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Published in:
Proceedings of the 5th International Conference on Computer-Human Interaction Research and Applications (CHIRA 2021)

DOI:
10.5220/0010719200003060

Acceptability and Acceptance of Connected Automated Vehicles: A Literature Review and Focus Groups

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Keywords: Connected Automated Vehicles, Autonomous Driving, Acceptance, Acceptability.

Abstract: A lot of resources and manpower are being allocated to develop Connected Automated Vehicles (CAV). CAV are Automated Vehicles (AV) with vehicle connectivity abilities to further increase road safety and user convenience. For a successful implementation of CAV, the psychological factors that predict its acceptance have to be researched. The present paper provides a literature review of the individual differences and perceived characteristics that could influence CAV's acceptance. Additionally, we report the results of several focus groups that were held in 4 European countries to highlight additional factors not reported in the literature yet.

1 INTRODUCTION

In the near future Connected Automated Vehicles (CAV) will be introduced to public roads. CAV are fully self-driving vehicles, which can share data with other vehicles and transportation systems. The traditional driver will take the role of a passenger in CAV. Major players in the automotive industry have already invested in designing vehicles with full automation, and many have started pilot testing these vehicles in designated test areas (SAE International, 2018).

At present, Automated Vehicles (AV) already exist and are allowed on public roads in some countries. However, AV sensing technologies are currently limited, and unreliable under extreme weather or road conditions (He et al., 2019). To illustrate, at least three Tesla drivers have died in crashes in which autopilot failed to detect obstacles on the road since 2016 (Boudette, 2021), with several crashes still under investigation. CAV improves upon existing AV by including vehicle connectivity abilities to communicate with other vehicles and transportation networks, enhancing the situational awareness. For example, they can share the vehicles speed, heading, and brake status to increase road safety (Eskandarian, Wu, & Sun, 2019). Moreover, they could help in improving traffic flow and plan the most efficient road, enhancing the vehicle's convenience. Lastly, more efficient driving and CAV's ability to platoon may reduce traffic CO_2 emissions, potentially making it more environmentally friendly than AV or traditional cars.

A lot of resources and manpower are being allocated to realize the goal of connected fully automated vehicles. However, whether these efforts will be successful depends on whether the public would accept and adopt CAV. The addition of vehicle connectivity may lead to improved safety and convenience over AV, but could also increase the public's concerns about for example data sharing and possible hacking of the vehicle. In this paper we explore which psychological factors are important for the acceptability and acceptance of CAV. We first conducted a literature review to answer this question. Additionally, we held several focus groups to discover other factors that could influence the acceptance of CAV that are missing or lacked attention in the literature.

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2 LITERATURE REVIEW

In the literature acceptability and acceptance are sometimes used interchangeably. However, in this paper we disentangle the two constructs and reason, in line with Schade & Schlag (2003), that acceptability refers to one's attitudes and evaluations before one has experienced CAV, whereas acceptance refers to one's attitudes, evaluations, and behaviour after having experienced CAV. Acceptability could be expressed as an attitudinal evaluation or intention (e.g. the willingness to ride CAV), while acceptance could both be expressed as an attitude, as well as actual behaviour (e.g. purchasing CAV). As those people that have had experience with CAV mostly had those experiences in an experimental setting and not in real-life, the present literature review will cover acceptability and not acceptance in the majority of the reviewed studies.

Few studies have researched the acceptance of fully automated vehicles (e.g. Kyriakidis et al., 2015; Distler et al., 2018). Previous studies have mainly focused on Advanced Driver Assistance Systems (ADAS), partially automated vehicles, public exposure to automated vehicles in the media such as Google car and Tesla, or slow-driving automated public transport shuttles. As such, we will extrapolate results from these studies to CAV.

2.1 Individual Differences

Innate demographic differences have often been analysed in an attempt to see whether they affect the acceptability of automated vehicles (AVs; e.g. Howard & Dai, 2014; Becker & Axhausen, 2017). Individual differences may be interesting to examine to be able to tailor CAV to specific needs of different user groups. However, previous research has shown that effects of individual differences on acceptability of CAV are often small, and sometimes contradictory (e.g. Becker & Axhausen, 2017 and Rödel et al., 2014).

2.1.1 Gender and Age

Most studies included gender and age in their analyses and examined whether innate demographic differences exist in acceptance of AV. Some gender differences surfaced. In general male drivers are reported to be less concerned to be a passenger in a fully automated vehicle than women (Schoettle & Sivak, 2014; Becker & Axhausen, 2017). Howard & Dai (2014), for example, reported that women and men differed in the concerns they have with regard to being a passenger in a fully automated AV. Women were more concerned with low control over the vehicle, while men were more concerned with potential liability issues. Differences between men and women in willingness to use an automated vehicle could be partially explained by emotions that they assign to automated driving. Women tend to assign more negative emotions to automated driving, and anticipate both less pleasure and more anxiety than men (Hohenberger, Spörrle, & Welpe, 2016).

Comparisons between age groups are less equivocal in the literature. Some studies reported that young people were more positive about automated vehicles than older drivers (Becker & Axhausen, 2017), while other studies report that older people were more interested in using an automated vehicle than younger people (Rödel et al., 2014). Gold et al. (2015) reported that older people tend to rate the potential safety gains of automated driving higher than younger people. Likewise, Regan at al. (2017) reported that younger people have a higher level of trust in CAV than older people, but they also have higher levels of concerns about their performance than older people have. Ease of technology use may be a moderating factor in the relationship between age and willingness to use CAV. For example, Schaefer et al. (2014) reported that higher self-reported ease of technology use among older people had positive effects on willingness to use AVs, and expected benefits from using AVs. Additionally, Souders & Charness (2016) found that reduced concerns related to AVs had positive effects on willingness to use them. As such, instead of focusing on differences in acceptance based on age, it may be better to focus on the ease of technology use.

2.1.2 Experience with Technology

Having no experience with an innovation can trigger a negative response to it, especially among people who are not open to new technology. On the other hand, having positive experiences with an innovation can increase willingness to use it. To illustrate, in a simulation study conducted by Gold et al. (2015), the researchers found that perceived trust and intention to use an AV increased after exposure to it (Gold et al., 2015). This means that even a simulated experience with the technology can benefit the relationship to it. In another study initial perceptions of highly automated vehicles were assessed, followed by letting participants experience the AV in a driving simulator, and finally letting them experience it on a test track. Acceptance, trust, satisfaction, and perceived usefulness of the AV increased significantly after experiencing the driving simulator compared to the initial attitudes (Hartwich et al., 2018). Moreover, these positive ratings remained stable over time after they had experienced the AV on a test track. Also, Qu et al. (2019) reported that self-reported familiarity with AVs is positively correlated with the expected benefits of AVs, and negatively correlated with concerns. These studies indicate that experience with the technology, even in a simulator, can significantly increase the acceptance of CAV.

However, direct experience with CAV may not be necessary to increase acceptability. Positive experiences with automated features in cars, such as automatic lane keeping, automated parking, or adaptive cruise control may enhance willingness to make the step to fully automated driving. Indeed, Sener, Zmud, & Williams (2019) found that intention to use AVs was higher among people who had experience with automated features in cars than people who did not have experience with features like this. These results indicate that having people experience driving with some automated functions could increase the acceptability of CAV and in turn acceptance.

2.1.3 Motives

Aside from previous experience with technology, examining people's motives for using cars could prove useful in determining which factors are important for acceptance of CAV. Most people will come up with all kinds of practical arguments when asked why they drive a car. Innovators generally also stress these commonly named instrumental advantages of AVs to promote their use. However, research into motives for private car use has shown that a car is much more for people than just a means of transportation (Steg, 2005). Aside from instrumental motives, symbolic and affective motives influence current private car use (Gatersleben, 2007; Steg, 2005). Symbolic motives for private car use include being able to express one's high status or identity by driving an expensive or luxurious car. Affective motives for car use include the joy of driving and seeing driving itself as a positive and enjoyable activity.

Although to date no research has extrapolated the motives for traditional private car use to intentions for the use of CAV, these findings have been replicated in the purchase intention of electric vehicles (Noppers et al., 2014). Participants indicated that instrumental aspects of electric vehicles were the most important for their purchasing intention, but purchasing intentions were actually better predicted by the evaluation of the symbolic aspects of the vehicle. More specifically, the purchase intention of an electric vehicle was mostly associated with gaining status. Especially the early adoption of new mobility choices may be driven by the association of high status (Egbue & Long, 2012). Extrapolating these findings to the intention to use CAV, CAV may benefit from being presented as a luxurious product at its launch to enhance acceptance.

2.2 Perceived Characteristics

Several models that aim to explain acceptance of technology or innovations include system and design features as predictors of acceptance (e.g. the Technology Acceptance Model; Davis, 1993), indicating that perceived characteristics of CAV may play a major role in its acceptance. We will, therefor, discuss the perceived characteristics of CAV that are mentioned the most often in the literature relating to acceptance below, namely perceived safety, pleasure, convenience, comfort, trust, and control.

2.2.1 Perceived Safety

A lot of individual variation exists when it comes to perceptions regarding the safety of automated vehicles. For instance, while some people associate full automation with high safety (Brell et al., 2019), others associate it with low safety (Zmud et al., 2016). A large-scale survey by Schoettle & Sivak (2014) with over 1500 participants revealed that a large portion of the respondents believed that fewer accidents will happen in the future thanks to automated vehicles, indicating they expected a high safety increase.

It seems people immediately think of safety when discussing AVs. In one questionnaire, more than half of the participants chose 'highest possible level of safety' as their greatest priority for automated cars (Lustgarten & Le Vine, 2018). The greatest concerns regarding the safety of automated driving people seem to have are about equipment failure, vehicle performance in unexpected situations, software hacking, and data misuse (Kryriakidis et al., 2015; Schoettle & Sivak, 2014). In short, people expect both safety gains, but are concerned about safety as well.

Additionally, Zoellick et al. (2019) reported that perceived safety correlated strongly with acceptance and was a solid predictor of intention to use automated vehicles in a study where potential users experienced a vehicle with high automation on the road. This indicates perceived safety may be a predictor of both acceptance of and intention to use CAV. In a different study it was found that the more driving experience respondents had, the more often they drove, and subsequently the more likely they had been involved in a conventional car-based crash, which made them view automated vehicles as a safer alternative (Montoro et al., 2019).

2.2.2 Perceived Pleasure

As said above, a significant percentage of drivers do not view driving as just a means of transportation, but enjoy the driving in itself, feeling it is thrilling, pleasurable, and adventurous (Steg, 2005). Driving in CAV could pose a threat to driving pleasure, in particular for those who associate driving with fun as it takes away the driving task of the driver. In turn this could affect the acceptability and acceptance of CAV. Indeed, Rödel et al. (2014) reported that the expected fun of driving was lower for higher automation, compared to lower automation. Intention to use these vehicles was also lower for higher automation levels.

Certain aspects of driving in CAV could also increase driving pleasure, though. For example, engaging in manoeuvres that are seen as difficult, such as reverse parking, could decrease the driving pleasure of a traditional car. When driving in CAV there is no need to deal with such hassles. In support of this reasoning, Bjørner (2017) found that people expect the highest pleasure with AVs in situations of parallel parking or in a traffic jam. In short, perceptions of pleasure regarding being a passenger in CAV could both be positive or negative. Future research needs to investigate if and how these perceptions influence the acceptability and acceptance of CAV.

2.2.3 Perceived Convenience and Comfort

Convenience appears to be an important factor associated with fully automated driving (Howard & Dai, 2014). The possibility of being able to work, socialise, or relax despite being stuck in a traffic jam is very appealing to some. Some benefits potential users imagine are (1) the ability to multitask, such as reading or working while travelling, (2) extended comfort (e.g. the ability to adjust the seat to a relaxing position; integrated multimedia applications) compared to a traditional vehicle (Pfleging et al., 2016), and (3) enhancing the mobility of those currently unable to drive or in situations in which driving manually is undesirable, such as after drinking or when one is fatigued (Jeon et al., 2018). In fact, in a study examining the prioritization of benefits of AVs, more than half of the respondents expressed willingness to pay more, as well as a willingness to accept slower travel in exchange for greater comfort while travelling in an AV (Lustgarten & Le Vine, 2018). Perceived convenience has been linked to acceptance of both partially automated vehicles and fully automated vehicles (Lee et al., 2018).

The level of automation seems to affect perceived convenience, though. Potential users believe fully autonomous driving would be easier for them than manual driving, while partially autonomous driving is seen as more difficult (Kyriakidis et al., 2015). The higher the level of automation, the more potential users would intend to rest, watch movies, or read while travelling.

2.2.4 Perceived Trust

In an international survey almost half of the respondents indicated that trust is the biggest barrier for accepting AVs (Jeon et al., 2018). Perceived trust can be defined as the belief that CAV will function as intended and without posing any danger to its passengers as well as to other road users. When one does not believe CAV will function as intended, one has low trust in CAV. Low trust may even lead to physiological responses among users. For example, in a simulation study participants with less trust in AVs experienced an additional increase in psychophysiological stress when the vehicle drove autonomously, compared to when the participant was in control of the vehicle (Morris et al., 2017). As such, enhancing trust in CAV should be a priority to enhance acceptance. Two factors may influence trust: previous experiences, and system transparency.

To start with the first factor, a simulation experiment with partially automated vehicles found that positive experiences enhanced trust in the vehicle, while negative experiences (such as a crash) decreased trust (Gold et al., 2015). Likewise, false alarms and errors might decrease trust in automated systems (Schaefer et al., 2016). Possibly, as CAV takes over all driving tasks, users may attribute the negative experiences such as crashes to CAV's computer system, while in a traditional car they may attribute a crash to other road users' behaviour or their own driving. The attribution of blame in case of crashes or errors with CAV still needs further research. It will be crucial to build CAV so that it can operate as error-free as possible, as people will be less forgiving of a machine than a human (Zhang et al., 2021).

Secondly, system transparency (the degree to which users can predict and understand the operating of the vehicle), as well as the perception of the vehicle's performance have been found to have positive effects on trust in AVs in a survey applying the Technology Acceptance Model to AVs (Choi & Ji, 2015). Moreover, greater trust is associated with a greater intention to use AVs. Perhaps explaining clearly and in an easy-to-understand manner how CAV functions could improve its acceptance.

2.2.5 Perceived Control

Another potential barrier towards the acceptance of CAV is the feeling of low control associated with fully automated driving. The higher the automation level of a vehicle, the less likely people are to prefer that vehicle over a vehicle with lower automation (Schoettle & Sivak, 2016). The majority of the current drivers indicate that they still would like to have some control over the pedals and the steering wheel. Current drivers would like AVs to have the option to be able to drive manually whenever they desire to do so (Liljamo et al., 2018). Lack of control is rated as the least attractive feature of fully automated driving (Howard & Dai, 2014). Full automation could pose a threat to the basic need of feelings of control, especially for those who enjoy car-use and value their car as a luxury possession.

On the other hand, when people believe that CAVs are capable to drive safely by having external control of the road situation at all times, they are also more likely to be accepting of CAV. For example, Dixon et al. (2020) reported that the more people perceived that an AV itself had control over and could avoid possible hazardous situations, the more they supported AVs. However, where these beliefs stem from is not clear. It could be that those who already have positive experiences with automation assign more external control to the car. For instance, drivers who already use adaptive cruise control indicate to be more comfortable about driving without a steering wheel than those who do not currently use adaptive cruise control (Kyriakidis et al., 2015). In short, perceived control does appear to play a role in the acceptance of CAV, but what the antecedents of perceived control of CAV are remains unclear.

3 FOCUS GROUPS

The literature review highlighted some important psychological factors that could influence the acceptability of CAV. The aim of the focus groups was to assess if other psychological factors could play a role in the acceptability of CAV that were not found or received little attention in the literature. To this end we conducted a total of 8 focus groups in Spain, Italy, France, and the Netherlands. They took place from late 2019 to early 2020.

3.1 Sample

In each country the focus group(s) targeted middle aged drivers (aged 31-55). Additionally, the focus groups were held to target specific groups: (1) cyclists, (2) pedestrians, (3) anxious drivers / low frequency drivers, (4) high frequency drivers, (5) older drivers (aged 56-75), (6) younger drivers (aged 18-30), and (7) persons with physical disabilities.

The total sample consisted of 70 participants, with a mean age of 40.8. The majority was male (61.4%), and held a university degree (47.1%). For an overview of the total sample per category, please refer to Table 1 below. Please note some participants may fall into multiple categories.

Table 1: Sample overview focus groups.

Participant type	N
Young drivers (18-30)	21
Middle aged drivers (31-55)	32
Older drivers (56-75)	17
Low frequency drivers	26
High frequency drivers	32
Vulnerable road users (pedestrians, cyclists, and persons with a disability)	21

3.2 Procedure

A script and questionnaires were prepared beforehand in English, and then translated to Spanish, Italian, French, and Dutch by native speakers. The focus groups followed the method of Focus Group based on Collective Questionnaire Sessions developed by Bellet et al. (2018), allowing for both qualitative and quantitative data collection.

Participants were first given an information form, which detailed the aims of the study and what was expected of them, as well as an informed consent form. After signing the informed consent form, participants completed a short questionnaire about demographics, driving behaviour, and interest in technology individually. After everyone completed the questionnaire, participants introduced themselves and were asked what comes to mind when thinking about CAV. They were then shown a short videoclip (3 minutes) that showed what driving in CAV is like and received a textual description of CAV. After this, participants individually filled out short questionnaires on various topics, alternated with rounds of discussion.

The topics discussed were: (1) acceptability, (2) safety, risk, and trust, (3) convenience, pleasure, and comfort, (4) perceived benefits and costs, and motives, and (5) ethical and legal issues.

Qualitative results were obtained from the recorded discussions, as well as any comments participants left on the individual questionnaires after each section. The group discussions were led by the test leaders, who had received the script and several discussion topics beforehand.

The focus group for the Dutch participants was held online instead, due to the COVID-19 lockdown in 2020. Dutch participants completed the same questionnaires online, and discussion rounds were omitted for this group.

3.3 Collective Questionnaire Sessions

We will discuss the outcome of the focus group sessions for each separate section.

3.3.1 Acceptability and Demographics

Acceptability of CAV was assessed at three points: (1) before participants watched the movie and read the description of CAV, (2) right after watching the movie and reading the description, and (3) after the group discussion about acceptability.

We took the mean of all these measurement points to assess their acceptability. We compared acceptability based on participants' gender, age group, driving frequency, and interest in technology. To compare low and high frequency drivers, we created two subgroups in which low frequency drivers scored below the average on driving frequency, while high frequency drivers scored above the average. Likewise, we created two subgroups for high and low interest in technology, based on whether participants scored above or below the average on interest in technology.

Overall, more than half of all participants viewed CAV at least slightly positively. Men, younger and older drivers, high frequency drivers, and those with a high interest in technology were slightly more positive than women, middle-aged drivers, low frequency drivers, and those with low interest in technology. Please refer to Figure 1 below for an overview.

3.3.2 Perceived Benefits and Costs, and Motives

The two largest benefits participants expected from CAV were reducing the traffic CO_2 emissions (70% of participants), and reducing traffic congestion (65% of participants). Only around half of the participants thought CAV will facilitate their mobility, and around 60% of participants believed the introduction of CAV could reduce car insurance rates.

3.3.3 Ethical and Legal Issues

Participants were separately asked who (the owner or the manufacturer) would be morally and legally responsible in case of an accident with CAV. Most participants agreed that the manufacturer was morally

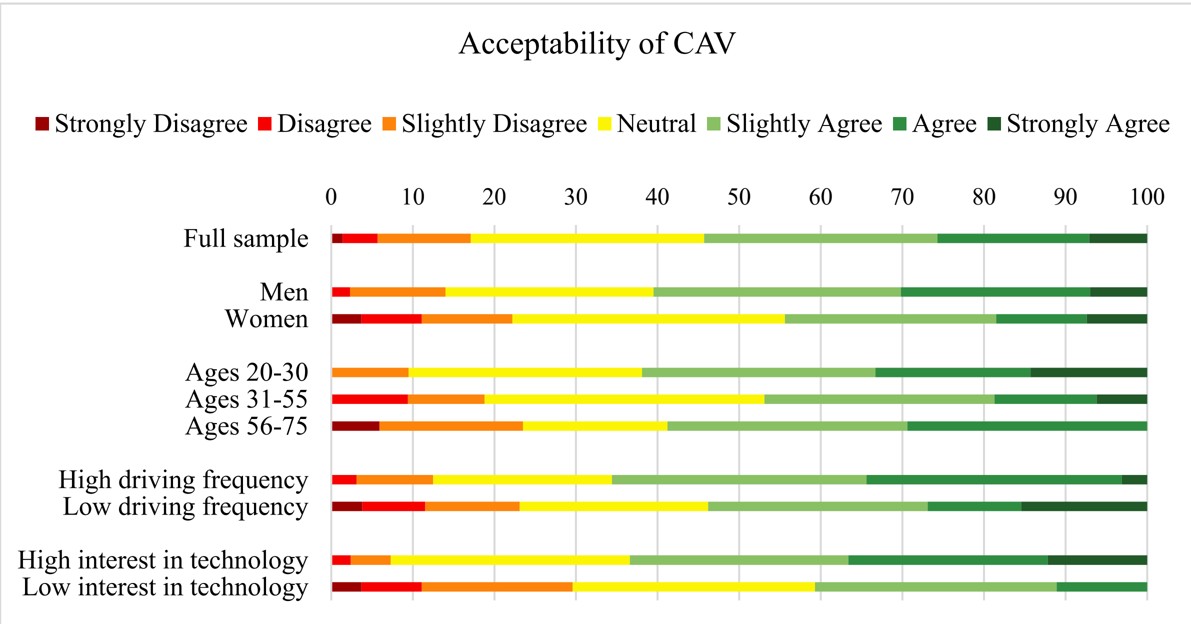

Figure 1: Acceptability of CAV in the focus groups.

responsible (70% of participants), compared to the owner (25% of participants). They also agreed that the manufacturer would be legally responsible (70% of participants), compared to the owner (25% of participants). They were also asked who CAV should protect in case of an accident. These questions proved difficult, as participants agreed that CAV should both protect the passengers at all costs (55% of participants), as well as protect the other road users at all costs (60% of participants).

Lastly, participants were asked some questions about how the introduction of CAV could lead to various changes. The majority of the participants thought CAV cannot coexist with traditional vehicles on public roads (55% of participants), and that both the infrastructure has to change for CAV (70% of participants), as well as that new legislation is needed (70% of participants). Many participants were worried that their privacy would not be protected in CAV (55%). Finally, although CAV would be fully automated, participants still thought a driving license will be required to use it (60% of participants).

3.4 Focus Group Discussions

The greatest concerns participants had, as well as the most intensely discussed topics will be reported below.

There was no consensus on the safety of CAV. Some participants believed CAV would be safer than traditional vehicles under all conditions and will be capable of detecting objects and other road users sooner than a human could see them. After all, CAV is never distracted or fatigued like a human driver. Others were overconfident in their own driving skills. For example, one participant commented that they could see a pedestrian earlier than a sensor could detect them. Some thought a human could react better in uncommon situations, while CAV would drive better in common situations. In common situations, CAV's behaviour will always be similar and thus CAV would be more predictable than a human driver. This could help make other road users feel safe. This indicates the predictability of CAV’s behaviour may play a role in the perceived safety of CAV, as well as in its acceptance.

Many other road users (cyclists and pedestrians) wished to know which vehicle is driving autonomously and which is driven manually. They suggested a sticker or logo could be used for this. Some participants indicated they want to receive some sort of signal when CAV has detected them as pedestrian or cyclist. Other participants disliked the idea of being unable to communicate with the driver, leading to feelings of unsafety. It seems some form of communication between other road users and the vehicle will be necessary to make CAV acceptable for other road users.

Some drivers wanted to retain the option to drive manually, even if the vehicle could drive autonomously. Others pointed out a driving license will be required if this option remains. This would mean CAV cannot facilitate the mobility of those currently unable to obtain a driving license. Others also indicated to like the idea of CAV in cases they normally would be unable to drive, such as when they are fatigued or have been drinking. The discussion showed a divide between current drivers who need some degree of control over the vehicle for CAV to be acceptable, while current non-drivers wanted CAV to be as accessible as possible to enhance their mobility. Drivers and current non-drivers may have different requirements of CAV, potentially causing differences in their acceptance of CAV.

In terms of legal issues, most participants thought legislation has to drastically change to ensure legal liability is clear. Without a clear legal framework, CAV would not be acceptable. A few participants suggested legal liability of the vehicle owner could depend on maintenance. The owner would be legally responsible if the vehicle was poorly maintained; otherwise the manufacturer would be responsible.

One potential issue of CAV is the sharing of data. Most participants believed that as long private data is not shared, it will not be problematic. Only data needed for the algorithms and anonymous data should be shared. If privacy cannot be guaranteed, CAV may not be acceptable to several participants.

In terms of environmental sustainability of CAV, most participants did not know CAV may be able to reduce CO_2 traffic emissions by platooning or by reducing traffic jams through more efficient driving. Electric cars would be more environmentally friendly, they thought. Some feared an increase in mobility will increase traffic and congestion, which will in turn increase traffic CO_2 emissions. Several participants suggested making all CAV electric. This indicates that the perceived environmental sustainability of CAV could influence its acceptance.

4 CONCLUSIONS

In the present paper we provide a literature review on psychological factors that could influence CAV’s acceptability and acceptance. Additionally, we conducted several focus groups to uncover other factors that could play a role in CAV’s acceptance that were not mentioned or received little attention in the literature.

In the literature review we found that individual differences may play a role in the acceptability and acceptance of CAV. Gender and age may have limited effects, while experience with the technology may be a more reliable predictor. Perceived characteristics of CAV may be the most important predictors of acceptance. We discussed perceived safety, pleasure, convenience, comfort, trust, and control as being particularly relevant.

The focus groups showed that the predictability of CAV's behaviour, perceived environmental sustainability of CAV, existence of a clear legal framework of liability, and capability of communicating with other road users may be additional factors that could influence CAV's acceptance. We also found that drivers and non-drivers may have different requirements for CAV, which could lead to differences in their acceptance levels. The finding also points out that marketing strategies should target different factors based on user group characteristics and needs.

Future research should determine whether factors influencing acceptance of AV can be extrapolated to CAV. Additionally, what drives different perceptions of CAV (for example whether one believes CAV is safe or not) is currently unclear. If these questions could be answered, we would have a better grasp on what is needed to enhance CAV's acceptance to facilitate its implementation.

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 814999. The content of this publication is the sole responsibility of the authors, and in no way represents the view of CINEA or European Commission.

REFERENCES

Becker, F., & Axhausen, K. W. (2017). Literature review on surveys investigating the acceptance of automated vehicles. *Transportation*, *44*(6), 1293-1306.

Bellet, T., Paris, J. C., & Marin-Lamellet, C. (2018). Difficulties experienced by older drivers during their regular driving and their expectations towards Advanced Driving Aids Systems and vehicle automation. *Transportation Research Part F: Traffic Psychology and Behaviour*, *52*, 138-163.

Bjørner, T. (2017). Driving pleasure and perceptions of the transition from no automation to full self-driving automation. *Applied Mobilities, 4*(3), 1-16.

Boudette, N.E. (2021, July 5). Tesla Says Autopilot Makes Its Cars Safer. Crash Victims Say It Kills. Retrieved July 19, 2021, from https://www.nytimes.com/2021/07/05/business/tesla-autopilot-lawsuits-safety.html

Brell, T., Philipsen, R., & Ziefle, M. (2019). sCARy! Risk perceptions in autonomous driving: The influence of experience on perceived benefits and barriers. *Risk Analysis*, *39*(2), 342-357.

Choi, J. K., & Ji, Y. G. (2015). Investigating the importance of trust on adopting autonomous vehicle. *International Journal of Human-Computer Interaction*, *31*(10), 692-702.

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

Distler, V., Lallemand, C., & Bellet, T. (2018). Acceptability and acceptance of autonomous mobility on demand: The impact of an immersive experience. *In Proceedings of the 2018 CHI Conference on Human Factors in Computer Systems* (pp. 1-10). ACM, New York, USA.

Dixon, G., Hart, P. S., Clarke, C., O'Donnell, N. H., & Hmielowski, J. (2020). What drives support for self-driving car technology in the United States?. *Journal of Risk Research*, *23*(3), 275-287.

Egbue, O., & Long, S. (2012). Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions. *Energy Policy*, *48*, 717-729.

Eskandarian, A., Wu, C., & Sun, C. (2019). Research advances and challenges of autonomous and connected ground vehicles. *IEEE Transactions on Intelligent Transportation Systems, 22*(2), 683-711.

Gatersleben, B. (2007). Affective and symbolic aspects of car use. In *Threats from car traffic to the quality of urban life: Problems, causes and solutions* (pp. 219-233). Emerald Group Publishing Limited, United Kingdom.

Gold, C., Körber, M., Hohenberger, C., Lechner, D., & Bengler, K. (2015). Trust in automation – Before and after the experience of take-over scenarios in a highly automated vehicle. *Procedia Manufacturing*, *3*, 3025-3032.

Hartwich, F., Witzlack, C., Beggiato, M., & Krems, J. F. (2018). The first impression counts; A combined driving simulator and test track study on the development of trust and acceptance of highly automated driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*, 522-535.

He, J., Tang, Z., Fu, X., Leng, S., Wu, F., Huang, K., … & Xiong, Z. (2019). Cooperative connected autonomous vehicles (CAV): Research, applications and challenges. In *2019 IEEE 27th International Conference on Network Protocols (ICNP)* (pp. 1-6). IEEE.

Hohenberger, C., Spörrle, M., & Welpe, I. M. (2016). How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups. *Transportation Research Part A: Policy and Practice*, *94*, 374-385.

Howard, D., & Dai, D. (2014). Public perceptions of self-driving cars: The case of Berkeley, California. *In Transportation Research Board 93rd Annual Meeting*, *14*, (4502) 1-16.

Jeon, M., Riener, A., Sterkenburg, J., Lee, J. H., Walker, B. N., & Alvarez, I. (2018). An international survey on automated and electric vehicles: Austria, Germany, South Korea, and USA. *In International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management* (pp. 579-587). Springer, Cham, Switzerland.

Kyriakidis, M., Happee, R., & de Winter, J. C. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, 32, 127-140.

Lee, J., Chang, H., & Park, Y. I. (2018). Influencing factors on social acceptance of autonomous vehicles and policy implications. *In Portland International Conference Proceedings on Management of Engineering and Technology* (pp. 1-6). IEEE, New York, USA.

Liljamo, T., Liimatainen, H., & Pöllänen, M. (2018). Attitudes and concerns on automated vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 24-44.

Lustgarten, P., & Le Vine, S. (2018). Public priorities and consumer preference for selected attributes of automated vehicles. *Journal of Modern Transportation*, *26*(1), 72-79.

Montoro, L., Useche, S. A., Alonso, F., Lijarcio, I., Bosó-Seguí, P., & Martí-Belda, A. (2019). Perceived safety and attributed value as predictors of the intention to use autonomous vehicles: A national study with Spanish drivers. *Safety Science*, 120, 865-876.

Morris, D. M., Erno, J. M., & Pilcher, J. J. (2017). Electrodermal response and automation trust during simulated self-driving car use. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting 61* (pp. 1759-1762). SAGE Publications, Los Angeles, US.

Noppers, E. H., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: Driven by symbolic and environmental motives. *Global Environmental Change*, *25*, 52-62.

Pfleging, B., Rang, M., & Broy, N. (2016). Investigating user needs for non-driving related activities during automated driving. *In Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia* (pp. 91-99). ACM, New York, USA.

Qu, W., Xu, J., Ge, Y., Sun, X., & Zhang, K. (2019). Development and validation of a questionnaire to assess public receptivity toward autonomous vehicles and its relation with the traffic safety climate in China. *Accident Analysis & Prevention*,*128*, 78-86.

Regan, M., Cunningham, M., Dixit, V., Horberry, T., Bender, A., Weeratunga, K., & Hassan, A. (2017). Preliminary findings from the first Australian national survey of public opinion about automated and driverless vehicles. *Australia and New Zealand Driverless Vehicle Initiative*, 10.13140/RG.2.2.11446.80967.

Rödel, C., Stadler, S., Meschtscherjakov, A., & Tscheligi, M. (2014). Towards autonomous cars: The effect of autonomy levels on acceptance and user experience. *In Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 1-8). ACM, New York, USA.

SAE International (2018, November 11). SAE International releases updated visual chart for
its "Levels of driving automation" standard for self-driving vehicles. Retrieved from https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles.

Schade, J. & Schlag, B. (2003). Acceptability of urban transport pricing strategies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *6*(1), 45-61.

Schaefer, K. E., Chen, J. Y., Szalma, J. L., & Hancock, P. A. (2016). A meta-analysis of factors influencing the development of trust in automation: Implications for understanding autonomy in future systems. *Human Factors*, *58*(3), 377-400.

Schoettle, B., & Sivak, M. (2014). *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia*. University of Michigan, Ann Arbor, Transportation Research Institute.

Sener, I. N., Zmud, J., & Williams, T. (2019). Measures of baseline intent to use automated vehicles: A case study of Texas cities. *Transportation Research Part F: Traffic Psychology and Behaviour*, *62*, 66-77.

Souders, D., & Charness, N. (2016). Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles. *In International Conference on Human Aspects of IT for the Aged Population* (pp. 428-440). Springer, Cham, Switzerland.

Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic, and affective motives for car use. *Transportation Research Part A: Policy and Practice*, *39*(2-3), 147-162.

Zhang, Q., Wallbridge, C. D., Jones, D. M., & Morgan, P. (2021, July). The blame game: Double standards apply to autonomous vehicle accidents. In *International Conference on Applied Human Factors and Ergonomics* (pp. 308-314). Springer, Cham.

Zmud, J., Sener, I. N., & Wagner, J. (2016). *Consumer acceptance and travel behavior: Impacts of automated vehicles (No. PRC 15-49 F)*. Texas A&M Transportation Institute, USA.

Zoellick, J. C., Kuhlmey, A., Schenk, L., Schindel, D., & Blüher, S. (2019). Amused, accepted, and used? Attitudes and emotions towards automated vehicles, their relationships, and predictive value for usage intention. *Transportation Research Part F: Traffic Psychology and Behaviour*, *65*, 68-78.