.

Trust

The majority of the participants did not trust the car. The lack of trust in the car's behaviour was due to that the participant did not know what the car was supposed to do and if it had detected them. However, the participants felt more trust in themselves than to the vehicle.

Understanding

There were split opinions about the understanding of the parked car's behaviour. The most recurrent reason to not understand the car was why it stood still during the test. Usually, when a car's engine is running in a parking spot, it is generally leaving the parking spot. They did not know if the vehicle had discovered them and wanted response of the vehicle. The reason for those who understood the car was fairly the opposite. The vehicle did not move when the participants walked behind the car, and there was nothing that indicated that it would do so, which gave a feeling that the car had seen the participants. There were more who did not understand the car then who did.

Control

There was an overall lack of control during the test; it was based on the fact that the participants did not know what the car would do. When will it start to reverse? Will it leave the parking spot? Since the participants did not know what the car was up to, the participants felt that the responsibility of control was more on them than in an interplay with the vehicle. Those who commend the tests specifically liked test A1 more than A2 with the reason that they had extra margin when they had passed the car.

Perceived safety

The most common was that the participants did not perceive safety during the test. They felt that they needed to be vigilant and uncertainty about whether they have been registered by the car or not. Those who perceived that it was safe did not think it felt like the car would start driving. They also said they felt safe because it is a user test, but in a real situation, it is probably about a learning phase before they get to know how an autonomous car would act and that it will gradually increase the grade of perceived safety.

SAM Method

The results from both test A1 and A2 were relatively similar, according to the SAM method. The differences are scant and can be negligible since both tests had the almost same emotional state in rate of pleasant, calm and control, see table 15. The results from the SAM scales showed a high emotional state of pleasure (7), the emotion of arousal was even between active and calm (5), and the feeling of control was in median emotion of control was over average (6).

The fact that the results were not higher in the SAM method can be due to lack of understanding, trust, control and perceived safety, which emerged during the interviews.

Table 15

Results from Test A1 and Test A2

Scenarios 1 & 2	**Test A1**	**Test A2**
Walk behind the vehicle,	Walk behind the vehicle, increasing distances Distance to car 2.1 m → 2.2 m → 2.4 m	Walk behind the vehicle, decreasing distances Distance to car 2.4 m → 2.2 m → 2.1 m
SAM: Unpleasant – Pleasant (1-9)	7.0	7.0
SAM: Active – Calm (1-9)	5.5	5.0
SAM: No Control – Full control (1-9)	6.5	6.0

In test A1, the group of women rated an overall lower median than the men in all scales. In the order, unpleasant – pleasant, active – calm, no control – full control, the group of women rated 4.5, 4.5 and 5.0, and the group of men, 7.0, 7.0 and 7.5. The differences are 2.5, 2.5 and 2,5. In test A2, there were no significant differences.

Summary – Validation test – Trajectory behind a car

The results indicate that some participants preferred the distances for trajectory in test A1 and some the distances for trajectory A2. To satisfy all, the trajectories from test A1 and A2 could then be merged into one line with the distances 2.4 m, 2.2 m and 2.4 m.

The car needs some kind of respondents to indicate its intention in order to have a clear behaviour. The lack of expressed purpose could be a reason why some of the participants thought the distances were too close.

6.5.2 Validation test – Lateral distance between pedestrian and vehicle

In test B1 and test B2, the participants were positioned at a lateral distance to a vehicle when it passed by, see figure 21. The distances to the vehicle and the speeds in the tests were based on the results of user test 1. Test B1 were tested with the most preferred median distance of 1 m and speed of 5 km/h, while Test B2 were tested with the least preferred distance of 0.45 m and speed of 8 km/h, see table 16. After the performed test, the participant rated their emotional experience by using the SAM method, and after performed scenarios was an interview session conducted.

Table 16

Validation tests B1 and B2

Car passing by	**Test B1**	**Test B2**
Speed of vehicle	5 km/h	8 km/h
The lateral distance between pedestrian and vehicle	1 m	0.45 m

Figure 21. Performance of tests B1 and B2.

Trust

Almost none of the participants did feel any trust to the vehicle in test B2 where the speed was 8 km/h, and the distance to the car was 0.45 m. That was due to the close distance to the car, but also because the speed felt too high. Test B1 gave a much better response of trust with respect to the distance, and the speed of the car was also experienced better.

Understanding

Some said that the constant speed and the straight driving trajectory gave an understanding that the car would not do anything unforeseen, as a sudden turn. However, most of the participants experienced that the car had not seen them since it did not increase its speed and neither given any indication that it had indicated them. They wondered why it drove so close to them in test B2 and did not give more space to them, a comment was for instance “an indication like a deceleration had given increased understanding”, which confirms that the driving behaviour was not understandable.

Control

The participants experienced lack of control of the traffic situation since the car did not give any indications that it had seen them and in combination with, they were asked not to take a step back when the car was passing. In a similar situation, in real life, they would have taken one or two steps back, they said. That means that the experience of having low control refers to that they could not affect the car, and thus not their traffic situation. They also pointed out that the opportunity to see a car for a longer time, like in the test, also increases the control.

Perceived safety

Both test B1 and B2 gave a higher perceived safety compared to the other validation tests as A and C. It was with regard to how they were standing, in relation to the car. They were not standing in the car's trajectory as they were in the other tests. The vehicle speed of 5 km/h and a distance of 1.0 m (test B1) experienced much safer than test B2 where the speed was 8 km/h, and the distance was 0.45 m.

SAM method

The result of this test shows a clear difference in all median SAM scale categories. Test B1 was rated high on all three scales regarding the emotional state of pleasant calm and control. B2 had low rates at the SAM scales compared to test B1. The results from the validation test confirm the outcome of the corresponding user test 1, see table 17. The tests are very similar.

Table 17

Results of the SAM method from the validation test and user test

	Validation test		**Previous user test**	
Car passing by	**Test B1**	**Test B2**	**User test 1A**	**User test 1E**
Speed of vehicle	5 km/h	8 km/h	5 km/h	8 km/h
Lateral distance to the car	1 m	0.45 m	0.97 m Participants' choice	0.49 m
SAM: Unpleasant – Pleasant (1-9)	8.0	4.0	7.5	4.0
SAM: Active – Calm (1-,9)	8.0	4.5	7.5	5.0
SAM: No Control – Full control (1-9)	7.5	5.0	8	5.0

The result from the SAM method differed among the genders in the validation test. The unpleasant - pleasant scale in test B2 differed with 2.5, the rated median was of 3.0 for women and 5.5 for men, otherwise, it was no significant difference in tests B2 or B1.

Summary – Validation test - Lateral distance between pedestrian and vehicle

The findings confirmed the results from the user tests, that the distance of 1.0 m to the pedestrian with a vehicle speed of 5 km/h was experienced much safer than a speed of 8 km/h at a distance of 0.45m. The SAM method showed a very similar result.

The validation test explored new findings, showing that the participants did not understand the intention of the car when it was passing them, regardless of different speeds and distances. The lack of understanding led to a lack of trust and control to the car's behaviour. The SAM scales indicated that test B1, the longer distance and slower speed, had a higher median result of the emotional states of pleasant, calm and control than in test B2. However, the interviews clarify that the car's intention and behaviour have to be clearly stated for an even higher perceived safety.

6.5.3 Validation test – Longitudinal distance between pedestrian and vehicle.

In test C1 and test C2, the participants were positioned on the road with a longitudinal distance to the vehicle, see figure 22. The vehicle moved forward in speeds of either 5 km/h or 8 km/h and slowed down to slow speed (about 2 km/h) at a distance of 21m or 23m to the participant, see table 18. Then, the car drove slowly until it had reached a distance of 7.5 m to the participant. The distances to the vehicle and the speeds in the tests were based on the median results of user test 2, see Appendix A2: Calculations. The test C1 and C2 are based on distances when the participants preferred the vehicle to decrease its speed and slows down in order to find an appropriate driving behaviour. After the performed test, the participant rated their emotional experience by using the SAM method, and after performed scenarios was an interview session performed.

Table 18

Test C1 and C2, Longitudinal distance between pedestrian and vehicle

Longitudinal movement	**Test C1**	**Test C2**
The initial speed of the vehicle	5 km/h	8 km/h
Deceleration distance	21 m	23 m
Final speed	Slow speed (about 2 km/h)	Slow speed (about 2 km/h)
Stop distance to the pedestrian	7.5 m	7.5m

Figure 22. Environment validation tests C1 and C2.

Trust

The participants had an overall high trust in the car during the tests. Both distances when it slowed down to low speed promoted the trust feeling that the car had indicated them. Both visual and hearing helped to increase the trust feeling when they saw the car deceleration and heard the reduced engine noise.

Understanding

Participants in the validation tests understood that the car had indicated them in both tests. Some understood the car more in user test C1 because of a shorter distance of slow speed than in C2. Then it was clearer that the car had decreased its speed because of them. Others preferred C2 because the deceleration was clearer when it slowed down from a higher speed, which felt like the car has indicated them in a clearer way. Thus, it was a greater speed difference between 8 km/h and slow speed than it was from an initial speed of 5 km/h to slow speed. A misunderstanding among one participant was when the car had stopped, then he/she did not know what the car would to next.

Control

The participants level of control was high in both tests C1 and C2, mostly because of the distance when the car slowed down, the participants felt that they had time to move, in both tests. The lower speed in C1 helped some of the participants to feel that they had control over the situation. In test C2, some liked when the deceleration was clearer because it indicated that the car had control, which made the situation more controlled.

Perceived safety

Overall, the perceived safety was high in both tests. User test C2 got better responses, but C1 was still safe. When the car decelerated from a higher speed made the breaking more distinct, which also increased the perceived safety.

The findings from the interview confirmed that stopping at 7.5 m was perceived safe. None of the participants expressed the stopped vehicle as too far away nor too close, one said, “If the car had stopped earlier, the distance becomes unfunctional, and closer would be scary. It might be regarding experiences of self-driving vehicles”.

SAM method

The result from both test C1 and C2 were relatively similar in all three scales, see table 19. The differences are so small that they can be negligible. Hence, both tests had the same emotional states of pleasant, control, and calm.

Table 19

Result from SAM scales in tests C1 and C2

Longitudinal movement	**Test C1**	**Test C2**
The initial speed of the vehicle	5 km/h	8 km/h
Deceleration distance	21 m	23 m
Final speed	Slow speed (about 2 km/h)	Slow speed (about 2 km/h)
Stop distance to the pedestrian	7.5 m	7.5m
SAM: Unpleasant – Pleasant (1-9)	**8.0**	**8.0**
SAM: Active – Calm (1-9)	**8.0**	**7.5**
SAM: No Control – Full control (1-9)	**7.5**	**7.5**

In test C1, the group of women rated lower median than the men in all SAM scales. In the order, unpleasant – pleasant, active – calm and no control – full control, the group of women rated 5.0, 5.0 and 6.5, and the group of men, 8.5, 8.5 and 7.5. The differences were 3.5, 3.5 and 1,0. The same tendency was seen in test C2, but then the differences were 1.5, 2.0 and 2.0 among the genders.

Summary – Validation test - Longitudinal distance between pedestrian and vehicle

The findings showed indications that the participants appreciate a speed change in order to understand the vehicle's intention and so its behaviour. The participants appreciated test C2 better than C1, because of the distinct deceleration the car got form 8 km/h to slow speed. It made the participant increase the trust in and understand the vehicle, but also to get a higher level of control to the traffic situation and perceived safety. However, in test C1, was the distance of when the car decreases its speed shorter to the participants than in test C2. The shorter distance of slow speed was experienced more clear and counteracted confusion among the participants.

The findings from the result of the SAM scales were almost identical, and perceived as positive, in the experience of pleasure, calm and control. That confirms that certainty in the previous user tests since the performed validation tests were based on them.

No significant differences could be seen in relation to the participants' technical interest nor adventurousness in the validations test, neither in scenario A, B or C.

7 Final concept (Guidelines)

This study has identified findings that affect the interaction experience between pedestrians and vehicles to obtain perceive safety. The findings suggest that the interaction experience is determined by several causes, such as the feeling of trust, control, understanding in order to increase the perceived safety to the vehicle.

7.1 Perceived safety

This study can show that pedestrians perceived safety when interacting with self-driving vehicles increased if the car's behaviour was understandable and clear. It is stated below what can affect perceived safety in situations such as when the car passes pedestrians, runs straight towards them, and when pedestrians walk behind a car.

7.1.1 Findings lateral distances – What can affect perceived safety

Findings indicated that the pedestrian appreciated getting a clear overview of the traffic situation. The pedestrian got a better overview of the traffic when the lateral distance to the car was greater. Hence, a close lateral distance to the car could not be seen as appreciated. Further, to increase the perceived safety, the pedestrian appreciated having a feeling that they had time to react and move further away from a car's trajectory, even if they technically would not be hit by the car. When the pedestrian felt they had time to react, the perceived safety increased. The perceived safety also seemed to differ during a sequence of event, when a car was passing by. For instance, it could be seen that the feeling of safety increased as soon as the front-wheels had passed a pedestrian, and by that, the pedestrian knew that they were safe.

A vehicle that was driving in a straight line while passing a pedestrian also seemed to imply an increased feeling of trust in the vehicle's behaviour. Hence, the car would not do any sudden turns when passing by.

In order to increase the perceived safety, understanding, trust of the vehicle's behaviour, the findings showed that pedestrians need the vehicle to confirm by a reaction that it had seen them. One way of doing that can be to let the vehicle decrease in speed, as seen in the validation test C2.

The findings showed that a lack of control in the traffic situation could be due to the pedestrians' impossibility to affect the car's behaviour. Hence, the car did not react to the pedestrians' presence.

In general, the perceived safety was higher when the pedestrians were out of the car's trajectory compared to when they stood in the longitudinal direction of travel.

7.1.2 Findings longitudinal distances – What affect perceived safety

Findings showed that it was hard for the pedestrians to recognise differences of the two speeds 5 km/h and 8 km/h of the vehicle at long distance, for instance, 30 to 50 m, to the pedestrians. However, result from user test E and F showed that pedestrians could discover speed differences around 20-25 m. This might imply that perceived safety does not concern a vehicle at a long distance from the pedestrian.

The feeling of when a pedestrian experiences the car as close was when they experienced a feeling saying that they might have to start moving away from the car's trajectory to avoid being hit, but at this distance, it still felt safe. The study showed that the car should decrease its speed before the pedestrians perceived the car as close.

When seeing the change in speed, it increased the perceived safety and gave the pedestrians an understanding of the vehicle's intention to stop and that the car had seen them. Also, to hear the decreasing engine speed increased the trust that the car was decreasing its speed.

When the car had stopped at a longitudinal distance, there was a lack of understanding of what the car's next intention would be.

7.1.3 Trajectory behind a car – What affect perceived safety

The study found that the participants perceived safety differently in the tests when they walked behind the car. They either wanted to have a longer distance to the car before they had passed the middle of the car, or they wanted to have a longer distance to the car when they had passed the middle of the car, see describing figure 23. Hence they had an increasing or decreasing distance to the car. The distance to the car depended on the level of trust they had to the car.

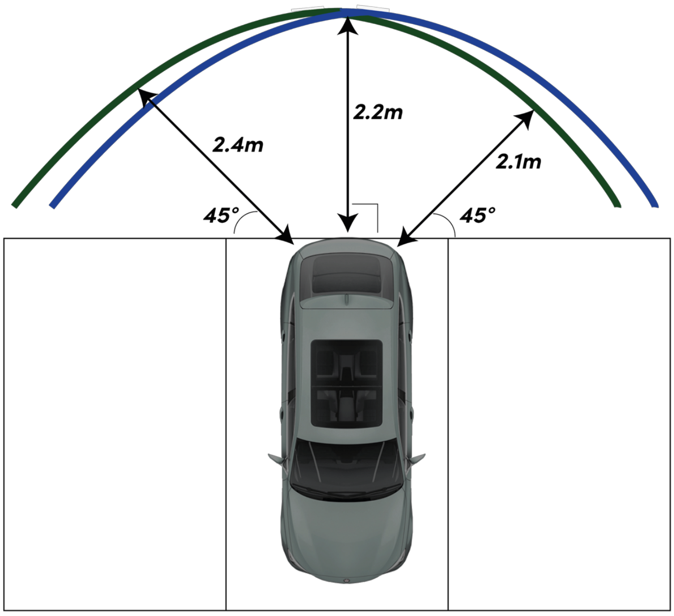


Figure 23. The participants either preferred the green or blue line.

No identifications on what the car was supposed to do, led to a low level of trust to the vehicle. Also, a low level of control to the traffic situation could be identified. No response from the car showed that the pedestrians had to put trust and control in themselves, that they kept a safe distance to the car. The behaviour did not perceive safety. Hence, the car needed a behaviour that indicated what the vehicle was supposed to do when it had a running engine.

7.2 Comfort zone

The study has also found proximal distances, that can be applied to pedestrians when interacting with vehicles, at low speeds. The distances can symbolise a comfort zone surrounding the pedestrian. The zone of comfort differs depending on how the pedestrian interacts with the vehicle. The study has identified comfort zones at lateral and longitudinal distances, and also a suggestion of comfort zone when pedestrians are walking behind a car that has a running engine. If a car is within the pedestrians' comfort zone, they seem to get a negative state of emotion and feel scared, irritated and nervous.

7.2.1 Lateral comfort zone

Findings suggest that the lateral comfort zone depends on the lateral distance the pedestrian has to the vehicle in combination with its speed. Low speed and a close distance are experienced safer than a faster speed and a close distance. The faster the speed is, the greater is the distance for perceived safety among the pedestrians.

Table 20 shows which distances and speeds that were experienced safe, marked with yes. No means that the distance, in combination with speed did perceive insecurity among the pedestrians. The recommendation of speed and lateral distance when passing a pedestrian is marked with green colour.

The car has to indicate that it has detected the pedestrian to increase perceived safety, and the study showed that it could be performed by a reduction of the vehicle's speed. The recommendation to increase safety is to drive 8 km/h and decrease the speed to 5 km/h before passing a pedestrian, at a lateral distance of 1 m. By doing that, the pedestrian can see a change in the car's speed which (according to the tests) can be predicted as the car has detected the pedestrian. At a distance of 1 m, the pedestrian did perceive safety. The use of deceleration as an indication has not been tested for lateral distances and is a finding for further work.

Table 20

Lateral Comfort zone

Distances/Speed	5 km/h	8 km/h
0.45	No	No
0.80	No	No
1.00	Yes (recommended)	Yes

7.2.2 Longitudinal comfort zone

The participant's longitudinal comfort zone differs from the lateral one, see table 21. An approaching car should not drive closer than 7.5 m to a pedestrian standing in the vehicle's trajectory, according to the user and validation test. It should also have a clear driving behaviour telling that it is supposed to stop. From the findings in the user and validation test should the car decrease its speed from 8 km/h to a slow speed about 2 km/h at a distance of 21 m to the pedestrian by doing that the vehicle will signal a clear, safe and understandable behaviour to the pedestrian.

Table 21

Longitudinal comfort zone

The initial speed of the vehicle	8 km/h
Deceleration distance	21 m
Final speed	Slow speed (about 2 km/h)
Stop distance to the pedestrian	7.5 m

7.2.3 Comfort zone – walking distance behind the car

The comfort zone behind the car seems to be 2.4 m (45°), 2.2 m (90°) and 2.4 m (45°), see figure 24. However, the car needs something to indicate its intention.

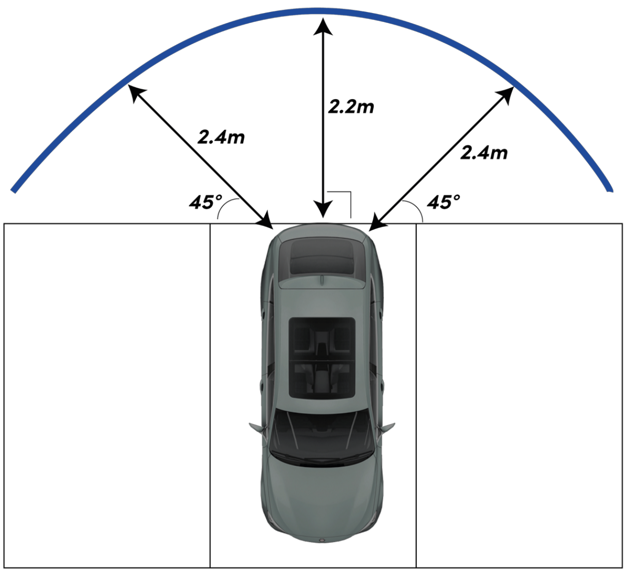


Figure 24. Comfort zone behind the vehicle.

7.3 Guidelines – Recommended driving behaviour

As a result of the study's all tests, a recommended driving behaviour to a driverless car in a parking garage has been developed. The recommendation for the driving behaviour is termed by guidelines that constitute how a car should act when it has a pedestrian in its trajectory or when passing a pedestrian.

7.3.1 Lateral distances to a pedestrian – Guidelines

When there is a pedestrian, who stands at a lateral distance over 1.0 m from the car. The car can pass the pedestrian at a speed of 8 km/h, see figure 25.

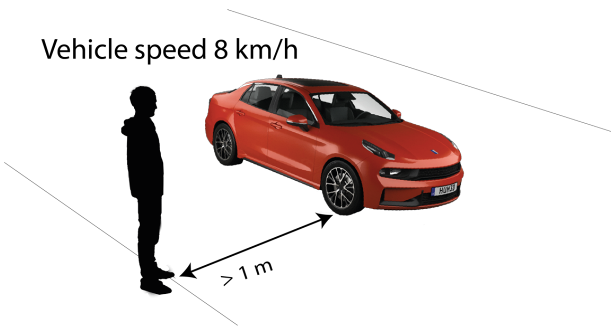


Figure 25. Recommended guideline. Pedestrian stands at a lateral distance over 1.0 m from the car, the vehicle can pass at a speed of 8 km/h.

When there is a pedestrian who stands at a lateral distance of 1.0 m from the car, the car should slow down from 8 km/h to 5 km/h to indicate that the pedestrian has been detected, and then pass the pedestrian, see figure 26.

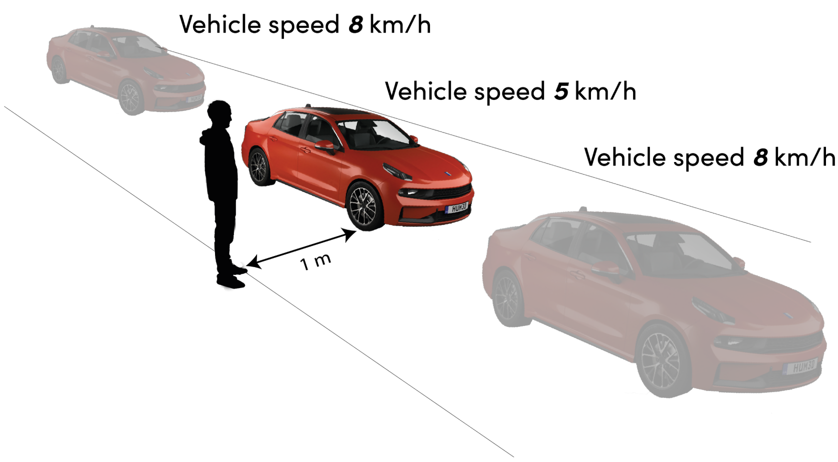


Figure 26. Recommended guideline. Pedestrian stands at a lateral distance of 1.0 m from the car, the vehicle can pass at a speed of 5 km/h.

When there is a pedestrian, who stands at a lateral distance under 1.0 m from the car, the car should slow down from 8 km/h to 5 km/h to indicate that the pedestrian has been detected. Then, the vehicle should give way to the pedestrian to maintain a distance of 1.0 m while it passes, see figure 27.

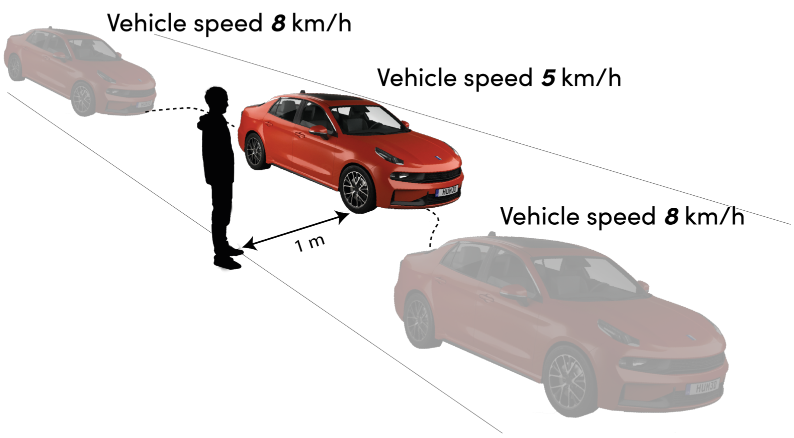


Figure 27. Recommended guideline. Pedestrian stands at a lateral distance under 1.0 m from the car, the vehicle should give way to the pedestrian to maintain a distance of 1.0 m.

When there is a pedestrian who stands at a lateral distance under 1.0 m from the car, and there is oncoming traffic or if there is no room to give way to the pedestrian the car should slow down from 8 km/h to indicate that the pedestrian has been detected. Then stop to let oncoming traffic pass, see figure 28.

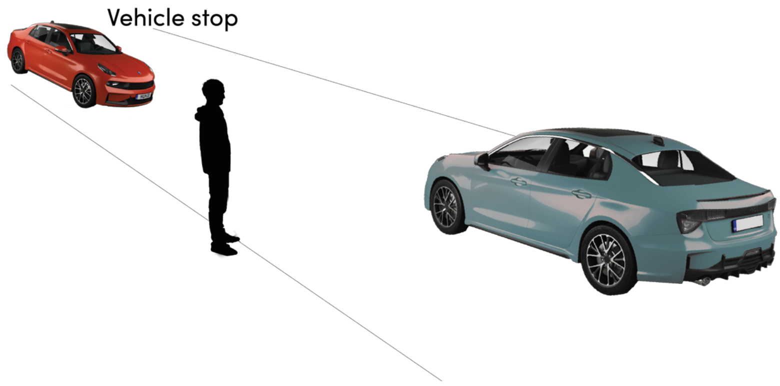


Figure 28. Recommendation guideline. Then stop to let oncoming traffic pass if it is not possible to keep a distance of 1 meter to the pedestrian.

7.3.2 Longitudinal distances to a pedestrian – Guidelines

If a pedestrian is standing in the vehicle's trajectory should the vehicle use following sequence of events in order to increase the perceived safety for the pedestrian, see figure 29.

- The vehicle should drive at a speed of **8 km/h**
- When detecting a pedestrian in its trajectory it should decrease its speed and slow down at a longitudinal distance of **21 m** to the pedestrian.
- The decrease of the vehicle's speed should go **from 8 km/h to a slow speed** to show an explicit behaviour that it has detected the pedestrian and it will stop.
- When there are **7.5 m** left to the pedestrian, the car should stop and wait to see if the pedestrian move.
- The vehicle should have a clear behaviour telling what its next intention is.
- If the pedestrian does not move, a suggestion is that the car gives way to the pedestrian and passes by the pedestrian at a lateral distance of 1.0 m at a speed of 5 km/h.

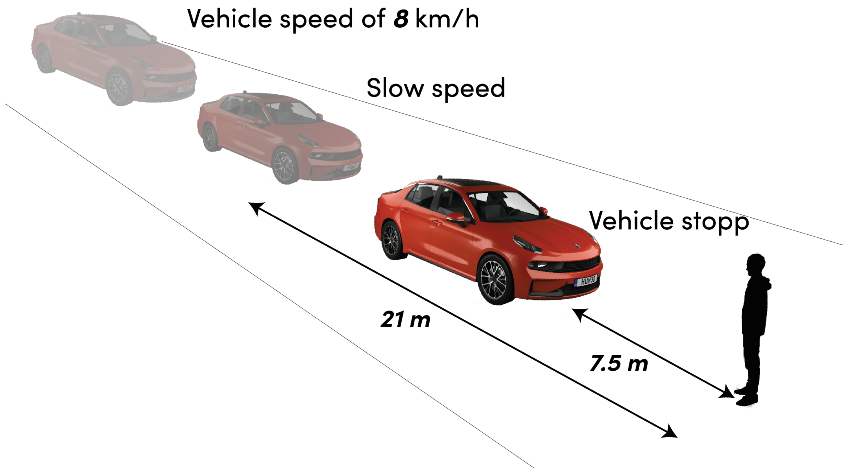


Figure 29. Recommendation guideline, if there is a pedestrian in the car's trajectory.

7.3.3 Leaving a parking spot – recommendations

- Keep a distance of 2.4 m to pedestrians, 45 degrees out from the vehicle's corners, see figure 30.

- Keep a longitudinal distance of 2.2 m to pedestrian, from the back of the vehicle's centre.

- The autonomous vehicle should have something that indicates its intention to not exiting the parking spot, while a pedestrian pass. It is to make it better understood and to promote the perceived safety and the feel of control for the pedestrian.

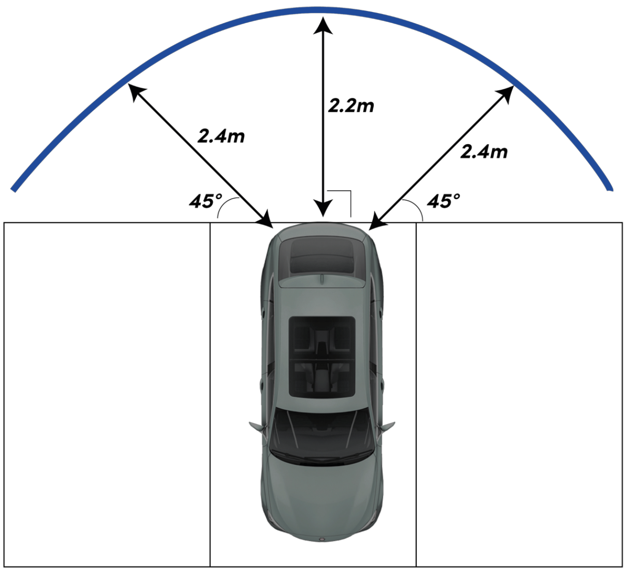


Figure 30. Recommendation guideline. Distance to pedestrian when vehicle exiting a parking spot.

8 Discussion

The discussion concerns the result, methods and the project's limitations. It also states the ethical aspects and future work.

8.1 Results

The project has investigated the pedestrian-vehicle interaction in a parking garage context. The study showed that the vehicle's body languishes affect the pedestrians' perceived safety positively to an approaching car. The most essential body languish that was found was a clear marking in terms of a clear speed reduction when the driverless car was approaching a pedestrian. That distinct body language, in turn, increased perceived safety for the pedestrians, but also the understanding, trust and control to the vehicle's intention. Rothenbücher et al. (2016) conducted a similar study, with a similar Wizard of Oz stimuli as in this study. The difference was that they tested the car's behaviour at a crossing, which is a place where vehicles usually give way to crossing pedestrians. Their study showed that pedestrians about to cross in front of a car like to get a sign that they have been seen as well, which increases the significance of this study.

Findings in this study have also shown that a comfort zone could be applicated to increase the perceived safety for pedestrians. The pedestrians comfort zones are results in distances relative to the cars lateral and longitudinal directions. The comfort zones could be an opportunity to regulate the vehicle's approach by set speeds for distances to pedestrians with the purpose to maintain perceived safety. The comfort zones could be described as a mental model where the vehicle's response is based on how the pedestrians expect it to behave by keeping distances which reinforce the comprehend of the vehicle's intentions (Jones et al., 2011).

The results' distances of the comfort zones do not match with the distances from the theory of proxemics by Hall (1982). It could be because Hall's social and personal spaces are studies based on boundary zones between humans, and not to human-machine interaction. However, the proxemics was taken into consideration because it is usually used in robot contexts while human interacts with robots (Rios-Martinez et al., 2015). The differences between Halls' proxemics and the resulted comfort zone could thereof depend on the context, like findings from Rios-Martinez et. al. (2015), that the context plays a vital role in detecting social situations. The participants' knowledge of the injuries and fatalities the traffic may cause might also have an impact on the differences in the distances. The study's finding of distances to promote perceived safety builds a comfort zone that appears in zones with longer distances than the findings from Hall (1982) and Neggers et al. (2018). Additionally, it is seen in this study that the pedestrians' comfort zone is not equal to a driver's perception of a perceived comfort zone compared to studies presented in chapter 3 theory.

What the study could not clarify was how the car's intention should be transferred to pedestrians that are walking behind a car that has a running engine at a parking spot. The pedestrians did not perceive safety when walking behind a potential running vehicle and were unknowing if the car had seen them or not. Neither could the study clarify a clear behaviour for a car that had stopped for a pedestrian in its trajectory. The concerning question remains how the pedestrian will know what the car's next intention would be. To develop an understandable driving behaviour is the cognitive process essential to consider to make the car easy to comprehend. Hence, how stimuli are processed in the memories which lead to decision making, as described in chapter 3.

8.2 Methods

The method the project used was ACD^3. By the method, it was possible for the project to have a continuous information collection during the whole process. The work has been performed in an iterative way where the iterative phases helped to dig deeper and successively deliver new findings and requirements. The method is maybe not the main tool for this kind of research studies and some of the made work during the project may have been outside the scope.

The SAM analysis was a method with an emotional scale that several of the participants were not familiar to fill in. The mixture of familiarity with the method might have an effect on how the participants rated the different scales. The method SAM might have been more useful in a study context where there was a significant known good and bad answer. In this case, the SAM scales only indicated how emotions of valence, arousal and dominance were rated and not the cause behind the state of the emotions. Therefore, the conduction of interviews became essential to find answers to the causes of negative and positive vehicle-pedestrian experiences.

During the tests, there were none of the participants who believed that it was a real autonomous vehicle, even though the driver was hiding behind a seat costume and a Wizard of Oz stimuli was used. The vehicle was not a brand new car, which most of the participant expect an autonomous car should be. However, the participants conceded that they got feelings of how it could be in a situation with a real driverless car since the driver could not be seen. The results from the study can nevertheless be considered significant, considering that the test participants were presented in a narrative scenario of what would happen, which further made it easier for them to familiarize themselves with a real situation. Concerning these aspects, the participants in the tests might have rated their emotions to the interaction experience higher since they knew it was a hidden driver that had control of the vehicle.

8.3 Limitations

The study might be biased to chosen participants. The user tests were limited to participants who mostly had an academic background with an age range of 20-30 years old that had a technical interest. With this bias group, it needs to take in consideration that there is nothing that says that the result might give other outcomes if there was a wider age range or mixed education level.

The user tests and validation tests have been performed in a parking garage with threaded helix with sloping floors and 90° parking lots. As described in chapter 3.3.2, there are also occurring parking garages designed with 30°, 45°, and 60° turned parking lots, and in different designs. Therefore, the result should only be seen as significant to the chosen parking garage, as described in Appendix A: User test method.

In user test 2, the participant had raised their arm to indicate where they wanted the test vehicle should stop, and distance measurement between the participant and the vehicle was performed. To determine where the real position of the car was before it braked and stopped, a general formula was used to calculate the stopping distance (Körkortonline.se, 2017). Also, a general reaction time of one second was used for both the driver and the participant (Sveriges trafikskolors riksförbund, 2009). With the reaction time and the formula, there was possible to calculate the total distance to stop. The used method to calculate the total distance to stop allowed a margin of error and did not take into account a slightly sloping floor in the parking house.

The used instrument to measure the vehicle's speeds during the tests were by its speedometer. The speedometer was used because of the lack of connection to the GPS inside the parking garage. Before the performed tests, the car's speedometer was controlled by a stopwatch and a GPS to find where the used speeds of 5 km/h and 8 km/h were on the speedometers dial. The speeds were then marked on the car's speed dial. The driving speeds could, however, vary during the tests due to the circumstances for the driver. The driver had to keep the specific speed, be prepared for signalling participants and drive in a straight line, hidden behind a costume. Because of the circumstances, decisions were made to use the same driver overall test sessions, and a reason to have several pilot tests before the ordinary.

It is important to know that earlier experiences of autonomous vehicles and advanced driver-assistance systems might have played a role in how the participants described their interaction with the vehicle, according to Rasmussen's SRK knowledge-based task in chapter 3. Additionally, their reliably of the autonomous vehicle's behaviour was in an extended trust than participants who do not have any earlier experiences (Rasmussen, 1986). However, only one participant had previous experiences in advanced driver-assistance systems in the user test, but four had in the validation test.

In the user test, the participants experienced fifteen sub-tests, and in the validation test, six sub-tests, all in random order. It needs to take in consideration that they might have got used to the situation. At the beginning of the user tests, the participants might have used a processing more of a bottom-up nature, and when the tests have been going on, and they become more accustomed to the tests, the top-down processing might be used in a higher grade. Participants who got more familiar during the tests could have an impact effect to the findings and results, which has been counteracted by mixing the order of the tests for each participants user test session (Wickens, 2004).

8.4 Ethics and sustainability

The ethical aspects of the outcome concern how people in the parking garage feel and behave when they get in touch with an autonomous vehicle. People should not feel unsafe, scared and frightened due to the project's outcome, which study has tried to avoid by the recommended comfort zone.

During the tests, the group of participants has been average people with normal conditions. None of the participants was a child or elderly. No one had impaired vision or impaired hearing, there was also no wheelchair users either. Hence, the results and the recommended concept guidelines are only based on average people.

The participants in the project had predominantly Scandinavian cultural backgrounds, which means that the result is bias adapted to one culture. According to the proxemics of Hall (1982), social and personal spaces differ between cultures. About that, the findings for comfort zones' distances might differ depending on the culture.

If those who interact with the car have a positive feel to the car's behaviour, this can lead to the automation being more widely accepted and that more people are using the Automated Valet Parking. From a sustainability perspective, this, in turn, can lead to more cars being able to park on the same surface, which saves on facilities resources, as up to 20 % of the parking lot can be saved (Bosch, 2019).

The solution also leads to a higher positive feeling to the car's behaviour, which in turn can lead to less stress for pedestrians and a more increased acceptance of driverless cars indoors. Automated Valid Parking can also reduce the drivers' stress, as they do not have to find a free parking spot.

8.5 Future work

Since the behaviour of autonomous vehicles is something new and are going to be implemented in the future, this research is a part of the beginning. The situations that have been tested in the study are only a small part of all existing situations that can occur in a parking garage. One situation that could be a future work is a research of perceived safety when the vehicle is taking a curve, or making a turn. Does the participant perceive safety differently?

Continued work on this project had been to try to clarify the aspects that have not yet been emerged. For example, how a car's intention can be transferred to a pedestrian when it has a running engine in a parking spot, as described earlier in this chapter. To find that out, more tests with pedestrians, with a Wizard of Oz approach are required. An increased understanding of a car's intention and behaviour can also increase the perceived safety.

The study showed that the vehicle's body language was essential and that a decrease in speed led to an understanding of the car's intention to stop for a pedestrian standing in its trajectory. For further work, it could be interesting to see if the decreased speed could be used as a body language even for pedestrians that are not standing in the car's trajectory. That is to say, as a body language, when the vehicle passes a pedestrian. If some connections could be seen had a further step in the work concern at which distance the car should stop. Also, to find out the distances when the vehicle should stop in the scenario when there is oncoming traffic. The guidelines should also be tested by a real autonomous vehicle to see if the behaviour would be accepted in the same way as the project's results

Neggers et al. (2018) showed that the comfort zone for a human interacting with a robot increased with the distance but also that the feeling of the comfort diminished and became stable after a certain distance to the robot. Further studies about a pedestrian's comfort zone could be to investigate whether such a phenomenon could be related to the lateral distance between a pedestrian and car with regard to perceived safety as well.

9 Conclusions

The project has been a starting point to explore the interaction between pedestrians and driverless cars indoors, with the intention of perceived safety. The results can further be used in the development of autonomous vehicles.

The study shows that pedestrians have a comfort zone that a car should not enter to increase the pedestrians' perceived safety. The pedestrians' comfort zone has a lateral distance of 1 meter to the vehicle and a longitudinal distance of 7.5 meters.

Further conclusions from the study are that the vehicle's driving behaviour and body language affect the pedestrian's perceived safety. A reduction in vehicle speed increased perceived safety and the understanding of the car's intention for pedestrians. The conclusion from this is that a self-driving vehicle should mark with a speed reduction that it has encountered a pedestrian. When discovering a pedestrian in the car's trajectory, the study shows that the car should slow down to slow speed when it has 21 meters to the pedestrian.

The study shows that pedestrians also have a comfort zone when they walk behind an idling car, parked in a parking lot, a distance of about 2 meters. However, the perceived safety was lacking because the test participants did not understand what the car would do. The conclusion is that this scenario needs further development.

The project can also conclude that tests with pedestrians and an illustration of a self-driving car (Wizard of Oz) can provide many insights and lessons to the continued development of driving behaviour for automated vehicles when integrating with pedestrians.

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Appendix A: User tests methods

To investigate how pedestrians perceive an autonomous vehicle in different situations. Three different tests were done to investigate how different speeds and distances on a vehicle impact pedestrians when it approaches passes by a person and what an appropriate walking distance behind a car is, in a parking garage.

All three tests were conducted followed consecutively in random order for each test participant. This chapter describes the common method for the tests.

Participants

In total, there were 22 participants in the test. Though, two participants have been removed from the results due to too much previous experience of autonomous vehicles and incorrect measurements. The results present data from 20 participants, 10 female and 10 male.

The participants were principally students from the Chalmers University of Technology and had an age range of 22 to 31 years old. Three out of 20 participants had no driving licence and the average time of how long they had a driving licence was seven years. The majority had no previous experience of autonomous functions, except for two persons who had used back assist and pilot assist.

The participants estimated themselves on a scale of 1 to 6 about their technology interest and how adventurous they were (figures A & B). The result showed that the majority of the participants rated themselves above average which can indicate that the participants had easy to absorb new technology and might take more risks than a person who would have given a lower rate.

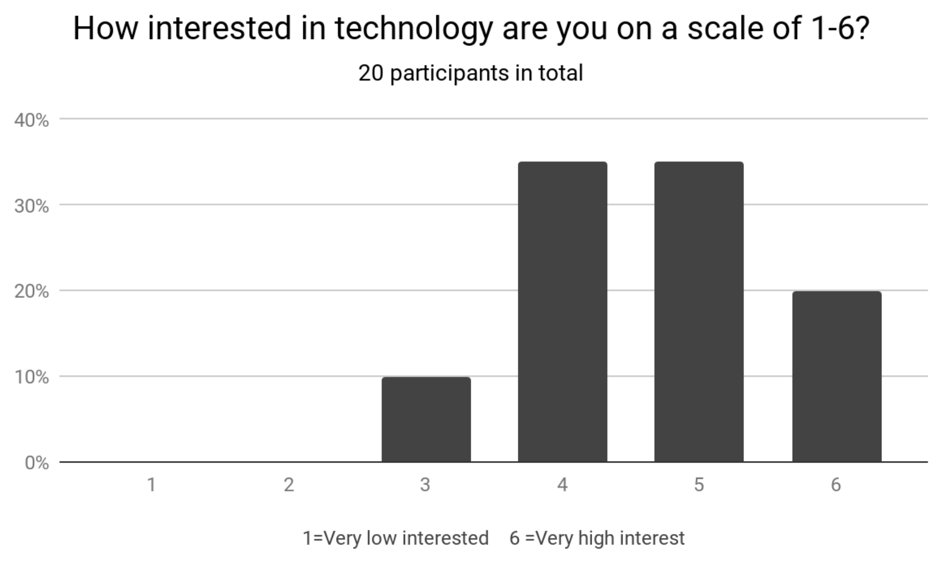


Figure A. Showing in per cent how the distribution was among the test participants regarding their technology interests.

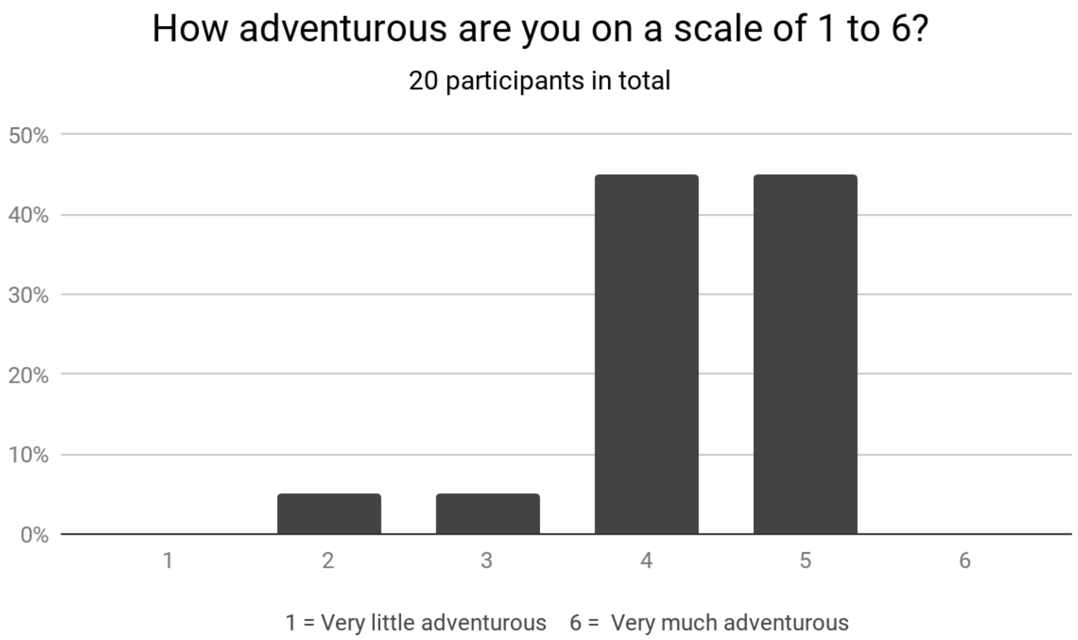


Figure B. Showing in per cent how the distribution was among the test participants regarding their adventurousness.

Data collection

Before the tests started, control questions were collected by using a questionnaire, see Appendix A1: Control Questions. During tests 2 and 3 were distance measurements conducted to measure distances between participants and vehicle.

To investigate how the participants perceived emotionally the situations the method Self-Assessment Manikin (SAM) was used after every test, followed by short interview questions, how did it feel and why?

Test Environment

The tests were held in the parking garage Gröna Mossen located at Betongvägen 12 in Gothenburg, close to the Chalmers University of technology. The parking garage was a single threaded helix with sloping floors, meaning the short side of the parking garage had flat floors while the long side sloped (Figure C).

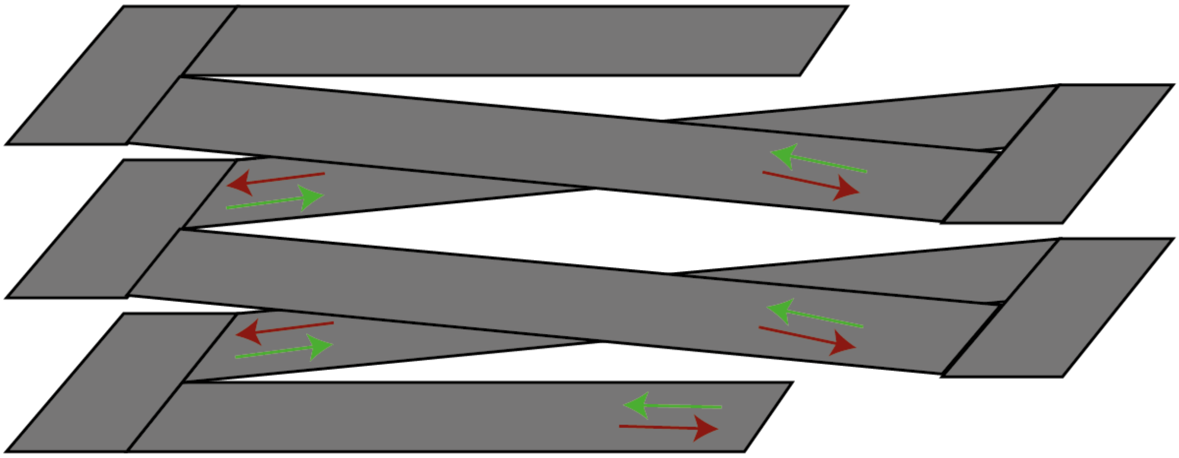


Figure C. Illustration of a Parking Garage with a single threaded helix with sloping floors.

The parking garage was chosen since its low activity, so the tests could be performed without interruption from other parking garage users. The tests were held on the second floor where the activity was even less. The parked cars were most of the time parked at the same parking spots for the whole day even though the parking garage never was full. The tests were running just over a week and the parking garage had approximately the same amount of cars every day.

The drawback of the chosen parking garage was the fact that even if it almost had the same amount of parked cars in the garage, it sometimes differed. However, the same could have occurred at any other parking garage which therefore outweighed to choose selected parking garage.

Stimulus material

Wizard of Oz was used to simulate an autonomous car, see figure D. The driver of the car during the user tests was hidden in a driving seat suit which made the car to look likes it was driving by itself without a driver. It was made to enhance the experience of a real situation as an autonomous vehicle, especially not to let the participants get eye contact with the driver.

Figure D. Wizard of Oz.

Material

The material needed for the test included:

- A test vehicle
- Two seat costumes
- A hidden driver
- Laser distance meter, Street Crayons and Tape Measure
- SAM-questionnaires
- Interview questions
- Laser distance meter tripod

Data Analysis

The impact of the vehicle's speed and distance to the pedestrian were analysed by medians of a within-group comparison of the SAM scales and comments from the interviews. The interviews were written out fair and an analysis was conducted to find common issues and thoughts among the participants.

Test 1: Lateral distance between pedestrian and vehicle.

The purpose of test 1 was to get a deeper understanding of how the distance in combination with the speed impact pedestrians when a vehicle was passing by at a speed of about 5 and 8 km/h. The aim was to find an appropriate distance between a pedestrian and a passing car where the pedestrian perceived safety.

Test procedure

Test 1 consisted of six scenarios. The test focused on the participants' experience of different distances to a passing vehicle at a speed of about 5 km/h and 8 km/h. The test was designed to avoid participants to be able to have eye-contact with the driver, in order to simulate an autonomous car, see figures E and F.

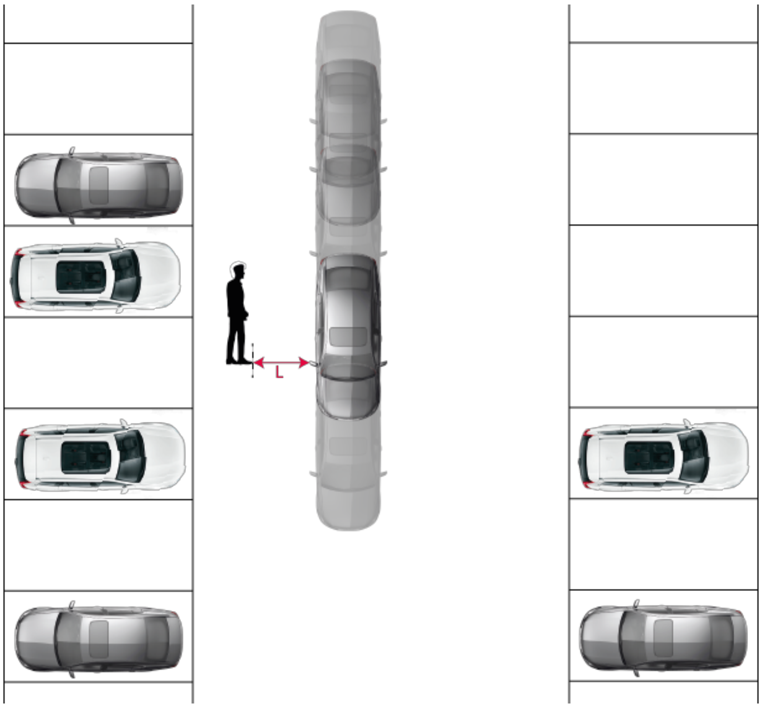


Figure E. Illustration of user test 1.

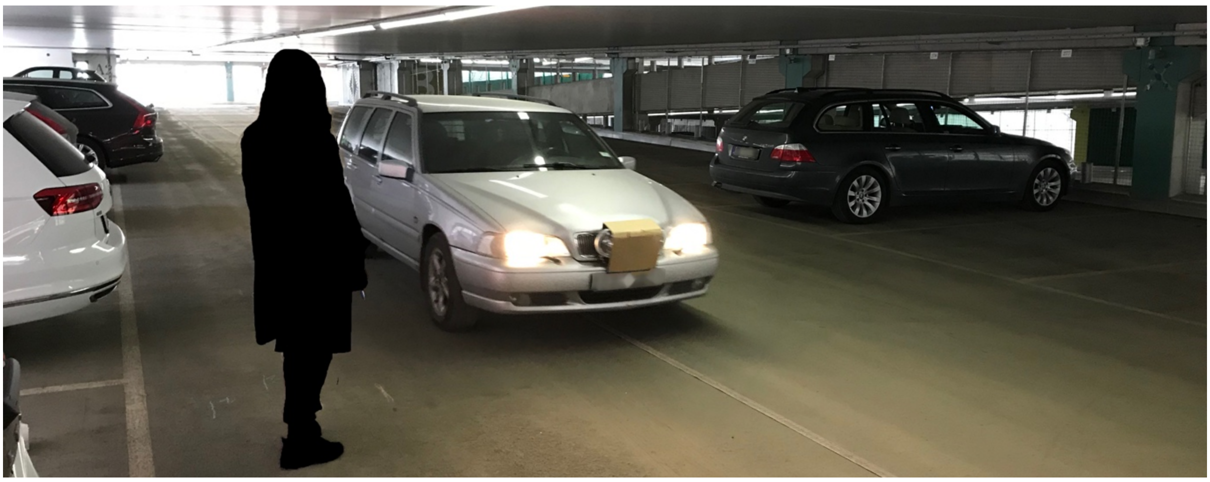


Figure F. Participant in user test 1.

The vehicle was approaching with a constant speed of about 5 km/h in scenario A and about 8 km/h in scenario B, with the real driver dressed as a seat. The front passenger seat had a similar costume as the driver. The task of the participants was to stand in the middle of the road in the parking garage while the vehicle started to approach. The participants should then depart themselves from the road and choose a distance where they felt secure to let the car pass. When the vehicle had passed, the test leader asked the participant to fill in the SAM-form and answer the following question: How did it feel when the car passed, and why?

Scenario 1A and 1B:
You are now standing in the middle of the road and in the direction of a travelling car. While the vehicle is approaching, take action and chose a distance to the car where you feel safe.

The scenario 1C, 1D, 1E and 1F was conducted in a similar way as the scenarios 1A and 1B. The difference was that the participants did not decide the distance to the car. The participant was asked to stand behind a crayon line representing a distance of 0.45 m respectively 0.8 m to the passing car, see table A.

There was a mark in the middle of the roadway to facilitate the driver to keep a straight course and drive similarly through all scenarios. The mark was a 50 m long cloth ribbon that allowed the driver to place the car at the same position in each scenario. After each test, in all scenarios, the distance to the vehicle was measured from a parking spot line to ensure that the participant had experienced the exact distance to the car. Appendix A2: Calculation describes more in detail how the measurements were carried out.

Table A.
The procedure of Test 1 with all scenarios

Test	The speeds of the vehicle	Distance between participant and vehicle (L)
1A	5 km/h	Participant own decision.
1B	8 km/h	Participant own decision.
1C	5 km/h	0.45 m
1D	5 km/h	0.80 m
1E	8 km/h	0.45 m
1F	8 km/h	0.80 m

Test 2: Longitudinal distance between pedestrian and vehicle.

The purpose of test 2 was to get a more profound knowledge of how the distance in combination with the speed impact pedestrians when a vehicle is approaching at a speed of about 5 and 8 km/h. The aim was to find an appropriate longitudinal distance between a pedestrian and the front of the car where the pedestrian felt safe and secure and to get information about :

- when a pedestrian starts to keep the attention to an approaching vehicle.
- which distance that perceives as a close distance.
- when a pedestrian wishes the car to decrease its speed.
- when a pedestrian wishes the car to stop.

Test Procedure

Test 2 consisted of eight scenarios (2A - 2H), see table B. The test focused on the participants' experience of different distances to an approaching vehicle at a speed of about 5 km/h and 8 km/h. Also, this test was designed to avoid eye-contact between the pedestrian and the driver. The driver was dressed as a driving seat, in order to simulate an autonomous car, see figures G and H.

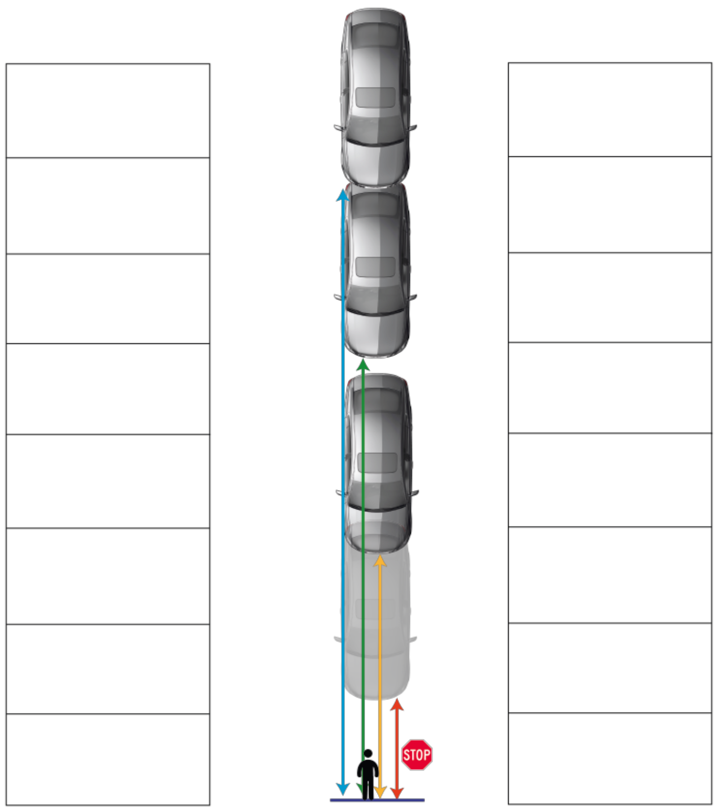


Figure G. Illustration of user test 2.

Figure H. Participant in user test 2.

The test participants were informed about the scenario. You are now standing in a parking garage. However, it is not a regular one. In this parking garage, there are both manually driven cars and autonomous vehicles. The autonomous vehicles are self-driving cars and are missing drivers.

You are now in the middle of the road. You have brought a bag and dropped it on the ground. You are waiting for a friend, in the meantime, a car is approaching you. Since you have your bag, you are not that quick leaving the position as if you had not brought it.

Table B
The procedure of test 2

Scenario	The vehicle's speed	Distance between participant and vehicle (L)
2A	8 km/h	When do you start to **keep attention** to the car?
2B	5 km/h	When do you start to **keep attention** to the car?
2C	8 km/h	When do you perceive that the car is **close**?
2D	5 km/h	When do you perceive that the car is **close**?
2E	8 km/h	When do you want the vehicle to **slow down**?
2F	5 km/h	When do you want the vehicle to **slow down**?
2G	Slow speed	When do you want it to **stop**?
2H	Slow speed	When do you want it to **stop**?

The participants were asked to raise their hand while they:

- wanted to keep attention to the vehicle, i.e. wanted to keep track of the vehicle, to see where it is going (2A & 2B)
- experienced the car as close to them (2C &2D)
- when they wanted the car to decrease its speed (2E & 2F)
- wanted the vehicle to stop (2G & 2H)

When the participant had raised their arm, the vehicle stopped and the test leader measured the distance between the vehicle and participant. The participant was then asked to fill in the SAM-form and answer the following question: How did you experience this, and why? At scenarios 2A - 2F the vehicle started from the same position, at the end of the parking garage, at a speed of either 5 or 8 km/h. Scenarios 2G & 2H was performed after scenarios 2E & 2F and was approaching the participant with a slow speed.

Concerning reaction times for both the test person and the driver in the car, all distances have been added a stopping distance including both reaction distance and braking distance. See Appendix A2: Calculations for complete calculations.

Test 3 – Walking distance behind the car

The purpose was to see how close a pedestrian was willing to walk behind a car, that has its engine on in a parking spot, and knowing the car can start to drive any time. The goal was to map up participants walking distances and find how big distance they preferred to a vehicle that anytime could leave the parking spot.

Test procedure

The test had only one scenario and did not involve the SAM-method. The participant's task was to go from position A to B, see figure I. The participant had been informed that the vehicle was self-driving and that its engine sound indicated that it could soon leave the parking spot. How would you go from A to B with knowledge the car might leave the parking spot? As the pedestrian walked from A to B, the test leader marked on the ground its route with a crayon. When the participant had arrived too position B, the test leader asked. If you would have kept a shorter distance to the car, how would you have felt?

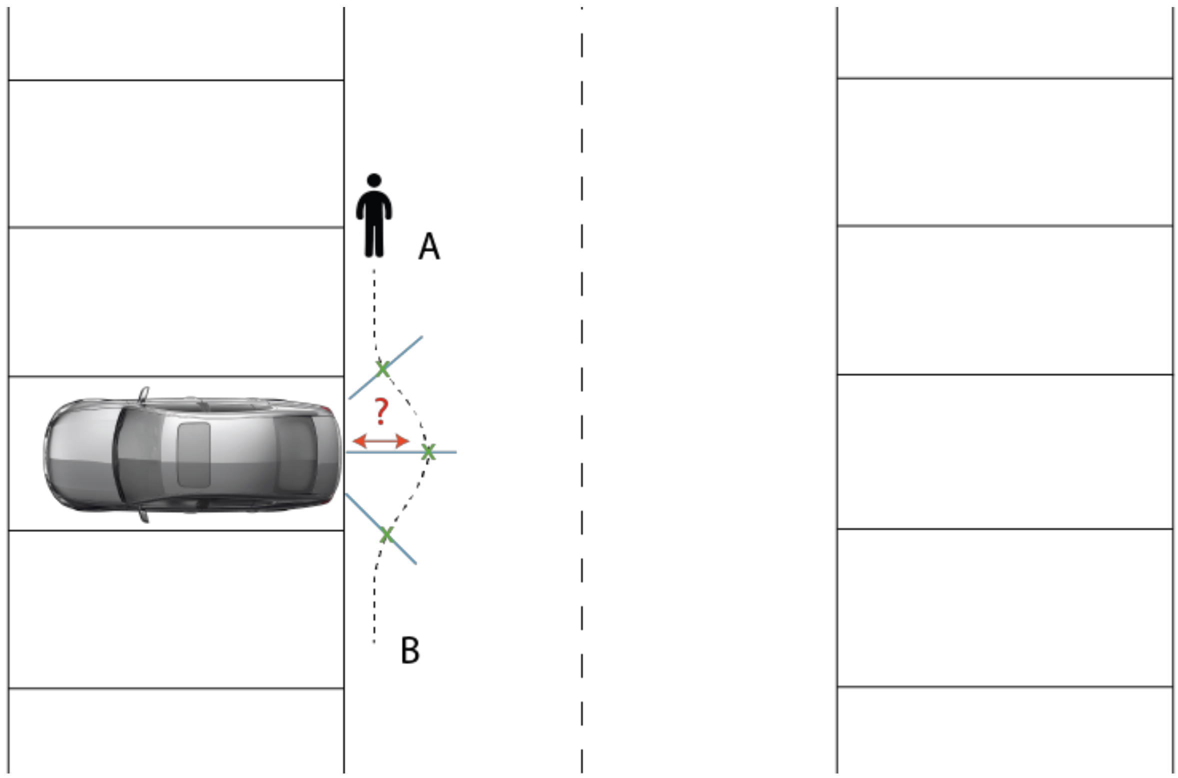


Figure I. Illustration of user test 3.

To help the test leader to mark the pedestrian's route, three lines were drawn on the ground. Two lines, 45° from the car's corners and one 90° line in the centre of the parked car, see figure J.

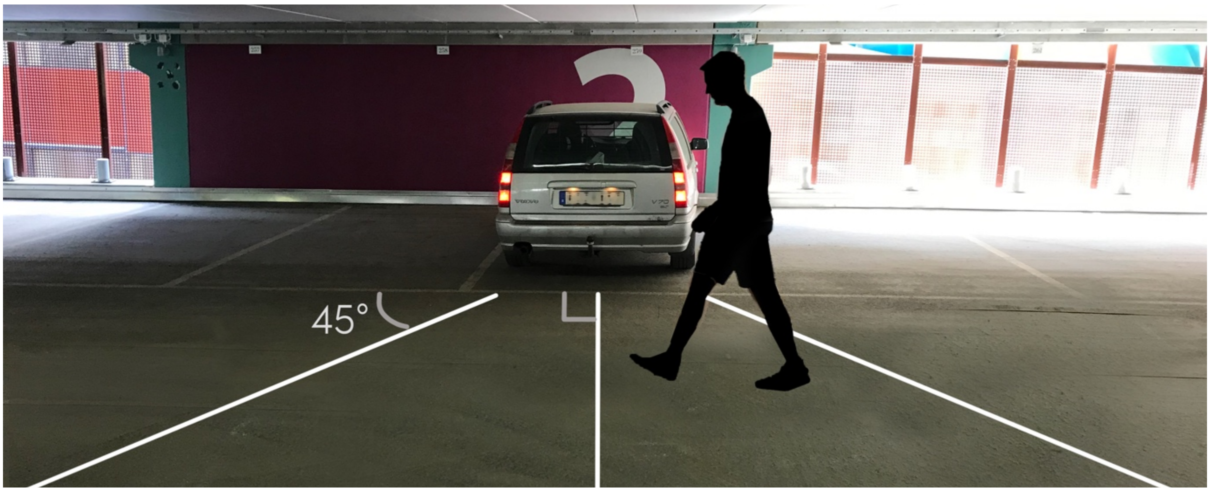


Figure J. Test 3.

Appendix A1: Control Questions

Kontrolluppgifter till deltagare
Control information for participants

Vilket kön identifierar du dig som?
What's your gender identity?

- ❑ Kvinna (Female)
- ❑ Man (Male)
- ❑ Annat (Other)

Hur gammal är du?
How old are you?

________________ **År** Years

Har du körkort?
Do you have a driving license?

- ❑ **Ja** Yes
- ❑ **Nej** No

Om ja, Hur länge har du haft körkort?
If yes, for how long have you had a driving license?

_______________________________ **År** Years

Utbildning? (Education?)

____

Har du tidigare erfarenhet av autonoma funktioner t.ex. ADAS eller Parking assist system?
Do you have previous experience of autonomous functions, such as ADAS or Parking assist system?

- ❑ **Ja** Yes
- ❑ **Nej** No

Funktion/er (Function/s):

____

Hur tekniskt intresserad är du, uppskattat på en skala 1-6?
How interested in technology are you, on a scale of 1-6?
1 = Mycket lågt intresse för teknik Very low interested
6 = Mycket högt intresse för teknik Very high interest

1 2 3 4 5 6

Hur äventyrlig är du, uppskattat på en skala 1-6? How adventurous are you, on a scale of 1-6?
1 = Väldigt lite äventyrlig Very little adventurous
6 = Väldigt mycket äventyrlig Very much adventurous

1 2 3 4 5 6

Appendix A2: Calculations

Test 1

The distance (L) between the participant and the vehicle depended on where the car was driving, see figure K. Measurements were carried out after each scenario and test. Table C shows how the distance differed and table D shows the actual distances the participants had to the vehicle.

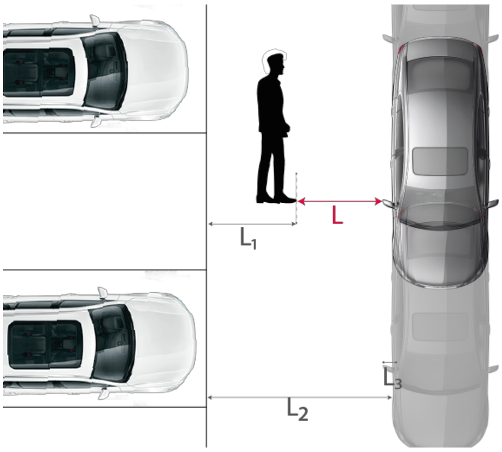


Figure K. Illustration of how the actual distance to the participant was measured.

Example of how the distance between the participant and vehicle (L) was measured. L_1 is the distance from the parking spot line to the crayon line, where the participant stood. L_3 represents the length of the protruding side mirror. L_2 is the varying distance. It is the distance between the parking spot line and the car's body, see below.

$L = L_2 - L_1 - L_3 = 0{,}45$ m
$L_1 = 1.08$ m
$L_2 \approx 1.65$ m
$L_3 = 0.12$ m

$L = L_2 - L_1 - L_3 = 0{,}80$ m
$L_1 = 0.75$ m
$L_2 \approx 1.67$ m
$L_3 = 0.12$ m

Table C

Distance differ between participant and vehicle in scenario C, D, E and F

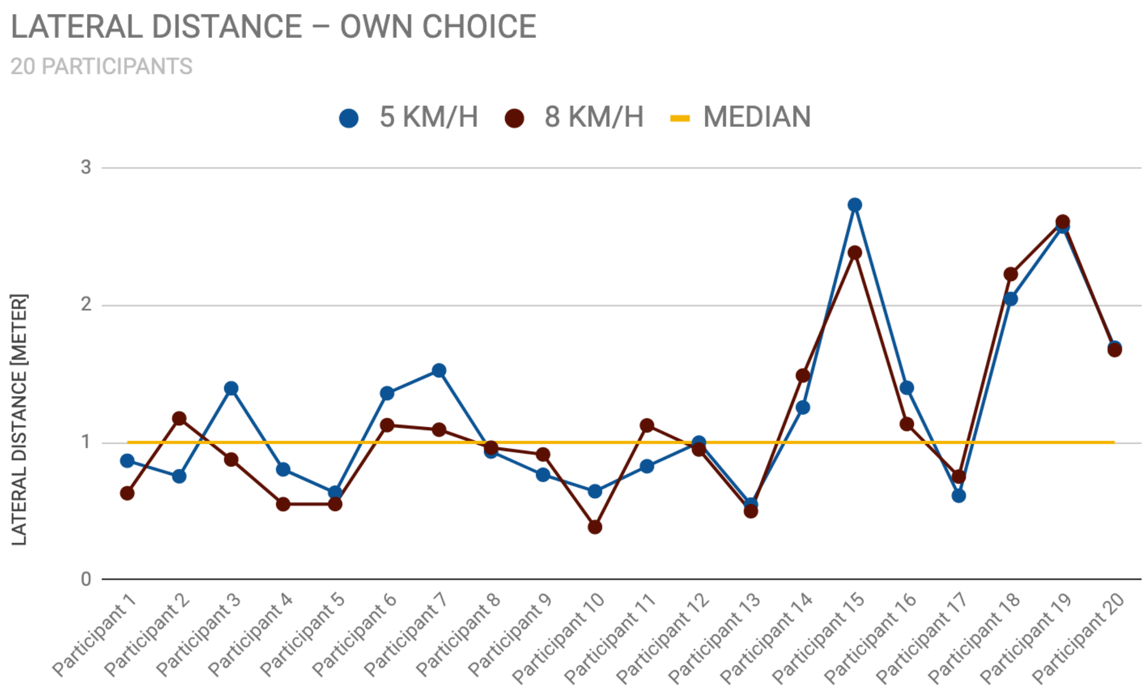
	Distance between the participant range	Mean distance	Median distance
Scenario C	0.40 - 0.64 m	0.48 m	0.47 m
Scenario D	0.67 - 0.94 m	0.81 m	0.81 m
Scenario E	0.36 - 0.70 m	0.50 m	0.49 m
Scenario F	0.77 - 0.91 m	0.82 m	0.81 m

Table D

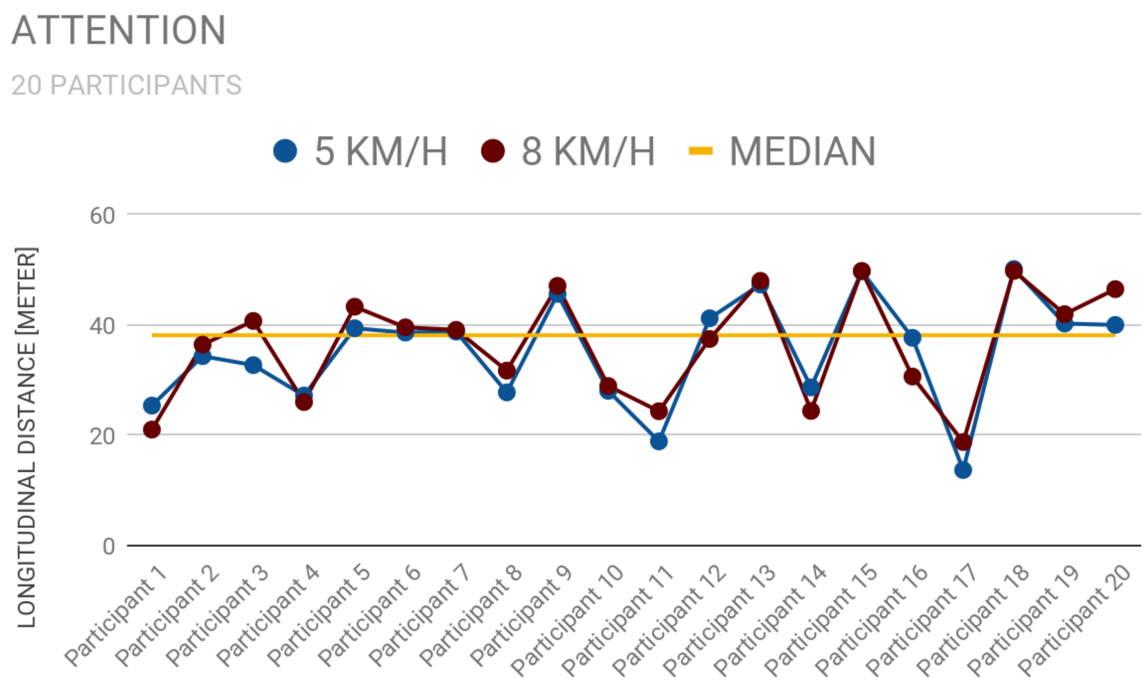
Actual distances the participants had to the vehicle

Test 1						
Distance between participant and vehicle [m]						
Participant	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F
1	0,87	0,63	0,47	0,76	0,46	0,80
2	0,75	1,18	0,46	0,79	0,49	0,78
3	1,39	0,88	0,41	0,78	0,46	0,81
4	0,80	0,55	0,52	0,75	0,36	0,80
5	0,64	0,55	0,42	0,76	0,50	0,82
6	1,36	1,13	0,50	0,89	0,51	0,86
7	1,52	1,09	0,48	0,79	0,43	0,80
8	0,93	0,96	0,47	0,81	0,49	0,80
9	0,77	0,91	0,44	0,80	0,43	0,79
10	0,65	0,39	0,51	0,84	0,48	0,82
11	0,83	1,12	0,47	0,77	0,70	0,85
12	1,00	0,95	0,48	0,83	0,53	0,86
13	0,55	0,50	0,40	0,67	0,45	0,84
14	1,26	1,49	0,47	0,82	0,49	0,85
15	2,73	2,38	0,64	0,79	0,64	0,77
16	1,40	1,13	0,54	0,87	0,50	0,91
17	0,61	0,75	0,56	0,87	0,52	0,84
18	2,04	2,22	0,42	0,83	0,51	0,81
19	2,57	2,61	0,62	0,94	0,53	0,89
20	1,69	1,67	0,48	0,84	0,52	0,78
GOAL	**-**	**-**	**0,45**	**0,8**	**0,45**	**0,8**
Mean	**1,22**	**1,15**	**0,48**	**0,81**	**0,50**	**0,82**
Median	**0,97**	**1,03**	**0,47**	**0,81**	**0,49**	**0,81**
Highest	**2,73**	**2,61**	**0,64**	**0,94**	**0,7**	**0,91**
Lowest	**0,55**	**0,39**	**0,4**	**0,67**	**0,36**	**0,77**

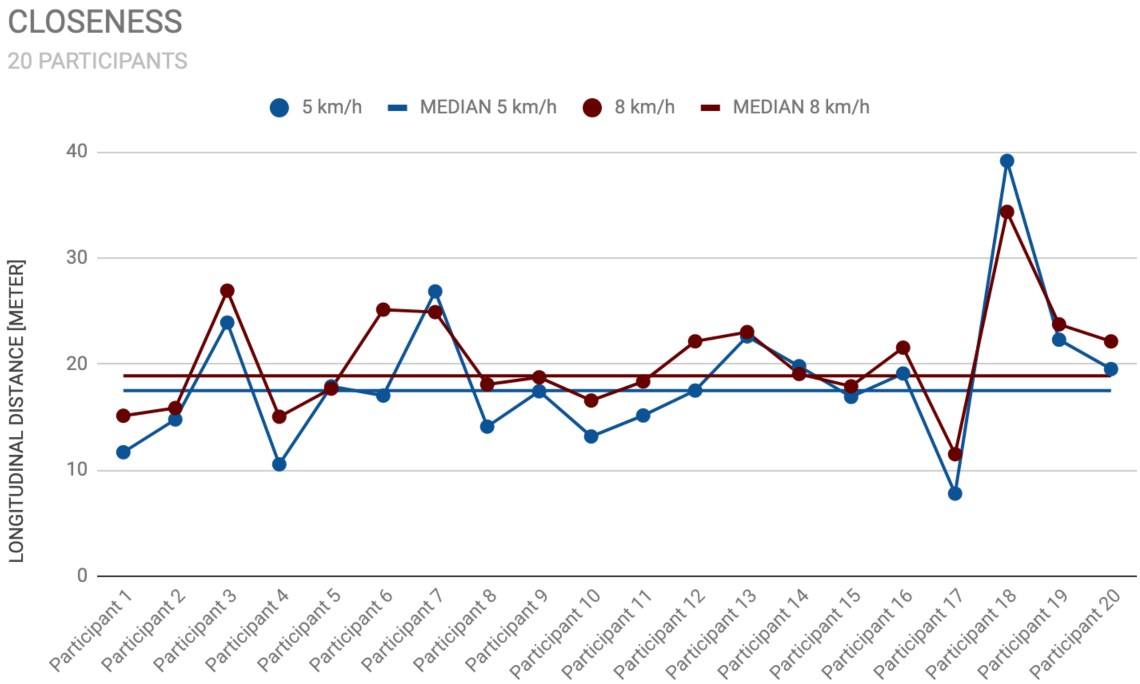
User tests 1A and 1B - Varying distances and median



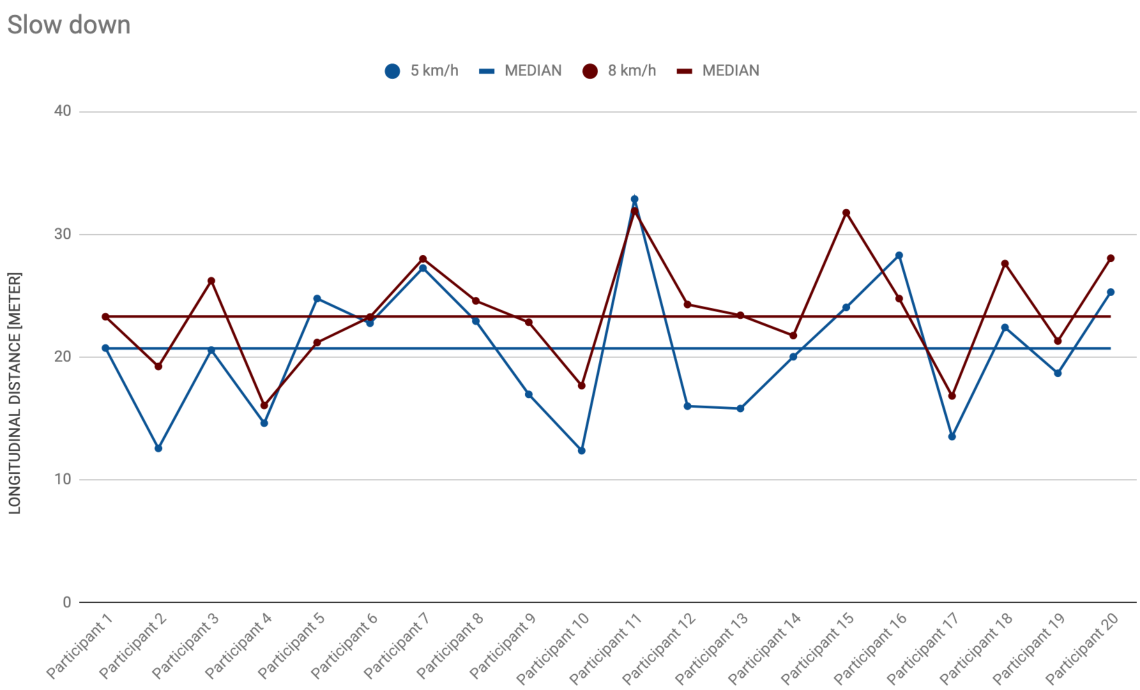
User tests 2A and 2B - Varying distances and median



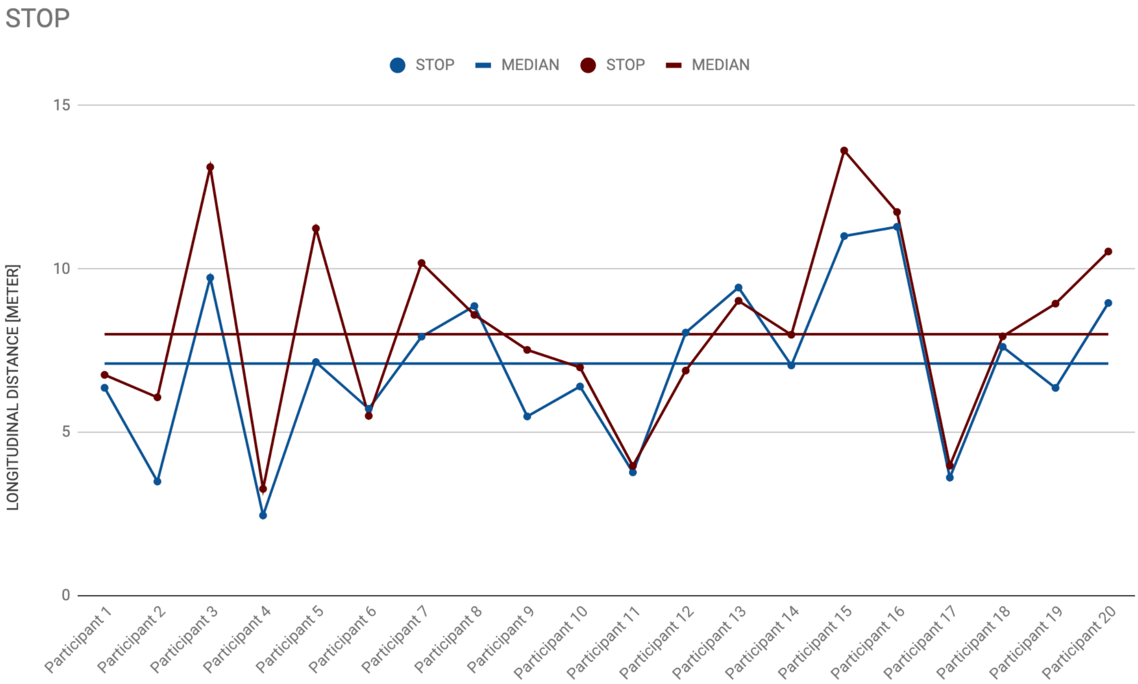
User tests 2C and 2D - Varying distances and median



User tests 2E and 2F - Varying distances and median



User tests 2G and 2H - Varying distances and median



User test 3 (meter)

NAME	Line 1 (45°)	Line 2 (90°)	Line 3 (45°)
Participant 1	2,03	2,18	1,73
Participant 2	2,18	2,28	2,22
Participant 3	3,77	2,95	2,98
Participant 4	1,33	1,05	0,95
Participant 5	0,95	0,93	0,85
Participant 6	2,69	2,54	1,90
Participant 7	1,55	1,50	1,40
Participant 8	2,10	1,92	3,30
Participant 9	1,59	1,70	1,64
Participant 10	1,40	1,04	1,22
Participant 11	1,41	1,54	1,32
Participant 12	2,40	1,93	1,78
Participant 13	3,21	2,69	2,60
Participant 14	2,32	2,60	2,77
Participant 15	3,30	3,90	3,64
Participant 16	2,60	1,95	2,02
Participant 17	4,32	3,69	4,17
Participant 18	3,19	3,03	2,88
Participant 19	3,00	2,87	3,03
Participant 20	2,60	2,38	3,15
Median	**2,36**	**2,23**	**2,12**
Average	**2,40**	**2,23**	**2,28**

Test 2

Stopping distance [S_S] = Braking distance [S_B] + Reaction distance [S_R]

Braking distance [s_B]

$$s_B = \frac{v^2}{250 \times f} \text{ [m]}$$

$v = speed\ [km/h]$

$250 = constant$

$f = friction\ coefficient \approx 0.8\ dry\ asphalt$

$$s_{B_{2km/h}} = \frac{2^2}{250 \times 0.8} = 0.02 \text{ m}$$

$$s_{B_{5km/h}} = \frac{5^2}{250 \times 0.8} = 0.125 \text{ m}$$

$$s_{B_{8km/h}} = \frac{8^2}{250 \times 0.8} = 0.320 \text{ m}$$

Reaction time [t_R]

Reaction time is between 0.5 to 1 second. The measurements have calculated the reaction time with a reaction time of 2 seconds since there were two persons who had to react before the vehicle stopped.

$t_R = 2$ s

Reaction distance [s_R]

$$\frac{1}{1}\left[\frac{km}{h}\right] = \frac{1000}{3600}\left[\frac{m}{s}\right] = \frac{1}{3.6}\left[\frac{m}{s}\right]$$

$$s_R = v \times t_R \text{ [m]}$$

$$v_{2\,km/h} = 2\frac{km}{h} = 2\left[\frac{km}{h}\right] \times \frac{1}{3.6}\left[\frac{m}{s}\right] = 0.556\ m/s \qquad s_{R_{2\,km/h}} = 0.556 \times 2 = 1.112 \text{ m}$$

$$v_{5\,km/h} = 5\frac{km}{h} = 8\left[\frac{km}{h}\right] \times \frac{1}{3.6}\left[\frac{m}{s}\right] = 1.389\ m/s \qquad s_{R_{5\,km/h}} = 1.389 \times 2 = 2.778 \text{ m}$$

$$v_{8\,km/h} = 8\frac{km}{h} = 8\left[\frac{km}{h}\right] \times \frac{1}{3.6}\left[\frac{m}{s}\right] = 2.222\ m/s \qquad s_{R_{8\,km/h}} = 2.222 \times 2 = 4.444 \text{ m}$$

Stopping distance [S_S]

$S_S = S_B + S_R$

$S_{S_{2\,km/h}} = 0.02 + 1.112 = 1{,}132$ m

$S_{S_{5\,km/h}} = 0.125 + 2.778 = 2.903$ m

$S_{S_{8\,km/h}} = 0.320 + 4.444 = 4.764$ m

Appendix B: Validation test method

As the tests 1, 2 and 3 were completed and analysed the last test called validation was set up to validate the previous data. Its purpose was to validate previous tests. The goal was to see if the tests received the same result as in previous tests. Therefore, the test environment and stimulus material as the Wizard of Oz costume were identical as in Test 1, 2 and 3 in Appendix A: User tests method.

Participants

There were 12 new participants in the validation test and they had not experienced the previous tests. The participants were principally also students from the Chalmers University of Technology, six males and six females in a range of ages from 22 to 35. All persons in the test group had had a driving licence for about eight years on average. The majority had no previous experience of autonomous functions, except for four persons who had used: adaptive cruise control, pilot assist and parking assist. The participants' height of technical interest and adventurousness can be seen in figure L and M.

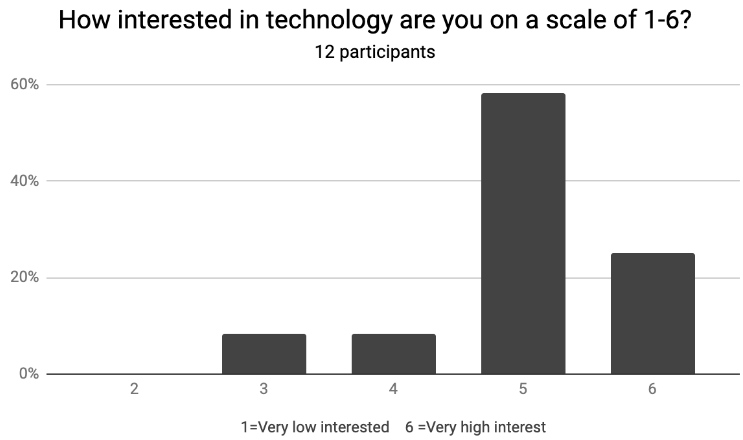


Figure L. Response to participants technical interest.

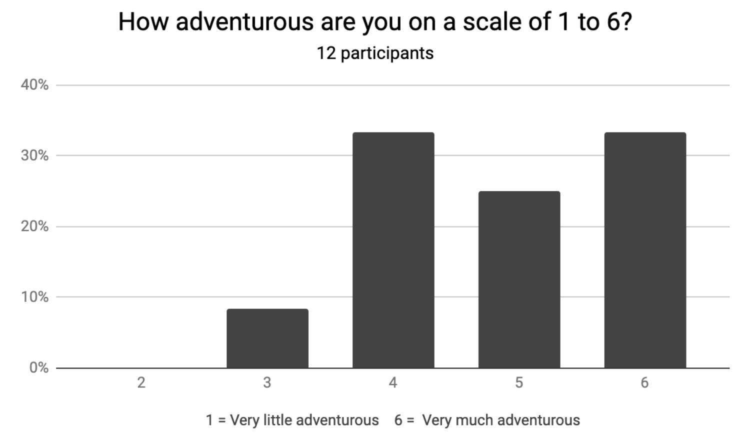


Figure M. Response to participants adventurousness.

Data collection
Before the tests started, control questions were collected by using a questionnaire, see Appendix A1: Control Questions. The method SAM was used during the test as well as a short semi-structured interview. After the test, a structured interview was conducted.

Material
The material needed for the test included:

- A test vehicle
- Two seat costumes.
- A hidden driver
- Street Crayons and Tape Measure
- Magazine
- SAM-questionnaires
- Interview questions

Test Procedure
The validation test consisted of two scenarios, 1 and 2, with three tests each, A B and C, see figure N Thus, a total of six tests. The focus was to see if similar results could be seen once again, with another test group. Tests 1A and 2A represented a median value from the result from test 3 in previous tests. However, since the result in test 3 showed that the participants either chose a longer distance before they had passed the car or after they just passed the middle of the car is the evaluation whether the participants feel depending walk closer to the car before or after they have passed it. Tests 1B and 2B is based on Test 1. 2A represents the most positive result, the highest score of pleasure, calm and control, 1.0 m speed about 5 km/h, while 2B represents the worst, distance of 0,45 m to the car, speed about 8 km/h, see table E,

Tests 1C and 2C is a result of test 2. Seen in tests 2 was that the participants wanted the car to increase its speed before the experience the car as close. The distance of having attention to the car is not tested over again in this validation test. 1C is a combination of test 2F and 2H and 2C is a combination of 2E and 2G. Thus, the median result of decreasing speed distance and when the vehicle should stop at 5 and 8 km/h.

Table E

The procedure validation test, scenario 1 and 2 including the six tests

Validation test			
Test	**Task**	**Distance to car**	**Speed of car**
1A	Walk behind the vehicle	1. 2.1 m 2. 2.2 m 3. 2.4 m	0 km/h
1B	Car is passing by	1.0 m	5 km/h
1C	Car is approaching	Decrease speed at 21 m Stops at 7.5 m	5 km/h Slow speed
2A	Walk behind the vehicle	1. 2.4 m 2. 2.2 m 3. 2.1 m	0 km/h
2B	Car is passing by	0.45 m	8 km/h
2C	Car is approaching	Decrease speed at 23 m Stops at 7.5 m	8 km/h Slow speed

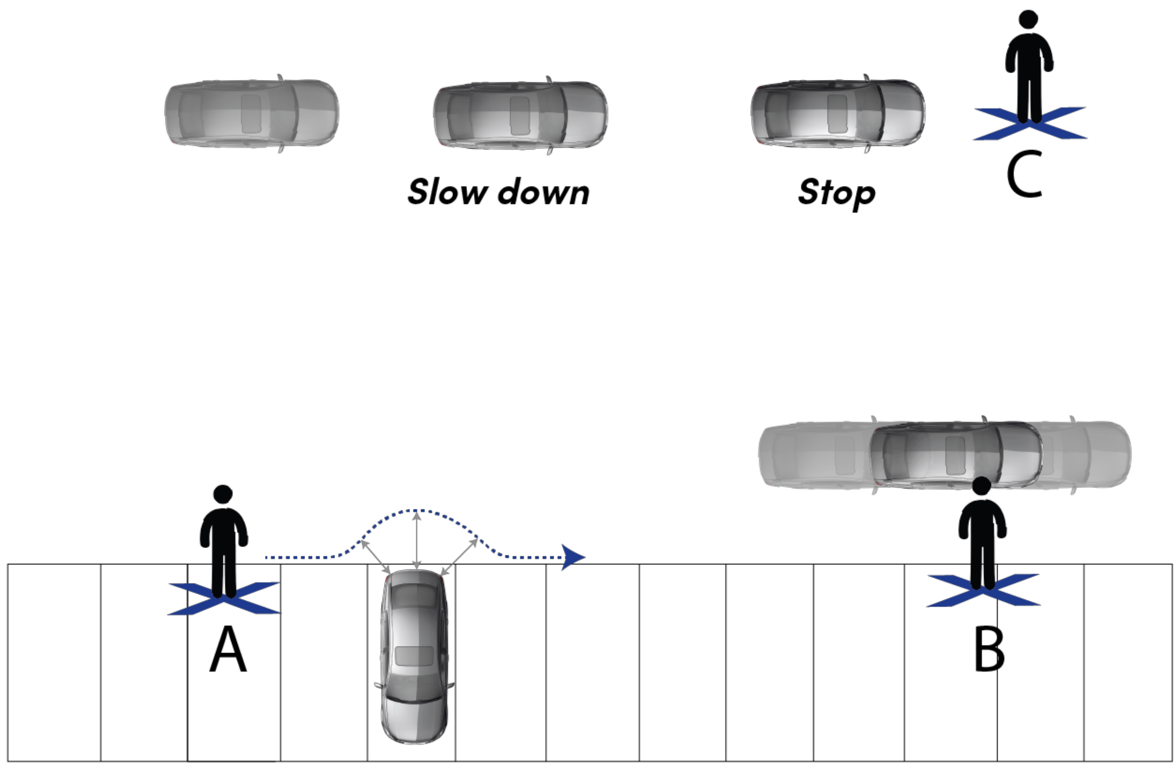


Figure N. Illustration of the validation test.

The participant experience first either scenario 1 or scenario 2, randomly, and then the other. Before it started they got informed about the procedure and filled in a questionnaire with questions as in the previous tests. They were only informed about one step at the time, that is to say, first, they got the scenario about test A, then B and at last test C. After every test within the scenarios, the participants were asked to fill in the SAM survey and answer how it felt and why. Both scenarios were experienced consecutively. After both of the scenarios an interview was conducted, see Appendix B1: Validation test, for the scenario and interview questions. Figures O, P and Q show the validation tests three scenarios.

Figures O, P and Q. Validation tests three scenarios.

Appendix B1: Validation test

Scenario

This is not an ordinary parking garage. In this parking garage, there are both ordinary cars and self-driving cars without drivers, autonomous cars. The test is to verify previously made tests, there are no good or bad answers, but we want to know how you feel about trust, control and security when you perform scenarios.

You will participate in two scenarios. During each scenario, you will answer three questions whether you feel comfortable, calm and in control of the traffic situation. After each scenario, we will ask a few more control questions on the same theme. So consider the speed and distance to the autonomous vehicle during the scenario.

1A/2A

You have now entered the parking garage after some time at Chalmers. Your car is parked further down in the parking garage and you will now go to your car. On the way, there is an autonomous car parked. It is just about to leave its parking spot which confirms that the lights and engine are on. Your task is to walk along the line when passing the car.

1B /2B

You have now arrived at your car, but realize that there is a magazine on the floor further away in the parking garage and you become curious about it. Before you go to the magazine, you see a vehicle and choose to wait until it has passed.

At this test, the participant got placed behind a line representing either 0,45 m to the car or 1,0 m to the car.

1C/2C

Now the car has passed, you continue to the object further down in the parking garage and remain in the same place when the autonomous car comes towards you.

Interview questions

- What is the first thing you have in mind, after the tests?

Trust

- Now that we have gone through the scenarios. How would you describe your trust in the autonomous car?
- Why did you feel confident / Why didn't you feel trust?
- Did you trust the car?

Understanding

- Did the car's behaviour give you an understanding of what it should do?
- What action did you understand or did not understand? Why?

Control

- During the tests, you had no opportunity to influence the car's behaviour, from that aspect, did you feel that you had control of the traffic situations?

Safety

- How do you experience safety in the parking garage?
- How would you describe perceived safety related to the autonomous car?
- Did you feel safe?

Would you like the car to behave differently in any of the scenarios?
Do you wish the car to have any external HMI?