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A PRIORI USER ACCEPTANCE AND THE PERCEIVED DRIVING PLEASURE IN SEMI-AUTONOMOUS AND AUTONOMOUS VEHICLES

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1. ABSTRACT

The aim of this minor pilot study is, from a sociological user perspective, to explore a priori user acceptance and the perceived driving pleasure in semi-autonomous and autonomous vehicles. The methods used were 13 in-depth interviews while having participants watch video examples within four different scenarios. After each scenario, two different numerical rating scales were used. There was a tendency toward positive attitudes regarding semi-autonomous driving systems, especially the use of a parking assistant and while driving in city traffic congestion. However, there were also major concerns about trust, user interactions and legislation, as well as the use of technology when driving on highways. Future studies should use a more substantial theoretical framework and real-life tests for a better understanding of user acceptance of driving automation.

2. AIM AND BACKGROUND

Car companies are focusing on both short- and long-term development of autonomous vehicles, the advantages of which include increased road safety (e.g., fewer traffic collisions), sustainable transportation, decreased fuel consumption and reduced traffic congestion. The development and planning within autonomous driving is rather complex, and involves barriers and problematizes issues, which include venues for IT-crime and terrorism, technological solutions for both urban and highway environments, technological reliability, environmental and societal transitions, law and insurance issues, ethical issues, and drivers' perceived control and trust (Chu et al., 2015; Maurer et al., 2015; Rödel et al., 2014; Yagdereli et al., 2015). The fully automated vehicle is not yet commercialised, but there are lots of semi-autonomous driving technologies, which have a wide range of functions ranging from less advanced to highly automated driving.

In order to structure the automation degree of vehicles, the NHTSA (National Highway Traffic Safety Administration, 2013) defines different levels of autonomy, ranging from 0 (No-Automation) to 4 (Full Self-Driving Automation). At level 2, there is combined-function automation, which, for example, includes assisting drivers in parking their vehicle (Intelligent Parking Assistant System, IPAS) or in keeping a safe distance between their vehicle and others (Adaptive Cruise Control, ACC). Level 3 involves limited, self-driving automation, which increases the complexity significantly when driving is going to be assisted. At this level, the vehicles (for example) automatically do the lane keeping (LKS, Lane Keeping Systems) and maintain a safe distance between their vehicle and others with stop and go devices (HAD, Highly Automated Driving). The driver can take their hands off the steering wheel, and they are only expected to be available for occasional control. At level 4, the vehicle is designed to perform all safety-critical driving functions, and the driver is only anticipated to give navigation input, but is not expected to be available for control at any time during the trip.
Previous studies have focused on technological acceptance toward autonomous vehicles (Helldin et al., 2013; Payre et al., 2013; Verbene et al., 2012) and some perceived disadvantages and user perspectives regarding the "loss of control" in the semi-autonomous vehicles (Eckoldt et al., 2012; Stanton et al., 2001). However, there are still many unanswered questions regarding semi-autonomous and autonomous driving, and perceived driving pleasure has not considered. The act of driving is not just about getting from point A to point B, as it also involves very complex, perceived issues full of meaning. This is not new knowledge, but both driving and the perception of driving pleasure could change and be understood in new ways with the emergence of autonomous vehicles. The aim of this study is, from a sociological user perspective, to consider: *"What are the a priori user acceptance and the perceived driving pleasure in semi-autonomous and autonomous vehicles".*

A priori user acceptance is, in this context, to be understood as a driver's evaluation of their willingness to use some of the semi-autonomous and autonomous technologies before interacting with them. This perspective deals especially with perceived usefulness and ease of use (Davis, 1989). For a new technology to be accepted by potential users, it needs to be positively perceived as useful, and it must be easy to enjoy the change (Davis, 1993). Driving pleasure is a very complex term, and, as Hagman (2010) outlined, there are many different definitions and understandings of driving pleasure. I will approach the definition of driving pleasure from a car user perspective in contrast to both advertising, motor press and the great deal of economic conceptualisations of time, and the values of travel efficiency. For example, the Highway Capacity Manual (HCM) is a widely used reference for flow measures and roadway planning. The HCM defines transportation quality according to six "levels of service" (LOS), labelled A through F (Transportation Research Board, 2000). This, among other economic conceptualisations, has, to some extent, led travel time to be viewed as a commodity (e.g., spent, wasted, saved time), as opposed to an experience or lifestyle. We are in the third age of a transport evolution (towards autonomous driving), in which an understanding of our lifestyle needs determines and influences how the transport system is best used to support those needs (Lyons and Urry, 2005); the economic conceptualisations can be advantageously supplemented by users' driving pleasure inputs. Driving pleasure stresses "the importance of the context, making driving pleasure dependent on external conditions instead of the capabilities of the car" (Hagman, 2010: 32).

3. PREVIOUS STUDIES

Studies and tests on automated driving have increased significantly in line with technological development. So far, there are almost no studies testing highly automated driving in its natural environment. Fully autonomous vehicles are not yet ready, and vehicles with highly automated driving technologies are still rather rare. Further, there are legislation problems for test studies within a real life context. Therefore, existing studies have used either interviews, online questionnaires (KPMG, 2013; Payre et al., 2014; Rödel, 2014) or different kinds of simulations (Strand et al., 2014, Lee et al., 2015, Merat et al., 2014). However, researchers are approaching more real-life studies. The University of Michigan and MIT have created a mock-up set of busy streets in Ann Arbor to provide tests for self-driving vehicles in an urban environment (Knight, 2014). They hope to have a large-scale test with 2,000 driverless cars on the road in Ann Arbor within the next eight years. Volvo is going to test its autonomous driving system in public traffic in Gothenburg with 100 real drivers in 2017.

Rödel et al. (2014) conclude that the perceived control and fun decrease continuously with higher autonomy in vehicles, but there are also some age and gender differences. Older, experienced, men prefer higher autonomy, as it facilitates both comfort and safety. The results are interesting, but as Rödel et al. (2015) mention, their study is biased and not representative, both due the method (an online questionnaire) and it being based on imagination and not actual experience. Also, based on an online questionnaire through mailings lists, Payre et al. (2014) found that fully autonomous driving was preferred on highways, in traffic congestion and for automatic parking. Different studies have also used different kinds of simulations for testing drivers' attention or situation awareness within semi-autonomous driving (Merat et al., 2014; Stanton and Young, 2005; Strand et al., 2014). Merat et al. (2014) showed that, within semi-autonomous vehicles, it took drivers 35–40 seconds to stabilise their lateral control of the vehicle when required by a situation. The ability to regain control of the vehicle was higher if they were expecting automation to be switched off. Similar results were revealed by Strand et al. (2014), who indicated that driving performance degraded when the level of automation increased. Further, drivers were less able to handle complete deceleration failures when compared to partial deceleration failures.

4. METHODS

It is difficult to test something that is not fully implemented in a real world context, as end-users tend to think in an abstract manner rather than thinking about the situation in the real world. The methodological aim of this study was to get as close to a real world situation as possible, and to avoid imaginative thoughts. The methods used were 13 in-depth interviews; meanwhile, participants were watching video examples of four different scenarios. The scenarios were chosen to have a focus on levels 3 (advanced, semi-autonomous driving) and 4 (fully autonomous driving) within the NHSTA categorisation. Scenario, level of autonomy and content of video examples are shown in Table 1.

Scenario	Level of autonomy	Content of video examples
1: Highway driving	Limited self-driving automation. NHSTA: Level 3.	A: Highway driving. Handless driving, steering and breaking completely autonomous. High speed. B: Highway driving. Traffic conjunction. Active Cruise Control with Stop and Go (HAD) and Lane keeping (LKS). Handless driving, steering and breaking completely autonomous.
2: Reverse parallel parking	Combined-function automation and limited self-driving automation. NHSTA: Level 2 + 3.	A: Reverse parallel parking. Use of parking assistant. The car finds automatically a free parking spot, and steering in the parking spot is handled automatically by the vehicle.
3: Traffic congested city	Limited self-driving automation. NHSTA: Level 3.	A: A focus on doing other things while driving (work, texting). Handless driving, steering and breaking are completely autonomous. Drivers own choice: turn off the autonomous driving for manual driving. B: Relaxing during driving in traffic congestion in the city. Handless driving, steering and breaking are completely autonomous.
4: Future scenario	Full self-driving automation. NHSTA: Level 4.	A: Future scenario. Driver only provide destination, otherwise, the driver(s) is not expected to be available for control at any time. B: Future scenario. Mercedes F015. Business.

Table 1. Scenario, level of autonomy and content of used video examples

All interviews took place in July and August 2015. Seven men and six women were interviewed with purposive sampling (Bjørner, 2015). The criteria for participation were: subjects must have a driver's license, with no previous experience with semi-autonomous driving technologies, and must drive more than 8,000 km per year. The video examples consisted of both clips from YouTube, as well as the researcher's own videos. The video examples were careful chosen to not affect participants' positive or negative attitudes. Each scenario also contained more than one video example. After each scenario, a use of two different NRS (numerical rating scales) were used where each participant placed a check mark next to a number (along a continuous line from 0–10) that best represented their attitude. The two NRS had the same questions for all four scenarios: 1. What is your willingness to use the functions that make the vehicle "drives itself", as in the video clips you have just seen" (0 is extremely unwilling, 10 is extremely willing). 2. "To what degree would the functions (as in the video clips you have just seen) give you driving pleasure" (0 is not at all, 10 is to a great extent). After each rating had been made, further questions were introduced, such as, 'you said 7; why not 8 or 9', which is a useful way for each individual to elaborate on their answers (Bjørner, 2015). Besides the NRS, a semi-structured interview followed, with three themes covered: 1. Before driving: Points of engagement (aesthetics, novelty, interest, specific or experimental goals) for attributes before the actual use of semi-autonomous technologies. 2. During driving: Match between challenges and skills. Do they perceive themselves as being in the flow channel (Csíkszentmihályi, 1991), or do they instead feel bored or anxious due to the technology? Has the car taken over too much – and do the drivers still perceive themselves as 'drivers' (when they are not driving)? How do the drivers perceive their attention towards the trip, and what is the perceived control, novelty and feedback of the technology? 3. After: What are the perceived positive and negative effects of the semi-autonomous technologies?

The interviews were transcribed and analysed as 'traditional coding' (Bjørner, 2015). Participants were given anonymised names and ID numbers. ID1 referred to the first interviewee, ID2 referred to the second, and so on.

5. TRUST OR OVER-TRUST REGARDING THE SEMI-AUTONOMOUS TECHNOLOGY?

Throughout all interviews, there were two words repeated: "trust" and "control". The element of trust and user acceptance is not new within applied new technologies, and has been covered from various perspectives and different fields. Trust and autonomous driving are also covered in previous studies within both simulation and experimental studies (Helldin et al., 2013; Verbene et al., 2012), as well as interviews or online questionnaires (Payre et al., 2014; Rödel, 2014). Strand et al. (2015) argued that the trust issue became even more relevant when the drivers' control tasks changed from manual to supervisory control, and thus increased the demand for monitoring. However, in the interviews, there were very different opinions in terms of user acceptance and trust:

> "I am sure there will be fewer traffic accidents, as we humans with only two eyes and one brain can't see as much as we should and could. I would just let the technology take over. Lean back, texting, working and drinking coffee and be even more relaxed when driving" (City traffic congestion example). ID4: Peter, 28 years.

> "I am not going to use it….Even within the reverse parallel parking, I do not trust the technology. Yes, the risk might be lower, but can the technology be sure that there isn't a small kid behind the car when parking?" (Parking assistant example). ID6: Hans, 35 years.

Trust is indeed complex, but Hoff and Basir (2015) provided a systematic review on trust in automation. They found that trust consisted of dispositional trust (culture, age, gender, personal traits), situational trust (setting, difficulty, task, risk), initial, learned trust (pre-existing knowledge), and dynamic, learned trust (system performance, reliability, validity, errors). Peter seemed to rely on the dynamic, learned trust, and let the system take over; however, Hans relied on situational trust, where even with the low risk, he would use the parking assistant. Nevertheless, in Hans' answers, he also emphasised that there might be an issue of over-trust: that we simply trust the technology too much. Strand et al. (2015) revealed that humans are poor monitors of automation. Further, over-trust is a phenomenon that is well-known among flight pilots (Molloy and Parasuaman, 1996). Over-trust in the context of semi-autonomous driving (NHSTA levels 2 and 3) is to be understood if drivers rely too much on the autonomous technology, causing them to drive differently and act in a riskier manner, or with increased non-driving activities (for example, Peter as he let the technology take over). However, it might also be that some drivers (as Hans) do not use the semi-autonomous technology due to distrust or uncertainties.

6. HIGH USER ACCEPTANCE TOWARDS SEMI-AUTONOMOUS DRIVING

Similar to other findings in the literature (Payre, 2014, Rödel et al., 2014), this minor pilot study revealed a tendency toward positive attitudes concerning semi-autonomous driving systems.

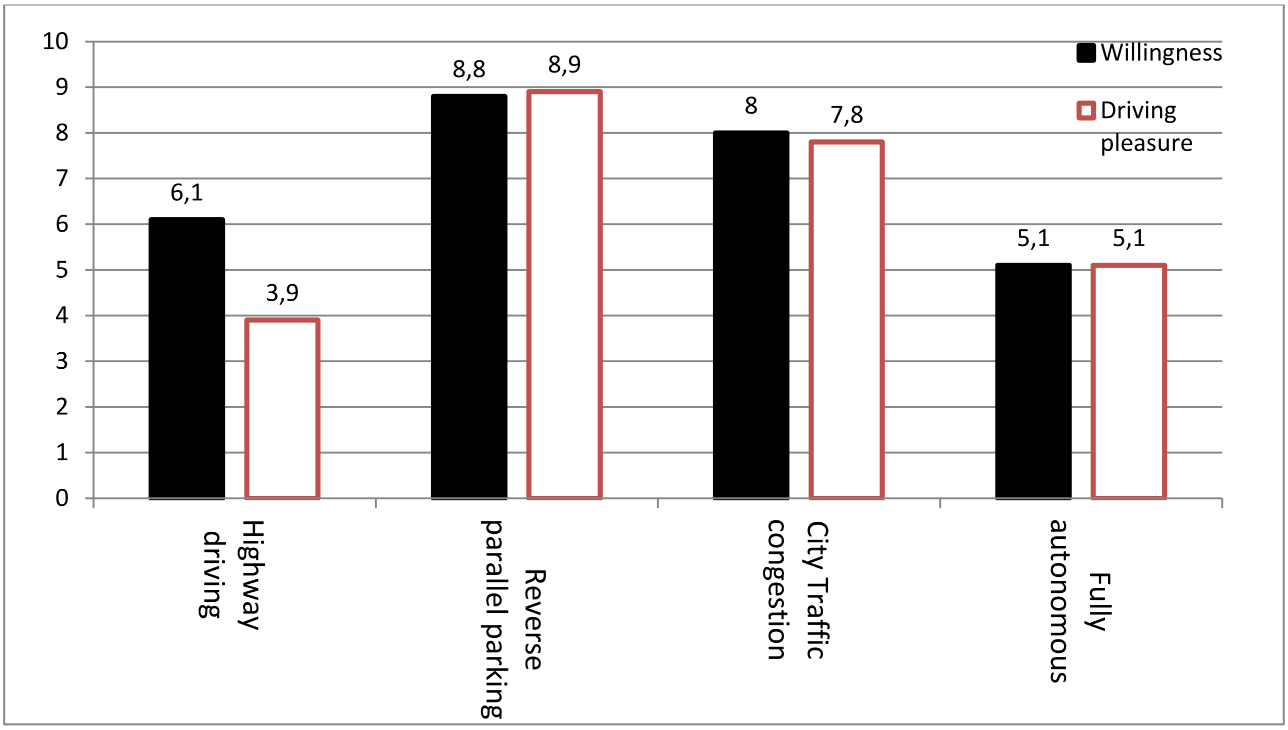

Figure 1: Average of the NRS (numerical rating scale, 0–10) based on 13 participants.

It appeared (Figure 1) that it might not be easy for the participants to separate willingness and driver pleasure, as this division might be more useful in a theoretical framework. However, what was interesting was the difference between participants' willingness and driving pleasure after watching the video clips of highway driving. It also seemed that the willingness to use the semi-autonomous technologies in a highway context was lower than when driving in a city context (Figure 1), which is elaborated in the interviews:

> "I have marked 5 because, if something goes wrong with this technology on the highway at a high speed, I don't think I'd have the time to step in and regain control. So, if the technology fails, it would end really bad". ID1: Laura, 45 years.
>
> "The pleasure of driving is to have a sense of freedom and control, especially on the highway. I don't need technology as my driving instructor on the highway". ID8: Otto, 53 years.
> "When I am driving on highway, I am most often in a holiday mood, where I enjoy driving". ID10: Steve, 47 years.

It was interesting how participants linked the highway drive with a special (holiday) mood, a sense of freedom and control, and the mistrust towards the reliability of the technology. None of the participants mentioned or elaborated on traffic conjunctions on the highway (even though it was an everyday problem for some participants); however, several participants mentioned the speed on the highway as a barrier to using the semi-autonomous technologies, and by that the missing dynamic learned trust towards the technology.

The highest a priori user acceptance was with the parking assistant:

> "Now, I drive longer and walk more than I parallel park. So yeah, I would really like if the car could do the parking". ID1: Laura, 45 years.
> "As I am not parallel parking that often, I don't have the training, and it always turns out to be a bit difficult and oblique". ID7: Mark, 36 years.

The focus on "distractions" was due to the increased possibilities of conducting non-driving activities, as the car will take over some of the driver's control. A potential risk is that these new technologies will make drivers fall asleep, do nothing, read the newspaper or use miniaturised electronic devices and ubiquitous technologies (mobile phones, tablets, mp3 players, laptops, wearable computers). There has been some focus on the disadvantages and distractive elements these new ubiquitous technologies have when driving (Holland and Rathod, 2013; McKeever et al., 2013; Zhao et al., 2013), but not within semi-autonomous driving. In the discourse, some companies are conscious of this; for example, Audi does not refer to this technology as 'autonomous driving' but 'piloted driving'.

7. USERS' PROS AND CONS

Besides the more explicit concerns regarding trust, several of the a priori users also expressed concerns about planning and legislation:

"Who is to blame if the technology fails and this [autonomous] car bumps into another car? What about the insurance? Is it the car company or the road construction authorities who should be blamed?" ID5: Elizabeth, 55 years.

"Are the roads and intersections actually built for this?" ID10: Steve, 47 years.

“That’s pretty smart if the car itself can stop if a pedestrian comes across the street. But, if the pedestrians know this, then why shouldn’t they just walk out in front of the cars?” ID12: Mike, 36 years.

Semi-autonomous and autonomous vehicle development not only concerns safety, trust and control, but also social interactions, embodied performances and planning and regulations, in what Jensen (2014) labelled ‘mobilities in situ’. The legislation within both semi-autonomous and autonomous vehicles was not only a future concern among the participants in this study, but is a major concern for research studies and pilot testing within the field. However, there is an increased focus on both the ethical and legislation problems in the European Union and national and international institutions (Schreurs and Steuwer, 2015).

An interesting comment from several participants involved the future perspectives of increased mobility for children, elderly people and persons with disabilities. However, as comments below also indicate, it is important not to have too romanticised an image of what the semi-autonomous and autonomous systems can achieve; it is important to think of different car designs for different target groups:

“The future perspectives might be a little too romanticised. Are there no problems with traffic congestion in the future, no traffic accidents? Probably not. But, I find it really interesting that the car can be used for different purposes based on my needs…This [fully autonomous] vehicle could also help kids get to school, and elderly and disabled persons get around more. But, they need to re-design this car then…with larger doors for better access”. ID8: Otto, 53 years.

8. CONSLUSION

The conceptualisation of driving is a very complex phenomenon, but scholars tend to link driving within an economic conceptualisation of time, which, to a high extent, led driving to be viewed as a commodity (e.g., spent, wasted, saved time) as opposed to a pleasure. Very few scholars have linked commodity and driving pleasure on a theoretical level, and few have provided empirical-based data on driving pleasure and semi-autonomous and autonomous driving. The autonomous vehicle can be said to be at the core of the third age of the transport evolution (Lyons and Urry, 2005), in which an understanding of our life needs determines and influences how the transport system is best used to support those needs. In order to have user acceptance for semi-autonomous and autonomous driving, it is important that users perceive it as useful and have an increase in driving pleasure.

An important issue is the matter of trust when changing to more autonomous driving technologies. However, trust is not just trust: it can be separated into different kinds of trust, e.g. dispositional trust (culture, age, gender, personal traits), situational trust (setting, difficulty, task, risk), initial, learned trust (pre-existing knowledge), and dynamic, learned trust (system performance, reliability, validity, errors). It may be worth looking into positive psychology, e.g. Csíkszentmihályi's (1991) flow model, with an understanding of a balanced level of both skills and challenges. The semi-autonomous technologies also need to be learned, experienced and trusted before successful acceptance can occur.

It is difficult to test something that is not fully implemented (and legal) in a real world context; however, using specific video examples may provide the users with a better conceptual understanding of what autonomous driving technologies can accomplish. In the development, it is important not only to be focused on technical and legislation problems; if successful implementation is to occur, other stakeholders (e.g., non-governmental organisations) and a variety of academic fields (including user perspectives) should be involved in the development and design of the fast growing development of autonomous driving.

BIBLIOGRAPHY

Bjørner, T. ed. 2015. *Qualitative methods for consumer research: the value of the qualitative approach in theory and practice*. Copenhagen: Hans Reitzel.

Chu, K., Kim, J., Jo, K. and Sunwoo, M. 2015. Real-time path planning of autonomous vehicles for unstructured road navigation. *International Journal of Automotive Technology*, 16(4): 653-668.

Csíkszentmihályi, M. 1991. *Flow: the psychology of optimal experience*. New York, NY: Harper Collins.

Davis, F. D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3): 319-340.

Davis, F. D. 1993. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal Man Mach Stud,* 38(3): 475-487.

Eckoldt, K., Knobel, M., Hassenzahl, M. and Schumann, J. 2012. An experimental perspective on advanced driver assistance systems. *Information Technology*, 54(4): 165-171.

Hagman, O. 2010. Driving pleasure: a key concept in Swedish car culture. *Mobilities*, 5(1): 25-39.

Helldin, T. et al. 2013. Presenting system uncertainty in automotive UIs for supporting trust calibration in autonomous driving. Proceedings, ACM, Automotive UI '13, October 28–30. http://www.his.se/PageFiles/11241/FINAL_AUI_Helldin_2013_09_24.pdf

Hoff, K. A. and Bashir, M. 2015. Trust in automation: integrating empirical evidence on factors that influence trust. *Human Factors*, 57(3): 407-434.

Holland, C. and Rathod, V. 2013. Influence of personal mobile phone ringing and usual intention to answer on driver error. *Accident Analysis & Prevention*, 50: 793-800.

Jensen, O. B. 2014. *Designing mobilities*. Aalborg: Aalborg University Press.

KPMG 2013. Self-driving cars: are we ready. White paper. 10.10.2013.

Knight, W. 2014. Town built for driverless cars. *MIT Technology Review*, October 3. http://www.technologyreview.com/news/531301/town-built-for-driverless-cars/

Lee, J. G., Kim, K. J., Lee, S. and Shin, D-H. 2015. Can autonomous vehicles be safe and trustworthy? Effects of appearance and autonomy of unmanned driving systems. *International Journal of Human-Computer Interaction*, doi: 10.1080/10447318.2015.1070547

Lyons, G. and Urry, J. 2005. Travel time use in the information age. *Transportation Research Part A: Policy and Practice,* 39(2/3): 257-276.

McKeever, J. D., Schultheis, M. T., Padmanaban, V. and Blasco, A. 2013. Driver performance while texting: even a little is too much. *Traffic Injury Prevention*, 14, 132-137.

Maurer, M., Gerdes, C., Lenz, B., Winner, H. eds. 2015. Autonomes fahren: technische, rechtlice und gesellschaftliche. Aspekte: Springer.

Merat, N., Jamson, A. H., Lai, F. C. H., Daly, M. and Carsten, O. M. J. 2014. Transition to manual: driver behaviour when resuming control from a highly automated vehicle. *Transportation Research Part F,* 27: 274-282.

Molloy, R. and Paraduraman, R. 1996. Monitoring an automated system for a single failure: vigilance and task complexity effects. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 38(2): 311-322.

Payre, W., Cestac, J. and Delhomme, P. 2014. Intention to use a fully automated car: attitudes and a priori acceptability. *Transportation Research Part F*.

Rödel, C., Stadler, S., Meschtcherjakov, A. and Tscheligi, M. 2014. Towards autonomous cars: the effect of autonomy levels on acceptance and user experience. Proceedings, Automotive UI '14, September 17–19, Seattle WA.

Schreurs, M. A. and Steuwer, S. D. 2015. Autonomous driving: political, legal social, and sustainability dimensions. In: Maurer, M., Gerdes, C., Lenz, B., Winner, H. eds. Autonomes fahren: technische, rechtlice und gesellschaftliche. Aspekte: Springer.

Stanton, N. A., Young, M. S., Walker, G. H., Turner, H. and Randle, S. 2001. Automating the driver's control tasks. *International Journal of Cognitive Ergonomics Science*, 27: 149-159.

Strand, N., Nilsson, J., Karlsson, I. C. M. and Nilsson, L. 2014. Semi-automated versus highly automated driving in critical situations caused by automation failures. *Transportation Research Part F,* 27: 218-228.

Transportation Research Board 2000. Highway capacity manual. National Research Council, Washington, DC.

Verbene, et al. 2012. Trust in smart systems: sharing driving goals and giving information to increase trustworthiness and acceptability of smart systems in cars. *Human Factors*, 54(5).

Yagdereli, E., Gemci, C. and Aktas, A. 2015. A study on cyber-security of autonomous and unmanned vehicles. *Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, 1-3.

Zhao, N. et al. 2013. Self-reported and observed risky driving behaviors among frequent and infrequent cell phone users. *Accident Analysis & Prevention*, 61, pp. 71–77.