Passenger Comfort and Trust on First-time Use of a Shared Autonomous Shuttle Vehicle

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Abstract

Automated Vehicles (AV) may become widely diffused as a road transport technology around the world. However, two conditions of successful adoption of AVs are that they must be synchronously shared, to avoid negative transport network and environmental consequences, and that high levels of public acceptance of the technology must exist. The implications of these two conditions are that travellers must accept sharing rides with unfamiliar others in Shared Automated Vehicles (SAV). Two factors that have been identified as being positive influencers of acceptance are comfort and trust. The present paper undertakes a novel examination as to how comfort and trust ratings are affected by specific attributes of the ride experience of travelling in a fully-automated real-world, shared vehicle. To this end, 55 participants experienced riding in an SAV shuttle under experimental conditions at a test facility. Each experimental run involved two unrelated participants, accompanied by a safety operative and a researcher, undertaking four trips in the SAV, during which two conditions were presented for each of the independent variables of 'direction of face' (forwards/backwards) and 'maximum vehicle speed' (8/16 km/h). Order of presentation was varied between pairs of participants. After each run, participants rated the dependent variables 'trust' and 'comfort' (the latter variable comprised by six comfort factors). Expected and evaluative ratings were also obtained during pre-experimental orientation and debriefing sessions. Statistically significant relationships ($p<.001$) were found between trust and each of the independent variables, but for neither variable in the case of perceived comfort. A strong correlation was found between comfort and trust, interpreted as indicating trust in the SAV as an important predictor of perceived comfort. The before and after-experiment ratings for both variables showed statistically significant increases, and particularly for daily car drivers.

Keywords: Shared Automated Vehicle (SAV); Comfort; Trust; Motion Sickness; User experience; test-track experiment.

1. Introduction

Predicting the market penetration of automation technologies into the road transport sector is complex. Applying a scenario analysis approach, Lyons and Babbar (2017) identified a range of 8-84% for highly and fully automated vehicles (AV) as a share of global new vehicle sales in 2035, with a 'central case' of 25%, assuming rapid technological development and moderate global uptake. More recently, analysing the North American context, Litman (2017) predicts around a 35% share of sales by the same year, with around one-fifth fleet penetration, but accelerating to 50% of fleet composition around 2050. Given the potential scale of change, it is essential that policymakers are able to respond drawing upon a strong evidence base about likely effects and consequences.

Whilst benefits from automation, notably relating to improved road safety, are widely promoted, the prospect of a rapid transition occurring within a laissez-faire policy framework has prompted major concerns about the possible negative consequences of rising demand due to falling user costs. Where a fare is paid, these are expected to fall if driver costs are eliminated, and travel time costs. On the other hand, a real business cost or a perceived personal cost, would fall if people who currently self-drive are able to reinvest travel time on more productive activities (Diels et al., 2017). Simulation demand modelling of such future market contexts has indicated that traffic and congestion in a typical city could double due to cost reductions (International Transport Forum - ITF, 2015), as could energy consumption and greenhouse gas emissions (Wadud et al., 2016). However, many commentators identify that a significant level of *shared* automated mobility could mitigate for the increase in demand (e.g. Fulton et al., 2017; McKinsey, 2016; NACTO, 2016), with the additional personal travel resulting in only modest increases in vehicle traffic and congestion (ITF, 2015), and energy and emissions potentially halved (Wadud et al., 2016).

To achieve this relatively benign adoption scenario for AVs, though, the key condition is that the vehicles must be *synchronously* shared. This distinction is important as the term 'shared' is often vaguely applied in the transport policy discourse. In fact, the assumption present in many visions of 'future mobility' that vehicle sharing will be a significant or dominant phenomenon is mainly based on aspiration or opinion (Parkhurst and Lyons, 2018). Also, it is worth noting that the existing, limited, evidence on willingness to share identifies significant social psychological barriers (Merat et al., 2017). The present paper therefore seeks to contribute to this scarce evidence base through an experimental exploration of factors influencing SAV acceptance.

1.1. Emergence of the SAV concept

The term Shared Automated Vehicle (SAV) is in current usage referring to both (i) a vehicle exclusively used by individual travel parties and subsequently used exclusively by other parties (asynchronous sharing) and (ii) used by more than one individual/group, each of which accepts sharing space in the vehicle for whole or part of the journey with others, who might be acquainted or strangers (synchronous sharing). In this paper we refer exclusively to the latter definition.

Several authors claim SAVs can provide higher benefit than AVs, especially due to the expected reduced need for parking space and reduced congestion (Liu, 2018). However, these benefits depend on the market penetration of SAVs, which is currently estimated considering simulation that might not be realistic (Narayanan et al., 2020). In principle, SAV services could be offered in niches currently served by human-driven taxis, taxi-buses or buses. Whilst, they would tend to compete or replace taxis and taxi-buses, they might either replace or integrate with established fixed route public transport systems (Levin et al., 2019), in which case they might focus on low-demand routes within a network, or provide feeder services to trunk routes, or service low-demand periods of the day (Shen et al., 2018). In the implementations and demonstrations to date, the term 'shuttle' is often applied. The vehicles are typically capable of carrying 4-12 people. However, according to Vosooghi et al (2019) the financially sustainability of a SAV service is strongly correlated to the fleet size, and the benefits of more than 4 seats in SAVs might be limited. Given this relatively low vehicle capacity, the 'business model' will ultimately require full automation to Level 4 capability to be viable, implying no handover to a driver would be necessary within a defined spatial environment (Society of Automotive Engineers International – SAE, 2018) and for operation to be on-demand. Hitherto, the demonstrations in environments with public access have been at slow speeds and on constrained routes. Higher-speed operation would need a significant improvement in technology (e.g. sensors, software), adaptation of the infrastructure, and a clear definition of specific regulations (Schreurs and Steuwer, 2016).

SAVs have been trialled within projects in Europe (e.g. CityMobil1 (2006–2011) and CityMobil2 (2012–2016; WePods in the Netherlands (Liang et al., 2016; Van der Wiel, 2017); Smartshuttle in Switzerland (Eden et al., 2017); EUREF in Berlin-Schöneberg (Nordhoff et al., 2018), in the US (First Transit/Easymile), and in Australia (Navya). As the state of the art is currently one of demonstration projects, rather than full, permanent public services, actual adoption cannot be measured, but factors affecting target users' acceptance have been identified and confirmed. Alessandrini (2016) reported that users of demonstration services in the Citymobil2 project gave high ratings of comfort and safety, although it was observed that the stakes around trust were particularly high: on the one hand due to the radical step of replacing the driver with artificial intelligence and robotics, and on the other, due to the strong claims made about the potential of the technology to transform transport systems by improving road safety, traffic efficiency, air quality, and access to mobility services (Alessandrini et al., 2014). Comfort, can also be expected to influence the ongoing acceptance and adoption of AVs, and this is particularly important in the case of SAVs, due to the presence of other travellers, which will constrain choices about standing/sitting position in the vehicle, as well as potentially bring unfamiliar others into close physical proximity.

However, comfort and trust are very subjective, and so both human factors and people's perceptions become important in understanding how to design new vehicles and transport systems to make them more attractive for potential users. SAV services built around a ridesharing model will rely on social, as well as technical, innovation; that there will be a future willingness amongst travellers to share a small vehicle with strangers, despite the absence of a physical presence of an operative 'in authority', which might actually render synchronous sharing less attractive than it is now. The present paper therefore contributes to enhancing understanding of the perceptions of first-time users of a SAV providing data about acceptance in the context of a test-track environment with Level 4 operation of a four-seat vehicle. Full details of the experiment are given in Section 2. A particular focus was to examine the interactions between trust and comfort, based on these having been identified as key variables in the literature (Siebert et al., 2013; Bellem et al., 2018).

1.2. Trust in Autonomous Vehicles

Whilst the evidence base specifically on SAVs is limited, trust has been widely recognised as an important factor in the acceptance and utilisation of automation across different sectors, as it both depends on people's beliefs toward automation and influences their intention to use it (Carter and Bélanger, 2005; Choi and Ji, 2015; Körber et al., 2018; Gefen et al., 2003; Lee and Moray, 1992, 1994; Lee and See, 2004; McKnight et al., 2002; Merritt and Ilgen, 2008; Noy et al., 2018; Parasuraman et al., 2008; Parasuraman and Riley, 1997; Pavlou, 2003; Shariff et al., 2017; Siebert et al., 2013). According to Du et al. (2019), understanding what kind of factors influence trust in automation is very important for a better understanding of AV use. For this reason, trust has been identified as a key issue for AV acceptance and adoption (Bazilinskyy et al., 2015; Verberne et al., 2012; Bansal et al., 2016; Molnar et al., 2018; Zhang et al., 2019), and according to Morgan et al. (2018), it can be considered "one of the most important enablers (and indeed barriers) to humans adopting and continuing to use new automation technology". However, trust is a subjective factor and depends on the personality of the individual (e.g. differences in the propensity to trust) and sociocultural context (e.g. social norms and expectations) in which the decision to trust takes place (Lee and See, 2004). Notably in the context of the current paper, Molnar et al. (2018) found that people who prefer being a passenger rather than a driver were more accepting of the concept of AVs.

Khastgir et al. (2018:291) adapted the definition provided by Lee and See (2004), defining trust as "a 'history-dependent' attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability". Following Khastgir et al., the inclusion of 'history-dependent' in the previous definition highlights the importance of previous knowledge about the system on trust, as unfamiliarity with AV technology might have a negative impact on public acceptance (Dong et al., 2019). According to Du et al. (2019), increasing the level of information about AVs can reduce potential users' anxiety, increase their trust in AVs and the likelihood that they will exhibit positive attitudes towards AVs. Furthermore, the social learning theory approach assumes that expectations for specific events strongly depend on previous experiences on similar events or situations (Rotter, 1971). This is supported by Gold et al. (2015), Hartwich et al. (2018), and the Venturer Project Partners (2018), who found that participants' self-reported trust in AVs increased after experiencing automated driving across experimental runs in a simulation trial, and by Xu et al. (2018), who found that direct experience increased participants' trust, perceived usefulness, and perceived ease of use ratings towards AVs.

Lee and See (2004) stated that trust in automation is strictly related to "emotions on human-technology interaction", which is a key factor for acceptance, but is also important for safety and performance. For this reason, it should be a factor considered when designing complex, high-consequence systems like AVs. Despite the difference between interpersonal trust and trust in technology, they have some similarities (Hoff and Bashir, 2015). For example, Parasumaran and Riley (1997) suggest people's trust in technology can be considered as being akin to their degree of trust in the designers of technological systems.

Figure 1 presents a summary of the main factors influencing trust that have been identified above. It includes the three main groups identified by Hoff and Bashir (e.g. dispositional trust, situational trust, learned trust), factors related to expectations, personality and emotions of individuals, and finally, external factors like social norms and people's beliefs about AVs. In the context of a SAV, social norms about shared transport-related behaviours are likely to be important, as will be the influence of personality, experience and expectations, and situational and learned trust on an individuals' willingness to share. Age, gender, and culture can be expected to interact with these factors. In the present study, expectations were assumed to be weakly defined, and learned trust low, due to the rareness of exposure to SAVs to date, whilst social norms were expected to be drawn from other travel experiences, but with the norms and expectations about behaviour in an experimental context also having an influence. Some aspects of experience, beliefs and personality were addressed through survey data, whilst the experiment was primarily a test of situational trust.

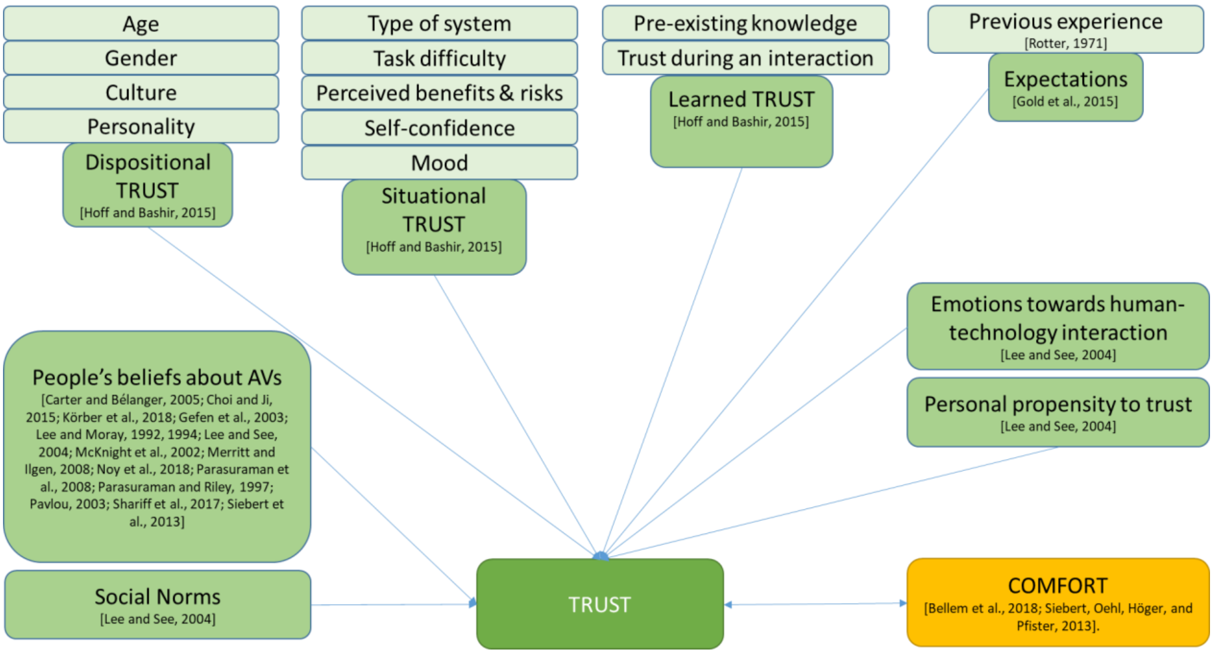


Figure 1. Principal factors influencing trust in AVs.

Figure 1 also shows there is a relationship between trust and comfort. Bellem et al., (2018), citing Siebert et al. (2013), identify a close relationship between comfort and trust in the context of AV acceptance, highlighting the importance of comfort for future implementations of AV services. However, the literature provides little information about this relationship. For this reason, the paper includes a review of the main factors influencing comfort in road transport in the next section, and then in the experimental study addresses the inter-relation of the two concepts.

1.3. *Existing research on road-user comfort*

The literature does not offer a unanimous definition of comfort (Bellem et al., 2018). However, de Looze et al. (2003) identified the most common factors as being: (1) comfort (like trust) is subjective, (2) comfort is influenced by external factors influencing the body and the body's response to those influences (internal), and (3) comfort is experienced as a reaction to something. Comfort in private passenger cars has been important in the literature to date and has focussed on the physical parameters of thermal, acoustic, and vibrational comfort. These in turn take into account a wider set of factors including temperature, noise, humidity, lighting, driving position, and the duration of the exposure to each of these factors (Zuska and Więckowski, 2018). The most important factors that influence comfort perceived by both drivers and passengers have been identified as acceleration and vibration (Eriksson and Friberg, 2000; Lin et al., 2010), with the latter being potentially injurious for humans (Stańczyk and Zuska, 2015), especially at high speeds. Hence, speed has a negative impact on comfort when driving in a car (Uys et al., 2007; Barone et al., 2016) or riding on a bus (Bodini et al., 2014; Barone et al., 2018). The increased vibrations at higher speeds make drivers feel uncomfortable (Hu et al., 2017), and feeling less safe at high speed can lead drivers to reduce speed (Branzi et al., 2017). This suggests speed might have a negative relationship with trust and comfort, at least in some driving conditions. Figure 2 shows the relationship between perceived risk and speed, which has impacts on infra sound, noise and vibrations and an indirect but significant effect on comfort.

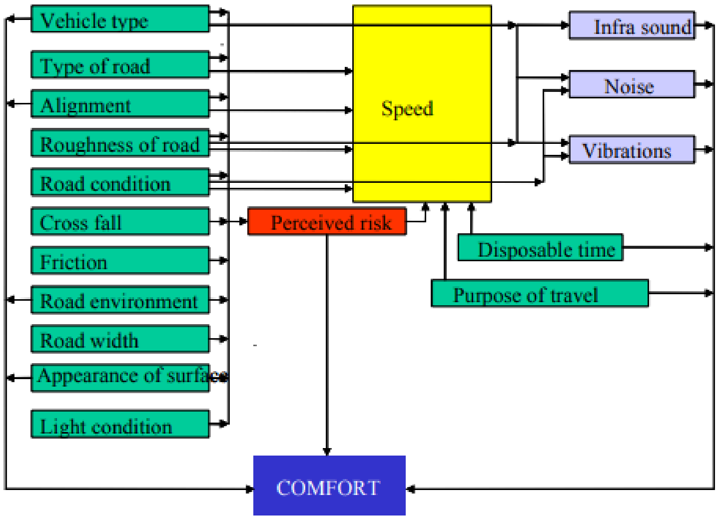


Figure 2. The factors contributing to the ride comfort and their relationship. Source: “Figure 6 by Greg Magnusson VTI” from Ihs (2005).

Within the literature on private car comfort there has been a focus on the driver and the driver’s seat, emphasising the active role of driving within the vehicle, with relatively little concern for passenger comfort (Erol et al., 2014; Bellem et al., 2018), despite passengers not having the cognitive load of the driving task to ‘distract’ them, so their comfort perceptions potentially being more acute. Indeed, this difference in comfort sensitivity has been found in the previous studies which did consider passengers (Tan, 2005; Fitzpatrick et al., 2007), which suggest that car passengers usually experience higher discomfort at lower rates of acceleration than car drivers do, probably because they are involved in different tasks to drivers during the journey. Also, the degree of ‘jerk’, or lack of smooth progress, has been widely recognized as a determinant of passenger comfort (Le Vine et al., 2015; Bellem et al., 2016). Hence, it is argued that a refocus on passenger comfort is important to understand AV acceptance, particularly if considering that an uncertain but potentially large proportion of AV users who would normally have expected to take the role of driver will become passengers.

If a key relevance of the car comfort literature arises due to the aspiration that current car drivers will become SAV passengers, it is nonetheless important to consider the road public transport comfort literature, due to the potential similarities with aspects of the SAV service model, for example, the collective nature of the services, and their need for some form of stops and access management. Comfort has been recognised as an important factor influencing perceived satisfaction with public transport services (Dell’Olio et al., 2011; Fellesson and Friman, 2012; Beirão and Cabral, 2007; Lin et al., 2010). In addition to the above-mentioned factors influencing comfort on cars, comfort on buses can depend on the availability of soft and clean seats, an in-vehicle temperature range identified as pleasant, and a low occupancy factor (Beirão and Cabral, 2007), with crowding increasing perceptions of risk to personal safety and security (Cox et al., 2006; Katz and Rahman, 2010), which can increase anxiety (Cheng, 2010) and stress (Lundberg, 1976; Mohd Mahudin et al., 2011, 2012). It can also cause a feeling of invasion of privacy (Wardman and Whelan, 2011) and possibly ill-health (Cox et al., 2006; Mohd Mahudin et al., 2011).

If the AV passenger experience is likely to be different, research questions emerge as to whether differences in perceived comfort will arise, and more generally, whether the difference in style will be universally welcomed, or whether, for passengers at least, the AV experience will be in conflict with expectations born from habituated experience, for example, experiencing loss of control (Elbanhawi et al., 2015) or being seen as insufficiently assertive. Within the SmartShuttle project carried out in Switzerland, researchers identified positive attitudes towards the use of SAVs. However, many participants affirmed that the low operational speed of the SAV did have a negative impact on other traffic (Eden et al., 2017), highlighting the high importance of speed for a successful SAV implementation. Furthermore, within their project with SAV shuttles in Germany, Nordhoff et al. (2018) found that (low) speed had a negative impact on comfort and acceptance. The relationship between speed, comfort and trust is complex, however, as other studies showed that low speed can be positively appraised because it increases perceived safety (Bekhor et al., 2003; Rodríguez, 2017). At the same time low speed can have a negative impact on users' satisfaction with the experience due to the longer travel and waiting times (Bekhor et al., 2003; Krueger et al., 2016; Nordhoff et al., 2019). The relative influence of these factors will vary according to context, notably whether operating on a shared-space campus environment or on roads with faster-moving traffic, and is likely to change as SAV shuttle competences grow and speeds can increase.

A further specific debate refers to the likely incidence of motion sickness on comfort. Notably, a review published subsequently to the experimentation for the present paper (Iskander et al., 2019) also investigated the factors that can cause 'autonomous carsickness', finding that nausea can have a strong impact on comfort in AVs. Iskander et al. identified passenger-related factors, and vehicle-related components that can be responsible for autonomous carsickness. Among the vehicle-related components, they identified change in vehicle speed and direction (horizontal orientation), together with the levels of vertical vibration and temperature and seat and viewing position, in particular whether it allows visual motion information from outside the vehicle to be perceived. Sivak and Schoettle (2015) observe that the frequency and severity of motion sickness could potentially decrease if self-driving vehicles do indeed provide a smoother ride than conventional vehicles. However, Diels et al. (2016) and Krause et al. (2016) explain that passengers are less able to predict the 'oncoming motion profile' (the expected speed and acceleration/deceleration characteristics typical of a vehicle-driver combination) for a SAV, and so can feel conflicting motion cues when engaged in non-driving tasks (e.g. reading during the journey). Diels et al. (2016) suggest that motion sickness might be experienced by as much as 50%-75% of the population under these conditions. According to Iskander et al. (2019) motion sickness could represent a significant issue with fully automated road travel, as drivers cede control over the motion of their vehicles, and even drivers who never experienced motion sickness before could become susceptible, due to their reduced attention towards the vehicle's motion and progress.

Given the importance of having a view of the oncoming road, it can be expected that being seated travelling facing backwards in a SAV would result in increased incidence of motion sickness and therefore reduced comfort. As considered further in the methodology section below, in the current study eight comfort factors were measured in the experiment, whilst direction of travel/face was a key variable, and nausea was monitored before, during and after the experiment. Subsequent to the experimental work taking place, Nordhoff et al. (2019) reported qualitative findings from shuttle riders in Berlin confirming that being seated backwards was identified as less comfortable.

1.4. Summary of knowledge and knowledge gaps

The need for synchronously-shared mobility services has been identified as a policy imperative for governance of the transition to AVs. An emerging SAV implementation niche is for small-to-medium size vehicles to operate at slow speeds in environments with some regulation over interactions with other users of the space. Some initial findings from SAV demonstration studies note relationships between speed, comfort, and trust, but these are partly an artefact of the limited capabilities of the prototype services and there are some contradictions as to whether greater or lesser speed promotes trust.

The wider literature to date on comfort and trust, some of which in the context of automation more generally, has identified many factors which contribute to driver and passenger ratings, although with an emphasis on the perceptions of car drivers. Trust is strongly subjective in being influenced by individual-experiential factors, although information provision can have a positive influence as an alternative to direct experience, and current passengers were identified as more accepting of road transport automation than drivers. Both comfort and trust are reduced by relatively high-speed travel, with greater vibration being one explanatory factor. Comfort is also subjective, with many influencing factors, but key points for the present analysis are that passengers experience comfort differently from drivers, partly due to their focus of attention and cognitive load, and the difference in automated versus human driving styles will likely affect perceptions, in different ways for different perceivers. Direction of face was implicated as a specific factor influencing comfort in a previous study. Reviews of comfort factors have also predicted that motion-related nausea will be a significant problem in AVs, particularly if passengers do not attend to the oncoming motion profile.

Having identified knowledge gaps, and given the rare opportunity to undertake research with a prototype Level 4 SAV at a closed test site, an experiment was designed primarily to measure trust and comfort perceptions in the context of a social environment of unfamiliar travellers and with the manipulation of two variables identified in the literature (speed and direction of face). In addition, the incidence of nausea was appraised and the ratings of people who mainly travelled in daily life as a car driver, or in another way, were compared. The research opportunity enabled a contribution to the relatively small evidence base of experimental studies using actual vehicles. The experimental design and conduct are explained in the next section, whilst Section 3 presents the results, Section 4 the discussion and Section 5 the conclusions and implications.

2. Methodology

Xu et al. (2018) have argued that the understanding of public acceptance of AVs is over-dependent on online surveys, the participants of which have rarely had any experience with an AV, potentially reducing the validity of the findings. Similarly, the use of simulator studies for user-related research on AVs has advantages and disadvantages in terms of technological limitations (Payre et al., 2017) but, following Xu et al., (2018), for the present study the experience of an actual vehicle was critical to maximising affect-belief-behaviour consistency, and due to the possible differences between trust measurements in the 'safer' environment of a simulator compared with the real world (Gold et al., 2015). The authors were fortunate in having access to an AV through partnership in a consortium project considering the potential 'user cases' for commercially and socially beneficial applications of a specific four-seat electric autonomous vehicle technology.

2.1. Experimental design

The experiment explored the relationships between trust and comfort in SAVs considering three steps in the participants' first interaction with the vehicle: expectations prior to experience, the event of experience itself, and post-experience reflections. Figure 3 shows how the authors explored the relationships between trust and comfort during the different stages of the experiment (i.e. before, during, after).

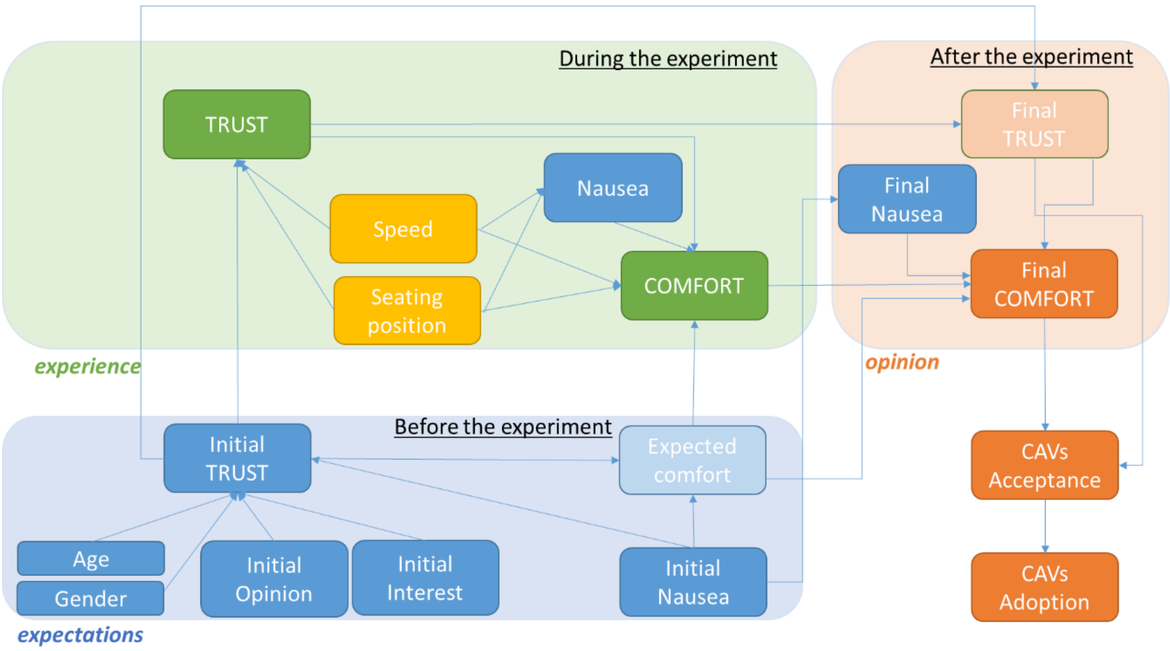


Figure 3. Trust in and Comfort with SAVs: theoretical framework to explain the relationship between *expected* and *experienced comfort* on and *trust* in SAVs.

A within-subjects experimental design was adopted, whilst the experimental conditions were delivered through travel in an actual SAV operating under Level 4 automation (without human driver engagement on the defined route) under conditions which, as far as possible, were controlled.

'Speed of travel' and 'direction of face' were selected as the independent variables. These were two factors identified from the review as potentially influencing the dependent variables trust and/or comfort, and which could be readily manipulated in the experimental context. In addition, the potential for comfort and trust to influence motion sickness was recognised and this was posited as a further dependent variable. Ratings for all three dependent variables were obtained at the three stages of exposure to the SAV.

The experimental hypotheses are presented below and diagrammatically in Figure 4:

H1: Trust ratings would be significantly lower at the higher speed, rather than the lower speed, due to reduced confidence in the operating system's ability to control the vehicle at the higher speed.

H2: Trust ratings would be significantly lower with the rater seated facing backwards, rather than facing forwards, due to the inability of a rear-facing passenger to observe the future path of the vehicle.

H3: Comfort ratings would be significantly lower with the rater seated facing backwards, rather than facing forwards, due to greater presence of negative influences, such as motion sickness.

H4: Comfort ratings would be significantly lower at the higher speed, rather than the lower speed, due to greater cabin movement, acceleration forces on the body and vibration.

H5: Nausea ratings would be significantly higher with the rater seated facing backwards, rather than facing forwards, due to combination of physical and psychological factors.

H6: Nausea ratings would be significantly higher at the higher speed, rather than the lower speed, due to a combination of physical and psychological factors.

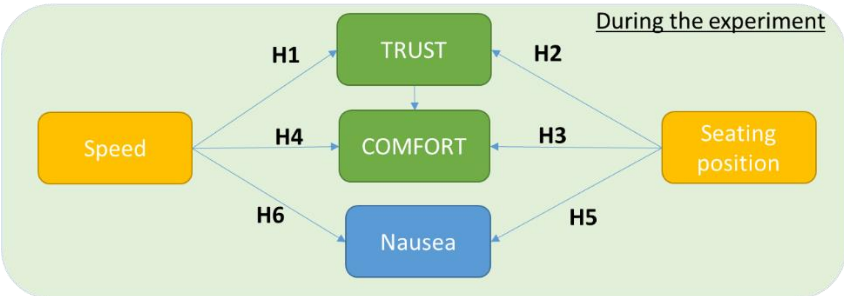


Figure 4. Theoretical framework for trust and comfort during the experiment

2.2. Vehicle and test site characteristics

Figure 5 shows the external aspect of the SAV used in the experiment, the vehicle being an automated development from a guided vehicle used on a transit system at London's Heathrow Airport, and with very similar characteristics to the four-people-capacity SAV considered by Shen et al. (2018) in their study. Features of this vehicle are that two passengers can be seated facing forwards and another two facing backwards (Figure 6), enabling participants' orientations to be varied during the experiment. This configuration is also observed in some other SAV shuttle designs.

Figure 5. Westfield autonomous shuttle vehicle. Photo credit: CAPRI Project.

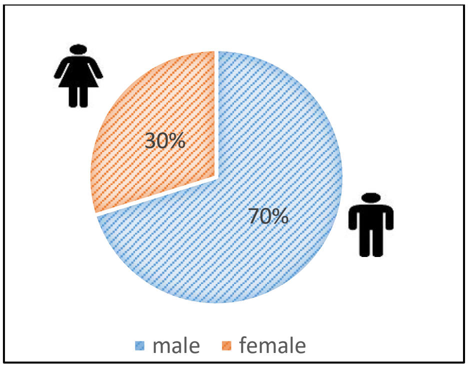
Figure 6. Cutaway of shuttle seating arrangement. Photo credit: Westfield Technology Group.

The test site was a disused airfield surrounded by secure fencing. In the context of a negligible risk of incursions, the research team was able to operate the vehicle at higher speeds than would have been possible in a public demonstration site. As members of the public and the research team would be travelling in the vehicles without safety harnesses, the maximum speed was limited to around 16km/h, but this nonetheless gave the opportunity to test whether, in the real-world, trust ratings might be affected by a doubling in maximum speed, even if only to a modest absolute level.

Sample Recruitment and Characteristics

Fifty-six participants were recruited from the local public, drawing on people who had been involved in social research on the theme of automated vehicles in the past and through public invitations using social media and the university's own recruitment channels. Seventy-seven people applied to take part, with the final selection based on availability for the trial timeslots and promoting inclusion of both genders and a range of ages (although most were in the 35-74 range), and most common mode of transport for daily travel. Seven participants reported some previous experience with automated driving capabilities. None had taken part in a SAV trial or experiment. Participants were paired so that none was related or a friend of the other, and, as far as participant availability allowed, to give a variety of combinations of age and gender. Two recruited participants did not attend the trial as planned; in order to maintain the condition of pairing, a member of the wider project team (but not one of the researchers) took part in the relevant vehicle runs.

Figure 7 reports that somewhat more than two-thirds of the sample was male (69.6%). The average age of participants was 51 years, with a median value of 53 and a mode equal to 67. The most represented age categories are 35-44 years old (21.4%), 55-64 years old (21.4%), and 65-74 years old (26.8%).



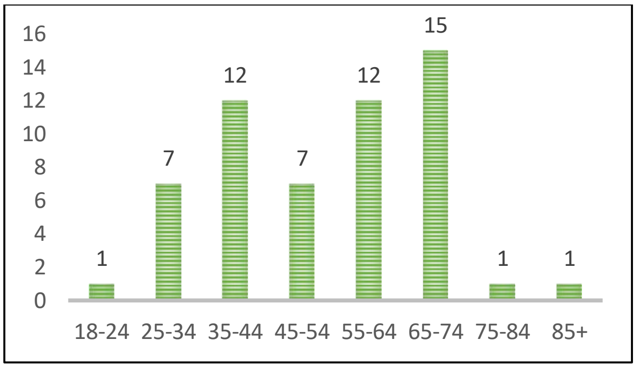


Figure 7. Age and gender of participants

In terms of travel behaviour, the sample had a range of weekly travel experiences. It is worth noting that almost half of the sample (48.2%) identified as a daily car driver, whereas two-thirds walked, including as part of a multimodal journey. Even though cycling has been growing as a mode of transport in the city of XXXX, and some employment sites do exhibit cycling shares for commuting of over a fifth, daily cyclists were somewhat over-represented in the sample with respect to overall travel around the city.

Experimental procedure

The experiment was conducted over three consecutive days (17-19/07/2018). Weather conditions were typical for England in July, with periods of warm sun, sometimes overcast with rain, and low-to-moderate wind speeds.

The experiment was organised in three stages, each lasting approximately 30 minutes. In Stage 1, participants arrived at the airfield and entered an indoors waiting area where they received an induction including information about the project, and health and safety briefing, and were informed about the broad aims of the experiment but without revealing the specific hypotheses under test. In line with ethical procedures (approved by University Research Ethics Committee) consent for participation was established. Pre-experimental questionnaires covering socio-demographic information and attitudes to and experience with new technologies, automation, and AVs in particular, were administered.

In Stage 2, the participant pairs were invited into the AV in the company of the safety steward and a member of the research team, with one participant seated next to the steward, facing forward, and the other seated diagonally opposite, travelling backwards, facing the steward, and next to the researcher. The researcher's role was to observe the experiment and prompt the participants to complete ratings and swap seats between rides. The presence of the steward and the researcher also meant the vehicle was full and each participant was riding with three people he or she had not met prior to the experiment, thereby, within the constraints of the experiment, creating a social context as close to future ridesharing as possible. A vibration monitor and an audio recorder was in operation (with the consent of participants) during each run. The analysis of the data collected is beyond the scope of the current paper but the presence of the audio recorder to some extent mirrors the likely presence of a remote audio-visual connection to a control centre in a future SAV operating model.

The steward and researcher adopted a friendly disposition and responded to participants, but did not proactively seed conversation. When directly asked questions about the automated technology or the experiment they responded, but without entering into detailed explanations, nor disclosing the nature of the hypotheses under test. Participants were often keen to know at what speed they were travelling. Rather than disclose this during the runs, they were informed at the end of Stage 2.

Each pair experienced four runs of a standardised circuit coded into the automated driving system of the AV and performed on the former runway. The circuit incorporated both left and right-hand turning movements and the associated accelerations and decelerations that accompanied those. Each pair experienced two runs at one of the two speeds (8 or 16 km/h), and then two at the other speed. Order of presentation was switched between pairs. After each run participants rated trust in the AV, level of nausea currently perceived, and six comfort attributes (seating, noise, acceleration/deceleration, vibration, temperature, and amount of personal space), all on eleven-point Likert scales. After the first and third runs participants were asked to swap seating positions in order to experience the alternate DoF.

Hence, each run generated eight scores from each participant, and together provided one set each for the four different possible combinations of the two independent variables. Other than a few minor technical issues, the hardware and software operated effectively and consistently throughout the three days of the experiment.

After the four runs, Stage 3 involved the participants returning to the reception area where they completed a final questionnaire about their experiences and were debriefed. The follow-up questionnaire included questions related to overall trust in AVs, nausea and perceived comfort (the 'pre' and 'post' experiment ratings used the same factors and scales as in Stage 2). Questionnaire items at Stage 3 also covered participants' willingness to use SAVs in the future under different use cases (including commuting, shopping trip, airport transfer, hospital appointment).

In accordance with the experiment carried out by Morgan et al. (2018), trust was measured on an 11-point Likert scale ranging from 0 (no trust) to 10 (complete trust). In addition, participants' general trust in automation was investigated through the 'Trust in Automation Checklist (TAC – Jian et al., 2000), a 12-item-questionnaire used to measure trust in autonomous vehicles, with higher scores indicating increased dependability and trust in the system. Comfort and Nausea ratings were also measured using an 11-point Likert scale ranging from 0 (completely uncomfortable/not at all nauseous) to 10 (completely comfortable/completely nauseous). In particular, comfort was measured by considering an adapted version of the 'Comfort Checklist' (Zhang et al., 1996). Internal consistency reliability was measured through Cronbach's alpha (.782), which indicates a high level of internal consistency reliability. All the items showed a Cronbach's alpha value greater than .70, confirming indicator reliability. Convergent validity was also confirmed, as all the average variance extracted (AVE) values were higher than .50 (Fornell and Larcker, 1981). Also, the extracted variance was greater than correlation square, hence discriminant validity was established.

3. Results

This section presents the results of a range of data analyses the authors performed to understand how specific attributes of the experimental exposure affected comfort and trust ratings, and how trust and comfort are related. Subsection 0 describes the approach used to carry out the analysis of the principal hypotheses, and presents the results of the effects of the independent variables 'speed' and 'DoF' on trust, comfort and nausea. Subsection 0 analyses comfort and trust variations with length of exposure to the SAV, and provides a comparison of participants' expectations and valuations before and after the ride. Finally, Subsection 0 presents an analysis according to transport mode most often used for daily routine travel.

Analysis of the Principal Hypotheses

Approach to Data Analysis

Data analysis was performed using IBM SPSS Statistics software. Given the research design, based on the same variables being presented to the same subjects across four conditions, the hypotheses stated in Section **¡Error! No se encuentra el origen de la referencia.** were tested through a two-way repeated measures ANOVA, in order to explore the effects of two independent variables (and the combined effect of these) on specific dependent variables (e.g. trust, comfort, nausea). The two independent variables (speed, DoF) consist of two categorical, independent groups. Observations are independent, as there is no relationship between the observations in each group or between the groups themselves.

Considering the four different combinations of Speed (H: high, L: low) and DoF (B: backwards, F: forwards), there were four dependent combinations of the three dependent variables, which are shown in Table 1.

Table 1. Within-subjects Factors – Dependent and Independent variables

Independent variables		Dependent variables		
Speed	DoF	Trust	Comfort	Nausea
High (H)	Facing Backwards (B)	Trust_B_H	Comfort_B_H	Nausea_B_H
	Facing Forwards (F)	Trust_F_H	Comfort_F_H	Nausea_F_H
Low (L)	Facing Backwards (B)	Trust_B_L	Comfort_B_L	Nausea_B_L
	Facing Forwards (F)	Trust_F_L	Comfort_F_L	Nausea_F_L

Effect of speed and DoF on trust, comfort and nausea

The separate effect of speed (Factor 1) and DoF (Factor 2) on trust, and their combined effect, were analysed to test the hypotheses H1 and H2 (as stated in Section 2). Considering the different combination of the two factors during the four runs, the highest average score for trust was given when participants were travelling at the slower speed facing forwards and the lowest average score when passengers were travelling at the higher speed and facing backwards.

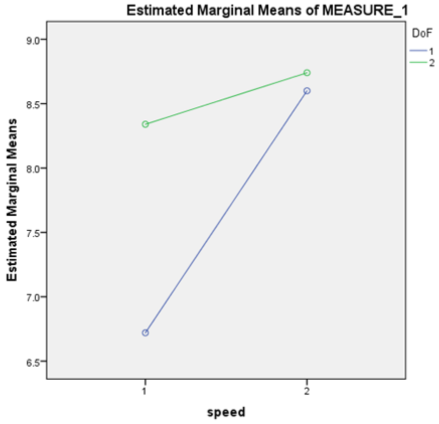


Figure 8. Results for trust (DoF: 1= Backwards; 2= Forwards. Speed: 1=high; 2=low)

Mauchly's Test indicated Sphericity had been violated ($\chi 2$ (0) =0, p=.00), so a Greenhouse-Geisser adjustment was required. The Two-Way repeated Measures (ANOVA) shows there is a significant main effect according to how fast/slow the vehicle was travelling (speed - $F(1)=18.618$, $p<.001$), a significant main effect according to direction of face (DoF - $F(1)=15.390$, $p<.001$), and a significant interaction between these two variables ($F(1)=11.913$, $p<.05$).

According to the results shown in Table 2, participants who face forwards (F) placed more trust in the AV, with a mean value ranging from 8.34 (when travelling at higher speed) to 8.74 (when travelling at lower speed). In general, participants trusted less when they travelled at the higher speed, in whichever direction they were seated. Results from the ANOVA therefore supported both the experimental hypotheses for trust (H1 and H2).

Table 2. Within Subjects Effect - Estimates – Trust

				95% Confidence Interval	
Speed	DoF	M	SE	Lower Bound	Upper Bound
High (H)	Facing Backwards (B)	6.720	.465	5.785	7.655
	Facing Forwards (F)	8.340	.235	7.868	8.812
Low (L)	Facing Backwards (B)	8.600	.183	8.232	8.968
	Facing Forwards (F)	8.740	.169	8.401	9.079

Similarly to trust, the effect of speed (Factor 1) and DoF (Factor 2) on comfort, and their combined effect, were analysed to test hypotheses H3 and H4. As in the case of trust, the highest mean comfort ratings were given when participants had travelled facing forwards at the lower speed (M=6.60; SD=1.498), and the lowest mean comfort ratings when participants were facing forwards at the higher speed (M=6.35; SD=1.983). However, differences between the mean comfort scores for the combined variables were absent or small and not significant, leading to the acceptance of the null hypotheses.

Further Analysis of Trust and Comfort

The following subsections present the findings of further analyses carried out on the core topics of interest using One-Way repeated measures ANOVA for the Stage 2 ratings and a paired t-test of some of the Stage 1 and 3 questionnaire data to compare participant attitudes and ratings before and after riding in the SAV.

Comfort and trust variations with length of exposure to the SAV

The Stage 2 experimental results showed that trust ratings increased between Runs 1 and 2, and again slightly after Run 3, but not Run 4 (Table 3). However, the skewness coefficients are less than two times their standard errors, so the data are not normally distributed. In particular, they are all negative, meaning the data are right-modal distributed (mode is closer to the higher values of the scale), which indicates participants expressed high scores. However, the one-way repeated measures (ANOVA) showed that increased experience did not have a significant effect on trust ($F(1.32)=.375$, $p>.05$).

Table 3. Descriptive statistics for Trust during the four runs

		Trust (run 1)	Trust (run 2)	Trust (run 3)	Trust (run 4)
N	Valid	52	50	51	51
	Missing	4	6	5	5
M		8.19	8.46	8.51	8.47
SD		2.030	1.446	1.515	1.617

Comfort was rated by participants in Stage 2 against the six factors (adapted from Zhang et al., 1996), which included seating, noise, acceleration /deceleration, vibrations, temperature and amount of personal space.

These ratings were then combined to provide an average comfort rating for each run. Only very minor, statistically insignificant differences emerged ($F(1.90)=.229$, $p>.05$) (Table 4).

Table 4. Descriptive statistics for overall "Comfort" during the four runs.

		Comfort (Run 1)	Comfort (Run 2)	Comfort (Run 3)	Comfort (Run 4)
N	Valid	53	53	53	53
	Missing	3	3	3	3
M		6.47	6.50	6.54	6.47
SD		1.479	1.366	1.531	1.597

It is notable that whilst the difference between Run 4 and Run 1 ratings for five of the comfort factors was a small positive (of up to 0.3 scale points), temperature showed a larger negative change of 0.7 scale points (F(1.85)=5.65, p<.05).

Comparison of participant's expectations and valuations before and after riding in the AV

A correlation analysis was performed to compare pre-experimental expectations and final evaluations of comfort, trust and nausea. The results showed a strong, statistically significant relationship between expected comfort and initial trust in AVs (r=.609, p<.001). A weak correlation was found between expected comfort and self-reported nausea prior to the experiment (r=.328, p<.05). There was also a weak correlation between initial trust and nausea before the experiment (r=.295, p<.05).

There was also a strong statistically-significant relationship between the post-experimental ratings of comfort and trust in the AV (r=.622, p<.01). However, unlike the pre-experimental data, comfort and nausea after the runs were not significantly correlated (r=-.250, p>.05).

The correlation analysis also identified interesting relationships between initial trust in the AV and initial opinions (5-point Likert scale – 1 = "Negative" to 5 = "Positive") about AVs (r=.402, p<.001): initial interest in AVs (5-point Likert scale - 1="Not at all interested" to 5="Extremely interested") and trust were found to be correlated (r=.407, p<.001), indicating that people who are more interested in AVs trust more, as do people who have more favourable/positive opinions towards AVs. No correlations between age or gender and comfort or trust or nausea were identified.

The differences in comfort and trust ratings and self-reported nausea before and after the experimental runs were investigated through correlation analysis and paired t-test analysis, with the following being the key findings:

- A moderate correlation (r=.302, p<.05) between expected and final comfort scores, and a statistically significant difference between comfort scores before (M=6.63, SD=1.74) and after (M=7.48, SD=1.59) the experiment (p<.05), t=-3.24, p<.05. These findings suggest participants found the AV shuttle to be somewhat more comfortable in practice than expected (.85 on the rating scale).

- A strong correlation (r=.616, p<.001) between initial and final trust in AVs, and a statistically-significant difference between trust before the experiment (M=6.79, SD=1.89) and trust scores after the experiment (M=7.84, SD=1.79), t=-4.960, p<.001. These findings indicate that participants were more trusting of AVs after the experience of riding in an AV, with the difference amounting to approximately one point on the rating scale.
- A statistically-significant difference between the level of self-reported nausea declared before (M=1.40, SD=2.59) and after (M=.55, SD=1.033) the experiment (t=2.405, p<.05).

Analysis according to use of car as driver for daily routine travel

As discussed in Section 1 where a regular car driver chooses in the future to use a SAV, s/he will cede the active role of driver and adopt the more passive role of passenger. For this reason, we explored, through descriptive and correlational analysis, whether there were any differences in the ratings of trust and comfort between people who reported driving a car every day (48.2% of the sample) and those who did not (being daily car passengers, pedestrians, cyclists, or bus users).

Table 5. Comfort levels reported by daily car drivers and other participants before and after the experimental runs

		Participants who drove a car every day		All other participants	
		Level of comfort expected in AV	Level of comfort reported after AV experience	Level of comfort expected in AV	Level of comfort reported after AV experience
N	Valid	27	27	28	28
	Missing	0	0	0	0
M		6.48	7.70	6.82	7.36
SD		1.929	1.382	1.565	1.747
Skewness		-.647	.013	.068	-.416
SE of Skewness		.448	.448	.411	.441
Minimum		1	5	4	3
Maximum		10	10	10	10

The descriptive statistics for comfort (**¡Error! No se encuentra el origen de la referencia.**) showed that mean expected comfort levels before the experiment were somewhat lower for car drivers (M=6.48; SD=1.93) than for other participants (M=6.82; SD=1.56). Both groups provided higher ratings after the runs, but car driver comfort levels increased by more than a scale-point (M=7.70; SD=1.38), whereas the other participants showed a lower increase (M=7.36; SD=1.75), meaning the positions of the groups reversed, with car drivers reporting higher comfort than the others.

Similar results emerged for trust (**¡Error! No se encuentra el origen de la referencia.**), which was lower for car drivers (M=6.59; SD=1.99) than for the other participants (M=7.00; SD=1.83) before the experiment, but then higher for car drivers (M=8.30; SD=1.73) than the others (M=7.40; SD=1.79) after the experiment.

Table 6. Focus on car drivers. Descriptive statistics - trust rates

		Participants who drove a car every day		All other participants	
		Level of trust in AV's ability to respond to events before experience	Level of trust in AV's ability to respond to events after experience	Level of trust in AV's ability to respond to events before experience	Level of trust in AV's ability to respond to events after experience
N	Valid	27	27	28	28
	Missing	0	0	0	0
M		6.59	8.30	7.00	7.39
SD		1.986	1.728	1.826	1.792
Skewness		-.880	-.642	-1.062	-.810
SE of Skewness		.448	.448	.441	.441
Minimum		1	5	3	3
Maximum		10	10	9	10

Results of the paired t-test for daily car drivers showed a moderate correlation (r=.46, p<.05) between expected and final comfort scores, and statistically significant differences between comfort scores before and after the experiment (t=-3.562, p=.001). In terms of trust before/after the experiment, the correlation is much higher (r=.732, p<.001; t=-6.408; p<.001).

4. Discussion

The section presents a discussion of the results presented in the previous section, structured in the same order of presentation, considering: (1) the impact of 'speed' and 'DoF' on trust and comfort; (2) comfort and trust variations with length of exposure; and (3) participants' expectations and valuations before and after riding in the SAV.

Impact of speed and direction of face on trust and comfort.

Considering the effect of speed and DoF on trust, participants trusted more when facing forwards and when travelling at lower speed. Although the absolute differences in the means between the three conditions other than facing backwards at the higher speed is small, it is notable that a significant effect was found between two operating speeds which were both relatively low (8 and 16km/h). The results for trust are in line with the ones of Bekhor et al. (2003) and Rodríguez (2017) who found that lower speed increased perceived safety, with a positive effect on trust. On the other hand, the results on comfort and nausea, concerning a speed differential cannot be directly related to Nordhoff et al.'s (2019) findings noted above about an absolute low speed being associated with low comfort ratings in a SAV and overall SAV acceptance due to a longer journey time. However, it is important to note that Nordhoff et al.'s (2019) SAV was travelling at an average 8 km/h, similar to the lower speed case in the present study, and based on a qualitative investigation of self-reported experiences. Notably, despite the significantly lower trust ratings at the higher speed, many of the participants in the current study commented to the effect that they preferred the higher speed to the lower speed, using terms such as "boring" and "less pleasant" to describe the experience. There is, then, a tentative finding here for further investigation that travellers 'trade' trust and aspects of comfort, prioritising the psychological need to be making sufficient progress over the desire to feel safe.

Further, if the results of the two-way repeated measure ANOVA for nausea**¡Error! No se encuentra el origen de la referencia.** are considered, there is a significant combined effect of speed and direction of face, whereas the single main effects are not significant. In particular, the highest mean nausea ratings (i.e. meaning a 'more nauseous' feeling) were given when participants were travelling at the lower speed and looking backwards (M=.84; SD=1.56), and the lowest when travelling at the lower speed looking forwards (M=.28; SD=1.18). It must be acknowledged that despite these significant results, the absolute ratings and differences were low, perhaps reflecting the low travel speeds, but the findings do contribute to hitherto small evidence base, supporting the expectation about negative impact of DoF on motion sickness, and corroborating the qualitative finding of Nordhoff et al. (2019). Indeed, we found that travelling facing backwards had a negative effect on all of comfort, nausea and trust. This also supports the propositions of Diels et al. (2016) and Krause et al. (2016), considered in the introduction, that users of highly automated vehicles in general might feel insufficient concordance between motion cues and visual cues due to the inability of predicting the oncoming motion profile. Notably, given the limited direct forward or backwards visibility from the shuttle vehicle, peripheral vision, noted in Iskander et al.'s (2019) review, may have played a key part in the effect. Further research, perhaps with passenger eye-tracking, would be useful to clarify this matter.

As with previous work evaluating trust in AVs and AV simulators (Venturer Project Partners, 2018), no gender and age-related effects were found for comfort or trust. Nordhoff et al. (2018) and Madigan at al. (2016) also did not find any relationship with gender. Both these latter studies did identify age effects, but they are in any case not directly comparable in terms of objectives and methods.

Comfort and trust ratings with length of exposure to the SAV

In terms of length of exposure and trust, ratings increased between Runs 1 and 2, and again slightly after Run 3, but not Run 4. These findings support previous studies (Khastgir et al., 2018; Dong et al., 2019; Gold et al., 2015; Hartwich et al., 2018; Venturer Project Partners, 2018) that identified an increased trust corresponding to increasing experience with AVs. The authors believe more research at higher speeds would be necessary to explore this finding further, especially with highly-automated SAVs, as the previous studies all focussed on AVs more generally.

Important for an investigation particularly of the SAV mode of operation, the highest rating was given to the amount of personal space available, which was found to be 'spacious', even at full occupancy. Given both the compact design of the vehicle and that it was fully occupied by previously unacquainted participants and experimenters, this result was somewhat unexpected and indicates the sample was accepting of the physical constraints of sharing in this particular, managed, context, and concerns about privacy (Wardman and Whelan, 2011) not present. Most participants found the overall experience similar to a journey on a bus. This might be related to the fact that they were sharing with strangers, but also to the absence of seatbelts, which was noted by some. Seatbelts were not a legal requirement for the vehicle in the trial circumstances, but the manufacturer was intending to add them in future. Provision might influence safety perceptions, although it is unclear whether they would allay or heighten such perceptions.

Similarly to trust, comfort ratings in general increased between Run 1 and Run 4, although the findings were not statistically significant. Two negative trends in particular countered this general improvement. First, the shuttle had to circulate with an audible alert sounding for safety reasons. Participants reported this sound as intrusive and annoying, with these feelings growing with length of exposure (e.g. Run1 to Run 4). Whilst electric vehicles increasingly operate with acoustic warnings at low speed, the device used in the experiment was more intrusive within the cabin than it should have been. Second, the rating of temperature decreased from Run 1 to Run 4, and this was the largest change (although excluding temperature from the analysis did not result in the overall comfort rating showing significance). The range in cabin temperature was high across the runs, which reflected the perceived comfort of the in-vehicle temperature changing along with variation of the ambient temperature across the day. This was due to the air conditioning (AC) capability being switched off due to its significant impact on vehicle battery range. Even with charging breaks, it was estimated that it would not be possible with confidence to operate the vehicle for a sufficient number of hours to achieve the target number of runs with participants. AC is relatively rare in the UK outside of large commercial and public buildings, although has recently become available in some local bus services, and is a near-standard feature in most private cars (Anonymous, 2008). Therefore, the decision was taken not to deploy the AC during the trial, which subsequently clearly impacted on the ratings for temperature, evidenced by comments made to the research team that the vehicle was “too hot” and “needs air conditioning”. Notably, though, the conditions were not so extreme that any of the participants exercised the right to terminate their involvement.

In terms of comfort related to acceleration and deceleration, when the AV was changing direction participants reported it as ‘jerky’, ‘abrupt’ and ‘too harsh’. This was more notable at the lower speed. It is worth noting that the software controlling the vehicle was under ongoing refinement and could be somewhat abrupt in terms of acceleration/deceleration and changes in direction. Given the importance of factor such as acceleration, vibration (Eriksson and Friberg, 2000; Lin et al., 2010) and smoothness (Le Vine et al., 2015; Bellem et al., 2016) identified in the introduction, smoother movements in the future resulting from technological refinement might be expected to improve perceived safety and overall trust and comfort (Heiderich et al., 2018). Otherwise, notwithstanding Schreurs and Steuwer’s (2016) suggestion that SAVs intended for higher speeds need to better equipped, at the more modest speeds of this experiment, and an in-vehicle duration of about half an hour, the absolute levels of the comfort ratings suggest that most participants, with the exception of temperature for some, found comfort levels to be satisfactory.

Comparison of participant's expectations and valuations before and after riding in the SAV

The findings of the study show a strong correlation between expected comfort and initial trust in the SAV. This result is consistent with Sielbert et al. (2013)'s highlighting of the relationship between comfort and trust, and their significant importance on AVs acceptance and adoption.

Some participants self-reported initial levels of nausea (before the experiment). These instances may have related to the journey to the test site that had just been made (variously by private car, bus, or cycle), or they may have reflected low-level anxiety about riding in the SAV or taking part in the experiment. This might also explain an important part of the before/after reported nausea, which was found decreased after the experiment (of .85 scale points). Future experimental designs could seek to discriminate between these effects by applying a longer interval between reporting for the experiment and initial ratings.

A partly unexpected finding emerged from the analysis by whether the participant was primarily a car driver or not in everyday life, which highlighted a statistically significant correlation between the before/after comfort and trust levels. As noted in the introduction, Molnar et al. (2018) had identified passengers as likely to be more accepting of AVs than drivers, and our 'before' trust and comfort ratings followed this expectation of reticence. Car drivers presenting for the experiment may have felt more committed to their current mode of transport, or with higher concerns about comfort levels, ceding control, and in-vehicle safety than the other group. At the same time, the greater experience of being a car or bus passenger, so being driven by others in vehicles with differing comfort levels, and sharing with strangers, may have resulted in the 'other' group having more positive and ultimately more stable, perhaps more realistic, expectations. However, the increased 'after' ratings by the driver group, 1.7 mean scale-points in the case of trust, showed them as more accepting than the passengers by the end of the experiment. It may be that factors such as not being in control was less of a concern in practice than it had been identified as being 'in principle', particularly in the context of the test site having had clear safety protocols in place. Nonetheless, with the caveats of the sample size being small and a safety steward being visibly present, it would appear that, similar to the findings of Xu et al. (2018), for novice riders at least, exposure is indeed important for acceptability ratings, and particularly so for car drivers.

4.1 Limitations

The results of this study are subject to a number of limitations. The first one is sampling. The sample size (N=55) was sufficient for the experimental design, but was opportunistically recruited; additional studies are needed to replicate the findings before they can be confidently applied to a wider population. Second, participants come from the same broad city-region, so there may be some geographical specificity in responses. Third, the study also focused on a SAV shuttle vehicle for 'last-mile' applications and the results are not generalisable to all possible forms of future AVs or SAVs. Fourth, the social environment of our 'SAV' was more controlled than a completely 'omnibus' shared service might potentially be. Also, the presence of a safety driver on board might have positively influenced participants' willingness to ride in the SAV (Dong et al., 2019), or at least positively influenced perceptual ratings. Nonetheless, many features of a SAV service were captured, and therefore the findings represent a relevant, early contribution to the knowledge base.

5. Conclusion

The present paper represents a contribution to the literature on AVs and SAVs based on a test-track experiment with a functioning AV, rather than a simulator-based scenario study. Hence the study contributes to the fairly small pool of experiments in which participants experience real AV, recognised as a desirable and needed methodological condition (Molnar et al., 2018).

The literature review highlighted that many factors influence comfort on and trust in AVs, but also the high importance of trust and comfort for AV acceptance and adoption. Two 'operational' factors, speed and DoF, were identified as important for trust and comfort. The experimental analysis not identify a significant effect on comfort, which may reflect the low maximum speed of the experiment, but significant effects were found between both speed and DoF on trust. In the case of speed, the finding was in line with evidence about speed and perceived driving risk (Branzi et al., 2017), even though the highest maximum speed in the present case was modest compared with the service speed of powered road transport modes. The effect due to seating position (DoF) is potentially explained in terms of the inability of a rearwards-facing passenger to observe the future path of the vehicle (Diels et al., 2016; Krause et al., 2016), although it should be observed that the forwards-facing field of vision is also limited within the type of vehicle used in the experiment (Figure 5 and Figure 6), suggesting peripheral observation may have been important for forwards-facing passengers. It remains likely that having a good view of the external environment remains important for trust, even when no-one needs to see forwards for the purposes of driving, perhaps to combat motion sickness, but also to provide feedback information about the safe progress of the journey (Zhang et al., 2019) and making the overall ride experience more comfortable. The findings of the paper also have relevance for vehicle and service designers and developers, in supporting Iskander et al. (2019)'s urging that manufacturers should consider these factors as essential for the acceptability of AVs.

In terms of further comparisons between comfort and trust, strong relationships were found both before and after the test runs. There was also a moderate correlation between comfort and nausea before the experiment (r=.31). No significant differences were found in comfort and trust ratings with length of exposure. The findings support those of Xu et al. (2018) regarding the positive effect of greater exposure to AVs on trust, and also Zhang et al.'s (2019) concerning the role of initial trust as an important predictor of users' attitudes towards AVs, and suggests this could be a key factor in driving users' decision-making in an uncertain environment that implies taking risks. The results of this study also highlighted that there is a strong statistically significant relationship between initial trust and expected comfort, suggesting that people who trust more expect a more pleasant experience in a SAV. Whether transport policy should support SAV development is beyond the scope of the current paper (although see Anonymous, 2018 for a review), but the findings reported suggest that if SAV services are pursued then trust will be a key factor for their successful implementation and so the basis for successful synchronous should be considered in the design of the vehicle and the service.

Lastly, the daily car drivers in the sample initially showed trust and comfort expectations towards riding in an AV that were significantly less favourable compared with those who did not drive every day, but actually became the more favourable group for both variables after the experience. This finding suggests that the current importance the literature gives to the trust and comfort perceptions of car drivers may in fact be well placed in terms of promoting SAVs, given that current drivers are expected to make two major behavioural shifts at once: moving from being driver to passenger, and sharing with strangers, rather than travelling in a private vehicle.

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