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

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Abstract

Many commentators argue that Autonomous Vehicles (AV) will become widely diffused as a road transport technology around the world. Implementation of high levels of automated driving depends on public acceptance of the technology, with comfort and trust being two important influencing factors. Hitherto, the evaluation of comfort and trust during travel in fully-automated real-world road vehicles is large unexplored. The present paper makes a novel contribution through analysing trust and comfort ratings of travel in an AV shuttle vehicle in a test facility. Two unrelated participants, accompanied by a safety operative and a researcher, experienced four runs in the AV during which two conditions were presented for each of the independent variables of 'direction of seat 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. A strong correlation was found between comfort and trust, interpreted as indicating trust in the AV as an important predictor of perceived comfort. Statistically significant relationships ($P<0.001$) were found between trust and each of the independent variables, but for neither variable in the case of perceived comfort. However, the before and after-experiment ratings for both variables showed statistically significant increases, and particularly for daily car drivers. Implications are considered for vehicle design and for policymakers promoting ride-share AVs.

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Keywords: Shared Autonomous Vehicle (SAV); Comfort; Trust; Motion Sickness; User experience; Real world experiment

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1. Introduction

According to Siebert et al. (2013), trust and acceptance of automated or autonomous vehicles (AVs) are important factors to consider when evaluating comfort, which might be a discriminant factor for adoption (Bellem et al., 2018). There is potential (Sivak and Schoettle, 2015) that travelling in AVs will be more comfortable than being driven by a human. If trust is placed in AVs, and riding in them is more comfortable for passengers, overall travel demand might increase, with potential negative consequences for traffic congestion and energy consumption. Such negative outcomes might be mitigated by providing for existing and additional travel demands through shared-use mobility systems (e.g. ride-hailing, ride-sharing, car-pooling, or a combination of these), which are hence seen by many commentators as a solution for an efficient adoption of AVs and the ‘connected’ AV (CAV) (Fulton et al., 2017; McKinsey, 2016; NACTO, 2016). It is therefore important to consider how comfort is likely to be influence the acceptance of CAVs in general, and shared CAVs (SAVs) in particular.

Comfort is usually one of the major aspects when people choose a vehicle to own, or a mobility service, and it is an important factor for competition in the automotive sector (Erol et al., 2014). However, it is a very subjective factor, as it depends on people’s perceptions and experiences (Vink, 2005). One of the factors influencing perceived comfort, particularly in the case of user-acceptance of new technologies and new types of transport service, is the other focus of this paper, trust. In the context of AVs, the stakes around trust are 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). Whilst considerable caution must be applied in predicting the future, particularly where there are significant financial interests (Parkhurst and Lyons, 2018), the study by IHS Markit (2017) is one example of a ‘confident’ prediction; in this case estimating that more than 33 million AVs will be sold worldwide in 2040, increasing substantially from a forecast 51,000 units for the first year of significant volume, seen to be occurring as soon as 2021.

Notably, the IHS Markit predictions relate to private ownership, rather than the shared-use business models some commentators favour for their efficiency advantages (International Transport Forum, 2015). The possible scale and implications of the adoption of Connected Autonomous Vehicles (CAV) reinforce the importance of Diels et al.’s (2017: 3) reminder that “future visions tend to be designed around technologies rather than humans”. For this reason, human factors and people’s perceptions both become important in understanding how to design new vehicles and transport systems to make them more attractive for potential users. CAV services build around a ridesharing model will rely on social, as well as technical, innovation; that there will be a future willingness amongst travelers to share a small vehicle with strangers, despite the absence of a physical presence of an operative ‘in authority’. The present paper contributes to responding to this challenge through analysing reported comfort and trust ratings from first-time users of an autonomous shuttle vehicle, conceived for ride-sharing operation. It begins with a review of comfort and trust in road passenger transport.

1.1. The concept of ‘comfort’ and ‘discomfort’

According to Helander and Zhang (1997), there is a conceptual difference between comfort and discomfort, thus they should be treated as two different topics for discussion. The latter is usually associated with fatigue, pain and restricted circulation, and increases over time. It is usually based on physical factors (Vink, 2005). Conversely, the former is usually related to aesthetics, relaxation, refreshment and wellbeing. It is not time-dependent (Helander and Zhang, 1997) and is mainly related to experience and feelings (Vink, 2005). It is worth noting that comfort might not be experienced in the absence of discomfort, whereas discomfort is a factor which tends to dominate when present.

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 is subjective, (2) comfort is influenced by factors influencing the body (external) and the body’s response to those influences (internal), and (3) comfort is experienced as a reaction to something. Further, eleven different types of comfort related to ergonomics have been identified by Berthelot and Bastien (2009):

- dimensional comfort i.e. the design of the vehicle's components should be in line with the needs of users, e.g. size of components, seats,
- comfort of usage i.e. design of new items/components should reflect considerations of how people would use them,
- contact i.e. measurements of comfort perceived by users when they are in contact with an item, e.g. contact pressure on the seat,
- postural comfort i.e. anthropometry and biomechanics should be considered when designing items to make them comfortable,
- comfort of interaction i.e. the degree of usability of the interface between users and objects,
- eco-design i.e. items should be more sustainable and with lower negative impacts on public health,
- comfort credentials of the chosen materials i.e. non-allergic materials to produce components,
- sensorial comfort i.e. how the user's five senses are activated by the vehicle's components,
- dynamic comfort e.g. level of vibration,
- hydrothermal comfort i.e. humidity and temperature,
- physical environmental comfort i.e. noise, light, space ventilation).

1.2. Existing passenger car comfort research and CAV-user comfort

Generally, the evaluation of in-car comfort considers physical parameters that are measured to assess: (1) thermal comfort; (2) acoustic comfort; and (3) vibrational comfort. These take into account parameters such as temperature, noise, air humidity, lighting, driving position, and the duration of the exposure to each of these factors (Zuska and Więckowski, 2018). In addition to these, the most important factors that influence comfort perceived by drivers and passengers are acceleration and vibration. In particular, the latter has been shown to be injurious for humans when occurring in a frequency spectrum ranging from 0.1 to 100 Hz (Stańczyk and Zuska, 2015). The effect of vibration is even more dangerous at high speeds, being responsible for damage to tyres, rims, shock absorbers, suspension components or brake discs.

Erol et al. (2014) found that visual appearance of vehicle seats had a large and statistically-significant effect on perceived comfort, with greater effect sizes found for females. Much ergonomic research has focused on ensuring the comfort of vehicle seating while at the same time reducing the weight of the vehicle, in order to respond to energy efficiency objectives. However, the studies mainly focused on the driver's seat, supporting the active role of driving within the vehicle, and little research exists on car 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. This difference in comfort perception has been found also in previous studies (Tan, 2005; Fitzpatrick et al., 2007) that suggest car passengers usually experience higher discomfort at lower rates of acceleration than car drivers do, probably because they are involved in other tasks during the journey. Also, 'jerk' has been widely recognized as a determinant of passenger comfort (Le Vine et al., 2005).

Due to comfort being based in part on personal experience, there are some so-called 'soft factors' that influence perceptions: smell, noise and service level (Vink and Hallbeck, 2012). It is unclear how personal experience from established modes of transport might transfer across to a novel vehicle and operating mode, for different individuals.

Another important factor influencing passenger's experienced comfort is the driver's driving style (Bellem et al., 2018). Elander et al. (1993) identified preference for speed, acceleration profiles, individual conditions for overtaking, preferred headway distance, and abiding to traffic laws as key factors defining a person's habitual way of manually driving.

However, autonomous driving systems can be expected to have different driving styles to human drivers, as they are not prone to emotional influences on driving decisions. It is assumed that they will be developed with smoother, more risk-respecting styles than many human drivers exhibit (Chan, 2017). 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 for some the AV passenger experience will be in conflict with expectations born from habituated experience, perhaps as a result being seen as insufficiently assertive.

In addition to the above-mentioned factors, other factors such as how far automated driving is in line with the expectations of travellers habituated to human driving, as well as experiencing loss of control, might influence comfort (Elbanhawi et al., 2015). Other more practical factors might also influence comfort while riding in an automated vehicle. CAVs in communication with the road system (i.e. vehicle-to-vehicle and vehicle-to-infrastructure) might use information to optimise driving to make it more comfortable (Diels et al., 2017). However, according to Payre and Diels (2017), the design of human-machine interfaces becomes very important to avoid or reduce stress due to confusion, distraction or disuse of bad quality displays, which compromise the comfort of the travel experience in AVs.

Also according to Diels et al. (2017), autonomous driving will be more pleasant due to it being smoother and allowing users to undertake other activities during the journey (e.g. relaxing, working, reading, chatting with other passengers), which might increase the level of comfort during the journey. However, some activities that might be carried out during the journey, such as reading, might negatively impact on comfort. Also, users might be more sensitive to some comfort factors like noise, vibration, temperature because they are not involved anymore in a demanding task like driving. According to Diels et al (2016) and Krause et al. (2016) passengers are less able to predict the 'oncoming motion profile' (the speed and acceleration/deceleration characteristics typical of a vehicle-driver combination) for an AV, and so can feel conflicting motion cues when engaged in non-driving tasks (e.g. reading during the journey). Also, users of future transport systems are expected to be less tolerant to the occurrence of motion sickness in automated vehicles compared to other means of transport (Diels et al., 2016). Motion sickness might be experienced by as much as 50%-75% of the population under these conditions. On the other hand, according to Sivak and Schoettle (2005), the frequency and severity of motion sickness could potentially decrease if self-driving vehicles do indeed provide a smoother ride than conventional vehicles.

In terms of the research agenda, an important difference between comfort in or on traditional vehicles and SAVs is that the research to date has focused on investigating drivers' experiences, whereas the latter, for obvious reasons, will focus on passengers, who have not been prioritised until now by research on comfort in cars. According to Diels et al. (2017), this is mainly due to commercial reasons that have pushed the automotive industry to focus more on drivers (e.g. low car occupancy rates of cars, meaning drivers are the key actors worthy of industry attention). Both for this reason, and the fact that some of the business models for CAV services have aspects in common with current public transport operations, research on comfort in cars is not the only appropriate reference, particularly for CAVs in ride-sharing modes. For this reason, we focus next on road public transport.

1.3. Existing collective road transport research and CAV-user comfort

Due to the potential similarities with aspects of the service model, and as they are collective vehicles, the present section considers the main factors influencing comfort on buses. 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), and it is indeed used to evaluate bus service quality. In general, and analogously to cars, the evaluation of comfort on board buses can be considered a very subjective factor as it depends on users' perception and preferences (Eboli et al., 2016). The literature shows that the perceived level of bus comfort varies according to the type of user: generally, regular public transport users perceive greater comfort on board buses than car users, or occasional public transport users, who find buses "uncomfortable, too crowded, smelly and airless" (Beirão and Cabral, 2007). Dell'Olio et al. (2011) found that perception of bus comfort varies with age. In their study, younger bus users put lower values on comfort when they evaluate the quality of bus services. On the other hand, adults and older users consider comfort an important factor, probably because they find it more difficult to stay in uncomfortable positions for long periods. In general, kinematic parameters significantly affect bus users' comfort (Eboli et al., 2016). They are strongly influenced by the driving style/behavior, making ride comfort a strong factor within overall bus passengers' comfort with acceleration/deceleration and vibration being identified in particular (Eriksson and Friberg, 2000; Lin et al., 2010).

Probably the point most relevant for understanding potential comfort on board SAVs is that passengers can relax and spend their time doing other activities (e.g. reading a book or a newspaper), as they are not involved in driving tasks. In the study carried out by Beirão and Cabral (2007), participants identified the fact of not driving whilst on public transport as an advantage compared with driving a car. However, this strongly depends on comfort attributes, such as availability of soft and clean seats on a bus, temperatures identified as pleasant, and a low occupancy factor. In particular, discomfort due to crowding is not only related to having to stand or to share a limited space in a crowded environment, but also because it can increase 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). Tirachini et al. (2013) identify crowding discomfort as likely to arise when four or five passengers share one square metre on a bus or train. However, for many travellers personal space is likely to be reduced below preferred levels well before that density. For this reason, crowding and the amount of personal space will be critical factors to consider when designing SAV services and vehicles to appeal to all travellers, including those with private transport options.

However, whilst the 'system operator' case for Shared Autonomous Vehicles (SAV) is clear, a convincing 'user-case' for sharing remains to be expounded, in particular explaining why significant numbers of time-poor, relatively wealthy travellers would accept longer travel times, sharing a small vehicle with strangers, in return for paying a somewhat lower fare (Parkhurst and Lyons, 2018). Nonetheless, if we allow that significant socioeconomic change may be possible, and SAVs do develop into a significant market niche, Diels et al. (2017) argues that there are four main factors influencing comfort on SAVs (and indeed these would also apply to exclusively-used CAVs):

- Loss of control, which will be transferred from the human driver to the car system;
- Coexistence – the need for AVs to share space with other road users (e.g. conventional vehicles, pedestrians, cyclists), particularly during the transition period from AVs, making acceptance more difficult;
- Moving environment, e.g. low speed (urban traffic) versus high speed (motorway traffic), as the type of traffic (e.g. long distances at constant speed) might influence the biomechanical response of the vehicle occupant and the perceived comfort;
- User expectations about activities which might be possible within a CAV, but which currently remain untested propositions by proponents of the technology.

1.4. Trust in Autonomous Vehicles

Bellem et al., (2018), citing Siebert, Oehl, Höger, and Pfister (2013), identify a close relationship between comfort and trust in the context of AV acceptance. Trust has been widely recognised as an important factor in the acceptance 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; Gefen et al., 2003; Lee and Moray, 1992, 1994; Lee and See, 2004; Parasuraman et al., 2008; Pavlou, 2003; Siebert et al., 2013; Choi and Ji, 2015). 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".

Different definitions of trust have been provided by several researchers (Hoff and Bashir, 2015). According to Lee and See (2004) 'trust' is a subjective factor that depends on individual (e.g. differences on the propensity to trust, which influence the initial level of trust), organisational (e.g. other people's opinion on trustworthiness), and cultural (e.g. social norms and expectations) context. They defined trust as "the attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability". 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), who found that participants' self-reported trust in automation increased after experiencing automated driving in a simulation trial. 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 it is also important for safety and performance. For this reason, it should be a factor to consider 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, according to Parasumaran and Riley (1997), people's trust in technology can be considered as their trust in the designers of technological systems. Marsh and Dibben (2003) defined a three-layered framework for conceptualising trust variability, which considers: (1) dispositional trust, individual's tendency to trust in automation; (2) situational trust, which depends on the specific context of interaction; and (3) learned trust, which is strongly related to past experience with automated systems. Based on this framework, Hoff and Bashir (2015) carried out a literature review on trust in automation, identifying the main factors that influence the three-layers of trust:

- Dispositional trust: culture, age, gender, and personality
- Situational trust: external (e.g. type of system, task difficulty, perceived benefits and risks) and internal (e.g. self-confidence, subject matter expertise, mood) factors;
- Learned trust: initial learned (e.g. pre-existing knowledge) and dynamic learned (e.g. trust during an interaction).

However, despite the relevance of the work carried out by Hoff and Bashir to AVs in general, it is focused on the transition period, with Level 3 automated vehicles; situations which imply that human intervention is still required or possible. Little experimental research on trust under high levels of automation (Level 4 or Level 5) has been carried out, due to the complexity of estimating trust in a simulated environment, as the final design of future fully-automated AVs is not available yet, and there are not many real-world trials with Level 5 AVs (Gold et al., 2015). However, some key results of the study of Hoff and Bashir can reasonably be extended to Level 5 automated vehicles; they pointed out that the complexity of automation and the novelty of the situation are the main factors influencing trust and reliance.

Another important factor that seems to influence trust ratings is the 'familiarity' with AVs. For example, mean trust ratings have been shown to increase across experimental runs (Venturer Project Partners, 2018), meaning that length of exposure might represent an important factor. Further research on the influence of exposure on trust was a factor examined in the research reported in this paper, alongside measurements of the influence of travel speed and seating position on trust and comfort.

In summary, research to date on comfort and trust has identified many factors which contribute to driver and passenger ratings, although with an emphasis on the experience of car drivers. However, existing research on comfort and trust in AVs is almost exclusively based on simulator studies. Hence, key objectives of the research reported in the present paper were to understand whether some of these factors also had discriminatory value on the context of AV travel, and to build the evidence base of real-world studies. The remainder of the paper is organised as follows: Section 2 describes the design and conduct of the experiment; Section 3 presents the results in respect of four hypothesis, while Section 4 considers further analyses of the dependent variables. Finally, Section 5 provides conclusions, considerations of limitations and implications for designers and policymakers.

2. Experiment

The authors were part of a project team considering the potential 'user cases' for commercially and socially beneficial applications of a specific four-seat electric autonomous vehicle technology (Figure 1), the vehicle being a development of a vehicle type in use on a guided transit system at London's Heathrow Airport. Features of this vehicle are that two passengers can be seated facing forwards and another two facing backwards (Figure 2). This configuration is also observed in some other CAV shuttle designs. The literature review did not explicitly identify that direction of face (DoF) as influencing comfort ratings in a CAV, as no studies on DoF in electric shuffle vehicles (automated, guided, or human-driven) were identified, although the range of factors identified as influencing comfort suggested it might. However, from the researchers own experiences, it is quite common for some travellers on all kinds of transport vehicles to express a preference for being seated facing towards the direction of travel, for reasons of travel comfort. Hence, the authors were interested to identify whether DoF would influence comfort ratings, in a context in which the driving style would be automated.

Figure 1. Westfield Capri autonomous shuttle vehicle

Figure 2. Shuttle seating arrangement

Hitherto, small electric CAV shuttle vehicles have mainly been deployed in demonstration projects, and in spaces in which motor vehicles are other not present or carefully managed. Due either to explicit sharing of space with pedestrians and cyclists, or the risk that they might encroach on the space reserved for the CAV, speeds are kept low; typically to a fast walking pace of 8km/h. These precautions reflect the early stage of development of the technologies, and the ambition of operating in entirely automated mode, albeit with a safety operative present and ready to halt the vehicle. In the case of the research reported for the present paper, however, the authors had access to a CAV operating on 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 a higher speed than typical for shared space. As members of the public and the research team would be travelling in the vehicles, 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. Although according to Le Vine et al. (2015), 20 miles per hour (32km/h) can be considered a 'comfortable' speed in a traditional car, otherwise the literature offered little by means of direct, relevant evidence on trust, speed and CAVS.

Having clarified these two knowledge gaps, an experiment was designed to test the following hypotheses:

- H1: Trust ratings would be significantly lower at the higher speed 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 seated facing backwards 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 when the rater is seated facing backwards 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 than the lower speed due to greater cabin movement, acceleration forces on the body and vibration.

Based on the above hypotheses, trust and comfort were identified as dependent variables and speed and DoF as independent variables (Table 1).

Table 1. Independent variables (factors) and related categories.

Independent variable	Category 1	Category 2
Speed	Fast (S1)	Slow (S2)
Direction of Face	Facing backwards (D1)	Facing forwards (D2)

2.1. Experimental procedure

The experiment was conducted over three consecutive days (17-19/07/2018) on the disused Filton Airfield, Bristol (UK), and involved fifty-seven participants who undertook the procedure as pairs allocated by the research team. Age and gender were mixed as far as possible once participant availability constraints had been resolved. Weather conditions were typical for southern England in July, with periods of warm sun, sometimes overcast with rain, and low-to-moderate wind speeds.

The experiment was organised in 3 stages; each lasted approximately 30 minutes.

Stage 1: Participants arrived at Filton Airfield and entered an interior 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 under reference FET.18.05.051) 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, facing backwards towards 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 at the appropriate moment. 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 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, so at the end of Stage 2 they were asked to provide their own estimates and were informed about the actual maximum speed.

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 circuits were not a simple 'oval' but instead 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 ten-point Likert scales. After the first and third runs participants were asked to swap seating positions in order to experience the alternate DoF (forwards or backwards).

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).

2.2. Characteristics of the Sample

Something more than two-thirds of the sample was male (70.2%). The average age of participants was 51 years old, with a median value of 53 years old and a mode equal to 67 years old. The most represented age categories are 35-44 years old (22.8%) and 65-74 years old (28.1%) - Figure 3.

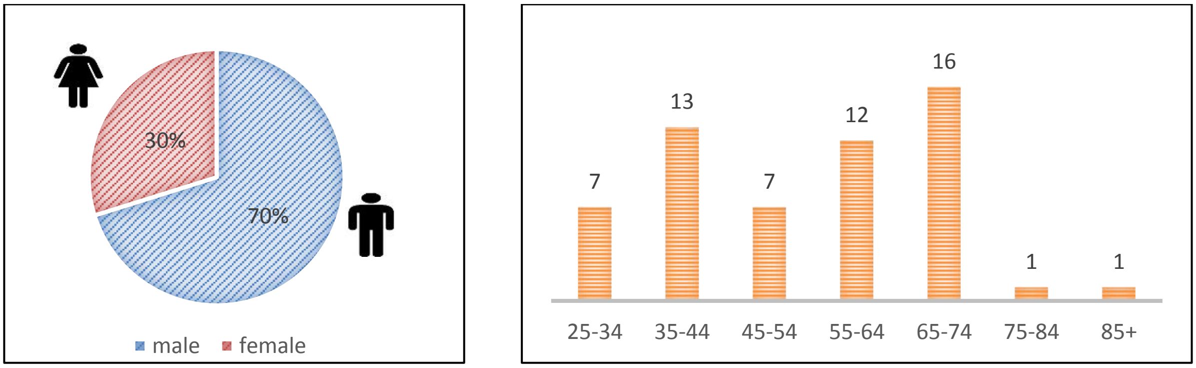

Figure 3. Age and gender of participants

In terms of travel behaviour, the sample had a range of weekly travel experiences, as reported in Table 2. It is worth noting that almost half of sample (47.4%) identified as a daily car driver, whereas most 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 Bristol, 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.

Table 2. "How often do you use each of the following means of transport for URBAN journeys?"

Frequency	Walking	Cycling	Bus	Train	Taxi or mini-cab	Car/Van (as driver)	Car/Van (as passenger)
Daily	38	13	8	1	0	27	6
	66.7%	22.8%	14%	1.8%	0%	47.4%	10.5%
Weekly	14	6	8	6	3	23	25
	24.6%	10.5%	14%	10.5%	5.3%	40.4%	43.9%

3. Analysis of the Principal Hypotheses

3.1. Approach to Data Analysis

Given the research design, based on the same variables being presented to the same subjects across four conditions, the hypotheses stated in Section 2 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.

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 (S1: faster, S2: slower) and DoF (D1: backwards, D2: forwards), there were four dependent combinations of the two dependent variables, which are shown in Table 3.

Table 3. Within-subjects Factors – Dependent and Independent variables

Independent variables		Dependent variables		
Speed	DoF	Trust	Comfort	Nausea
1	1	Trust_D1_S1	Comfort_D1_S1	Nausea_D1_S1
	2	Trust_D2_S1	Comfort_D2_S1	Nausea_D1_S2
2	1	Trsut_D1_S2	Comfort_D1_S2	Nausea_D2_S1
	2	Trust_D2_S2	Comfort_D2_S2	Nausea_D2_S2

3.2. Effect of speed and DoF on trust

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 2.1). Considering the different combination of the two factors during the four runs, the highest average score for trust is given when participants are travelling at a slower speed facing forwards; on the other hand, the lowest average score is given when passengers are travelling at higher speed and facing backwards (Table 4).

Table 4. Within Subjects effect - Descriptive statistics – Trust (N=52)

Dependent Variable	M	SD
Trust_D1_S1	6.67	3.353
Trust_D2_S1	8.35	1.655
Trust_D1_S2	8.56	1.290
Trust_D2_S2	8.77	1.182

Mauchly's Test indicated Sphericity has been violated ($\chi 2$ (0) =0, p=0.00), 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 - $F(1)=19.213$, $p<.05$), a significant main effect according to direction of face (DoF - $F(1)=17.729$, $p<.05$), and a significant interaction between these two variables ($F(1)=12.081$, $p<.05$). Results are shown in Table 5.

Table 5. Within Subjects effect - F values - Trust

Factor	df	MS	F	Sig.
Speed	1.000	69.231	19.213	.000
DoF	1.000	46.173	17.729	.000
Speed*DoF	1.000	27.769	12.081	.001

According the estimates in Table 6, participants who face forwards (D2) placed more trust in the AV, with a mean value ranging from 8.35 (when travelling at higher speed) to 8.77 (when travelling at lower speed). In general, participants trusted less when they travelled at the higher speed, in whichever direction they were seated, although trust when travelling at the higher speed facing backwards (8.35) was lower than trust when travelling at lower speed facing forwards (8.56). Hence, results from the ANOVA therefore supported both the experimental hypotheses for trust (H1 and H2). Although the absolute differences in the means between the three conditions other than facing backwards at the higher speed (6.67) is small, the operating speeds were also both relatively low, and it is notable that a significant effect was found with a maximum speed of 16km/h.

Table 6. Within Subjects Effect - Estimates - Trust

				95% Confidence Interval	
Speed	DoF	M	SE	Lower Bound	Upper Bound
1	1	6.673	.465	5.740	7.607
	2	8.346	.230	7.885	8.807
2	1	8.558	.179	8.199	8.917
	2	8.769	.164	8.440	9.098

3.3. Effect of speed and DoF on comfort

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 speed, the highest mean comfort ratings were given when participants had travelled facing forwards at the lower speed, and the lowest mean comfort ratings when participants were facing forwards at the higher speed. 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 (Table 7).

Table 7. Within Subjects effect - Descriptive statistics – Comfort (N=57)

Dependent Variable	M	SD
Comfort_D1_S1	6.51	1.525
Comfort_D2_S1	6.35	1.950
Comfort_D1_S2	6.51	1.692
Comfort_D2_S2	6.60	1.474

However, considering the sample, the estimated marginal means (Table 8) show that the mean values are much closer to each other. In general, participants feel more comfortable travelling at higher speeds, or when they travel facing forwards at higher speed (6.596). It is worth noting that values are much closer to each other for comfort than for trust.

Table 8. Within Subjects Effect - Estimates - Comfort

Speed	DoF	M	SE	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	6.509	.202	6.104	6.913
	2	6.351	.258	5.833	6.868
2	1	6.509	.224	6.060	6.958
	2	6.596	.195	6.205	6.988

4. Further Analysis of Trust and Comfort

The following subsections present the findings of further analysis 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 AV.

4.1. Comfort and trust variations with length of exposure to the AV

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 9). 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 ($F(1.38)=0.511$, $p>.05$). Therefore the findings are consistent with the first run being associated with slight anxiety about the experience, but already after two runs in the AV trust scores are more favourable. However, given the small differences, more research and higher speeds would be necessary to explore this further.

Table 9. Descriptive statistics for "Trust" during the four runs

		Trust (run 1)	Trust (run 2)	Trust (run 3)	Trust (run 4)
N	Valid	54	52	53	53
	Missing	3	5	4	4
M		8.19	8.46	8.51	8.51
Mode		8	10	10	10
SD		1.991	1.448	1.514	1.601

Comfort was rated by participants in Stage 2 against the six factors shown in Table 10.

Table 10. Mean values (M) and Standard Deviation (SD) of comfort during the four runs

		Seating	Noise	Acceleration & Deceleration	Vibrations	Temperature	Amount of personal space
Run 1	M	7.33	6.12	6.00	5.72	5.84	7.70
	SD	1.940	1.871	2.220	1.925	2.404	2.053
Run 2	M	7.42 ↑	6.09 ↓	6.04 ↑	5.89 ↑	5.58 ↓	7.72 ↑
	SD	1.861	1.796	2.044	1.875	2.352	2.016
Run 3	M	7.47 ↑	6.26 ↑	6.09 ↑	5.98 ↑	5.44 ↓	7.77 ↑
	SD	1.853	1.837	2.190	1.950	2.479	1.852
Run 4	M	7.44 ↓	6.20 ↓	6.30 ↑	5.91 ↓	5.16 ↓	7.80 ↑
	SD	1.832	1.843	1.908	1.985	2.724	1.958

These ratings were then combined to provide an average comfort rating for each run. Only very minor, statistically insignificant differences emerged ($F(1.96)=0.108$, $p>.05$) (Table 11).

Table 11. Descriptive statistics for overall "Comfort" during the four runs.

		Comfort (Run 1)	Comfort (Run 2)	Comfort (Run 3)	Comfort (Run 4)
N	Valid	57	57	57	57
	Missing	0	0	0	0
M		6.45	6.46	6.50	6.45
Mode		8	5a	6a	8
SD		1.458	1.355	1.503	1.587

However, 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. Also, the dispersion of the temperature data was highest (SD = 2.37) which likely reflects the perceived comfort of the in-vehicle temperature changing along with variation of the ambient temperature across the day. In contrast, the highest rating was given to personal space. Given the compact design of the vehicle this result was not confidently expected, given that the vehicle was full occupied by previously unacquainted participants and experimenters.

Air conditioning (AC) is relatively rare in the UK outside of large commercial and public buildings, and was not traditionally a comfort feature of road public transport services, although has seen growing application alongside the rise of AC fitted as a standard feature on most private car models produced for a global marketplace (Parkhurst & Parnaby, 2008). The Westfield AV does have an AC capability, but its use has a significant impact on the battery range of the vehicle. 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 participants. 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. Although the experimental context represented an intensive operating environment, it is notable that modelling scenarios for urban SAV fleets assume very intense utilization (e.g. International Transport Forum, 2015), emphasizing that further developments in vehicle design are necessary before electric SAV operations are a realistic proposition.

Notably, if temperature is excluded from the calculation of overall comfort, the ratings increase across the runs with a pattern similar to that for trust, although the differences are not significant ($F(1.64)=1.227$, $p>.05$). The absolute levels of the comfort ratings suggest that most participants, with the exception of temperature for some, found comfort levels to be satisfactory for an in-vehicle duration of about half an hour.

4.2. 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 ($r=0.614$, $p<.001$). A weak correlation was found between expected comfort and self-reported nausea prior to the experiment ($r=0.337$, $p<.05$). There was also a weak correlation between initial trust and nausea before the experiment ($r=0.304$, $p<.05$) and interest in AVs ($r=-0.303$, $p<.05$). It may be that the low levels of self-reported nausea related to the journey to the location of the experiment that had just been made (variously by private car, bus, or cycle), or reflected low-level anxiety about riding in the AV or taking part in the experiment.

There was also a strong statistically significant relationship between the post-experimental ratings of comfort of and trust in the AV ($r=0.622$, $p<.01$). However, unlike the pre-experimental data, comfort and nausea after the runs were not significantly correlated ($r=-0.262$, $p>.05$).

The correlation analysis also identified interesting relationships between initial trust in the AV and initial opinions about AVs ($r=0.391$, $p<.001$) and initial interest in AVs ($r=-0.303$, $p<.05$). The findings suggest that people who have favourable/positive opinions towards and a high interest in AVs tend to trust them more.

No correlations between age or gender and comfort or trust were identified.

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

A moderate correlation (r=0.304, p<.05) was found between expected and final comfort scores, and a statistically significant difference between comfort scores before (M=6.65, SD=1.74) and after (M=7.49, SD=1.58) the experiment (p<.05), t=-3.24, p<.05. These findings suggest participants found AVs to be more somewhat more comfortable in practice than expected (0.8 on the rating scale).
There was a strong correlation (r=0.615, 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=1.77), t=-4.942, p<.001. These findings suggest 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 was identified between the level of self-reported nausea declared before (M=1.41, SD=2.56) and after (M=0.66, SD=1.34) the experiment (t=2.059, p<.05). As the vehicle movement itself would be more likely to promote nausea than reduce it, the reduction (of 0.8 scale points) perhaps supports the explanation that the low levels of pre-experimental nausea were anxiety-related. However, in this case the correlation of values before and after the experiment was not statistically significant.

4.3. Focus on car drivers

The literature review (Section 1) highlighted that previous research has mainly focused on car drivers rather than car passengers when investigating comfort. However, in the new era of SAVs, the current car driver will lose the active role, moving to a more passive role of passenger. For this reason, we explored descriptive and correlational analysis whether there were any differences in rates of trust and comfort between people who reported driving a car every day (47.4% of the sample) and those who did not (being daily car passengers, pedestrians, cyclists, or bus users).

Table 12. 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	29	29
	Missing	0	0	0	0
M		6.48	7.70	6.86	7.38
SD		1.929	1.382	1.552	1.720
Skewness		-.647	.013	.000	-.459
SE of Skewness		.448	.448	.434	.434
Minimum		1	5	4	3
Maximum		10	10	10	10

The descriptive statistics for comfort (Table 12) 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=6.86; SD=1.55). 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=7.38; SD=1.72) meaning the positions of the groups reversed, with car drivers reporting higher comfort than the others..

Similar results emerged for trust (Table 13), which was lower for car drivers (M=6.59; SD=1.99) than for the other participants (M=7.03; SD=1.80) before the experiment, but then higher for car drivers (M=8.30; SD=1.73) than the others (M=7.41; SD=1.76) after the experiment.

The finding may reflect car drivers being more committed to their current mode of transport, or having higher concerns for comfort levels and in-vehicle safety than the other group. Alternatively, greater experience of being a car or bus passenger, so being driven by others in vehicles with differing comfort levels may have resulted in the ‘other’ group having more positive, realistic, and stable expectations.

Table 13. 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	29	29
	Missing	0	0	0	0
M		6.59	8.30	7.03	7.41
SD		1.986	1.728	1.802	1.763
Skewness		-.880	-.642	-1.116	-.855
SE of Skewness		.448	.448	.434	.434
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 ($r=.732$, $p<.001$; $t=-6.408$; $p<.001$). This is an interesting result, as it shows that car drivers more reticent towards AVs prior to experiencing the ride, but showed a 1.7 mean scale-point increase towards trust in the ‘after’ rating, even though the technology experienced was not yet in public service. It may be that factors such as not being in control was less of a concern in practice than in principle.

With the caveats of a small sample size and a safety steward being visibly present, it would appear that for novice riders at least, exposure is indeed important for acceptability ratings, and particularly so for car drivers.

5. Conclusion

The present paper represents one of few contributions so far to the literature on AVs and SAVs based on a real-world experiment, rather than simulator-based scenario study. The AV was capable of fully automated driving within a defined environment, so represented a high level of technological development, but one not yet in public operation. Participants, who had a high level of interest in CAVs, but had not experienced riding in an AV shuttle vehicle before, experienced the vehicle in ‘shared use’ mode for around half an hour in which four experimental runs were undertaken. To our knowledge the research represents an early test of public reactions to the social and physiological conditions of a small SAV vehicle environment.

The sample size (N=57) 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. The study also focused on an AV shuttle ‘pod’ vehicle for ‘last-mile’ applications and the results are likely not directly generalisable to all possible forms of future CAVs. Also, the social environment of our ‘SAV’ was more controlled than a completely ‘omnibus’ shared service might potentially be. Nonetheless, many features or such a service were captured, and therefore the findings represent a relevant, early contribution to the knowledge base.

The study found significant effects of travel speed and DoF on trust, even though the highest maximum speed was modest, compared with the service speed of powered road transport modes. The effect due to seating position are 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.

On the other hand, speed and DoF did not have any significant effect on comfort, despite the association of facing backwards with motion sickness. This may reflect the low maximum speed of the experiment.

In terms of comparison between comfort and trust, strong relationships were found both before and after. There was also a moderate correlation between comfort and nausea before the experiment (r=0.31). No significant differences were found in comfort and trust ratings with length of exposure. 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.

Lastly, the daily car drivers in our sample showed significantly less favourable trust and comfort expectations towards riding in an AV compared with those who did not drive every day, but actually became the more favourable group for both variables after the experience. This provisionary finding is potentially important given the importance the literature gives to trust and comfort and the focus previous work has had on car drivers.

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References

Alessandrini, A., Cattivera, A., Holguin, C., Stam, D., 2014. CityMobil2: challenges and opportunities of fully automated mobility. In Road Vehicle Automation (pp. 169-184). Springer, Cham.

Beirão, G., Cabral, J. S., 2007. Understanding attitudes towards public transport and private car: A qualitative study. Transport policy, 14(6), 478-489.

Bellem, H., Thiel, B., Schrauf, M., Krems, J. F., 2018. Comfort in automated driving: An analysis of preferences for different automated driving styles and their dependence on personality traits. Transportation research part F: traffic psychology and behaviour, 55, 90-100.

Berthelot, S., Bastien, J. M. C., 2009. The contribution of ergonomics to the design of product: an application to airplane passenger seats. ERGODESIGNFORUM (8-10 June 2009, Lyon, France).

Carter, L., Bélanger, F., 2005. The utilization of e-government services: Citizen trust, innovation and acceptance factors. Information Systems Journal, 15, 5–25

Chan, C. Y., 2017. Advancements, prospects, and impacts of automated driving systems. International journal of transportation science and technology, , 6(3), 208-216.

Cheng, Y.-H., 2010. Exploring passenger anxiety associated with train travel. Transportation 37 (6), 875–896

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

Cox, T., Houdmont, J., Griffiths, A., 2006. Rail passenger crowding, stress, health and safety in Britain. Transportation Research Part A: Policy and Practice 40 (3), 244–258.

de Looze, M. P., Kuijt-Evers, L. F. M., van Dieën, J., 2003. Sitting comfort and discomfort and the relationships with objective measures. Ergonomics, 46(10), 985–997. https://doi.org/10.1080/0014013031000121977.

Dell'Olio, L., Ibeas, A., Cecin, P., 2011. The quality of service desired by public transport users. Transport Policy, 18(1), 217-227.

Diels, C., Bos, J. E., Hottelart, K., Reilhac, P., 2016. Motion sickness in automated vehicles: the elephant in the room. In Road Vehicle Automation 3 (pp. 121-129). Springer, Cham.

Diels, C., Erol, T., Kukova, M., Wasser, J., Cieslak, M., Payre, W., Miglani, A., Mansfield, N. J., Hodder, S.G., Bos, J., 2017. Designing for comfort in shared and automated vehicles (SAV): a conceptual framework. Available at: https://dspace.lboro.ac.uk/2134/25572

Eboli, L., Mazzulla, G., Pungillo, G., 2016. Measuring bus comfort levels by using acceleration instantaneous values. Transportation research procedia, 18, 27-34.

Elander, J., West, R. J., and French, D. J., 1993. Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. Psychological Bulletin, 113(2), 279–294.

Elbanhawi, M., Simic, M., and Jazar, R., 2015. In the passenger seat: Investigating ride comfort measures in autonomous cars. IEEE Intelligent Transportation

Eriksson, P., Friberg, O., 2000. Ride comfort optimization of a city bus. Structural and multidisciplinary optimization, 20(1), 67-75.

Erol, T., Diels, C., Shippen, J., Richards, D., and Johnson, C., 2014. Effects of Appearance on the Perceived Comfort of Automotive Seats. Advances in Ergonomics In Design, Usability & Special Populations: Part II, 17, 115.

Fellesson, M., Friman, M., 2012, February. Perceived satisfaction with public transport service in nine European cities. In Journal of the Transportation Research Forum (Vol. 47, No. 3).

Fitzpatrick, K., Zimmerman, K., Bligh, R., Chrysler, S., Blasche, B., 2007. Criteria for High Design Speed Facilities. Texas Transportation Institute Report #0- 5544-1. Prepared for Texas Department of Transportation.

Fulton, L., Mason, J., Meroux, D., 2017. Three revolutions in urban transportation: How to achieve the full potential of vehicle electrification, automation, and shared mobility in urban transportation systems around the world by 2050 (No. STEPS-2050). Available at: https://www.itdp.org/2017/05/03/3rs-in-urban-transport/ [Accessed: 16/10/2018]

Gefen, D., Karahanna, E., Straub, D. W., 2003. Trust and TAM in online shopping: An integrated model. MIS Quarterly, 27, 51–90.

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.

Helander, M. G., and Zhang, L., 1997. Field studies of comfort and discomfort in sitting. Ergonomics, 40(9), 895-915.

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

IHS Markit, 2017. Reinventing the Wheel: The future of cars, oil, chemicals, and electric power. An IHS Markit multiclient study (September 2017). Available at: https://cdn.ihs.com/www/pdf/Reinventing-the-Wheel-2017.pdf?utm_campaign=pc9712&utm_medium=organic-social&utm_source=energyblog. [Accessed: 15/10/2018].

International Transport Forum, 2015. Urban Mobility System Upgrade: How Shared Self-driving Cars Could Change City Traffic. ITF/OECD, Paris.

Katz, D., Rahman, M.M., 2010. Levels of overcrowding in bus system of Dhaka, Bangladesh. Transportation Research Record 2143, 85–91.

Kolich, M., 2008. A conceptual framework proposed to formalize the scientific investigation of automobile seat comfort. Applied Ergonomics, 39(1), 15-27.

Krause, M., Henel, J., Bengler, K., 2016. Performance and Behavior of a Codriver When Using a Mobile Device. In 62. Kongress der Gesellschaft für Arbeitswissenschaft, Germany, Aachen.

Le Vine, S., Zolfaghari, A., Polak, J., 2015. Autonomous cars: The tension between occupant experience and intersection capacity. Transportation Research Part C: Emerging Technologies, 52, 1-14.

Lee, J., Moray, N., 1992. Trust, control strategies and allocation of function in human-machine systems. Ergonomics, 35(10), 1243–1270. https://doi.org/10.1080/00140139208967392.

Lee, J. D. Moray, N., 1994. Trust, self-confidence, and operators' adaptation to automation. International Journal of Human–Computer Studies, 40, 153–184.

Lee, J. D., See, K. A., 2004. Trust in automation: Designing for appropriate reliance. Human Factors, 46(1), 50–80.

Lin, C. Y., Chen, L. J., Chen, Y. Y., Lee, W. C., 2010. A comfort measuring system for public transportation systems using participatory phone sensing. ACM PhoneSense.

Lundberg, U., 1976. Urban commuting: crowdedness and catecholamine excretion. Journal of Human Stress 2 (3), 26–36.

Marsh, S., Dibben, M. R., 2003. The role of trust in information science and technology. Annual Review of Information Science and Technology, 37(1), 465-498.

McKinsey, 2016. Automotive revolution – perspective towards 2030. How the convergence of disruptive technology-driven trends could transform the auto industry. Available at: https://www.mckinsey.com/~/media/mckinsey/industries/high%20tech/our%20insights/disruptive%20trends%20that%20will%20transform%20the%20auto%20industry/auto%202030%20report%20jan%202016.ashx [Accessed: 21/09/2018].

Mohd Mahudin, N.D., Cox, T., Griffiths, A., 2011. Modelling the spillover effects of rail passenger crowding on individual well being and organisational behaviour. In: Pratelli, A., Brebbia, C.A. (Eds.), Urban Transport XVII, Urban Transport and the Environment in the 21st Century. WIT Transactions on The Built Environment, WIT Press, pp. 227–238.

Mohd Mahudin, N.D., Cox, T., Griffiths, A., 2012. Measuring rail passenger crowding: scale development and psychometric properties. Transportation Research Part F 15 (1), 38–51.

Morgan, P. L., Williams, C., Flower, J., Alford, C., Parkin, J., 2018. Trust in an autonomously driven simulator and vehicle performing maneuvers at a T-junction with and without other vehicles. In International Conference on Applied Human Factors and Ergonomics (pp. 363-375). Springer, Cham.

National Association of City Transportation Officials, 2016. NACTO Policy Statement on Automated Vehicles. Available at: https://nacto.org/wp-content/uploads/2016/06/NACTO-Policy-Automated-Vehicles-201606.pdf [Accessed: 01/10/2018]

Parasuraman, R., Riley, V., 1997. Humans and automation: Use, misuse, disuse, abuse. Human factors, 39(2), 230-253.

Parasuraman, R., Sheridan, T. B., Wickens, C. D., 2008. Situation awareness, mental workload, and trust in automation: Viable, empirically supported cognitive engineering constructs. Journal of Cognitive Engineering and Decision Making, 2, 140–160.

Parkhurst, G., Lyons, G., 2018. The many assumptions about self-driving cars – Where are we heading and who is in the driving seat? In: The 16th Annual Transport Practitioners' Meeting, Oxford, England, 5 - 6 July 2018. Available from: http://eprints.uwe.ac.uk/36997

Parkhurst, G., Parnaby, R., (2008). Growth in mobile air conditioning: a socio-technical research agenda. Building Research & Information, 36 (4), 351-362.

Pavlou, P. A., 2003. Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. International Journal of Electronic Commerce, 7, 101–134.

Payre, W., Diels, C., 2017. Human-Machine Interface Design Development for Connected and Cooperative Vehicle Features. 8th International Conference on Applied Human Factors and Ergonomics (AHFE 2017), 17-21 July, Los Angeles, CA, US.

Rotter, J. B., 1971. Generalized expectancies for interpersonal trust. American Psychologist, 26, 443–452.

Siebert, F. W., Oehl, M., Höger, R., Pfister, H.-R., 2013. Discomfort in automated driving: The disco-scale. In Communications in computer and information science. Hci international 2013 – Posters' extended abstracts: International conference (Vol. 374, pp. 337–341). Berlin: Springer. https://doi.org/10.1007/978-3-642-39476-8_69.

Sivak, M., Schoettle, B., 2015. Motion sickness in self-driving vehicles.

Stańczyk, T. L., Zuska, A., 2015. Application of anthropodynamic dummies for evaluating the impact of vehicle seat vibrations upon human body. Journal of Theoretical and Applied Mechanics, 53.

Tan, C., 2005. An Investigation of Comfortable Lateral Acceleration on Horizontal Curves. Doctoral Thesis, Pennsylvania State University.

Tirachini, A., Hensher, D. A., Rose, J. M., 2013. Crowding in public transport systems: effects on users, operation and implications for the estimation of demand. Transportation research part A: policy and practice, 53, 36-52.

VENTURER Venturer Project Partners. Trial 3: Interactions between Autonomous Vehicles and Pedestrians and Cyclists, 2018. Available at: https://www.venturer-cars.com/wp-content/uploads/2018/06/VENTURER-Trial-3-Participant-Experiments-Technical-Report.pdf. Accessed: 23/10/2018.

Vink, P., 2005. Comfort and design: principles and good practice. Boca Raton. FL: CLC Press.

Vink, P., Hallbeck, S., 2012. Comfort and discomfort studies demonstrate the need for a new model. Applied Ergonomics, 43(2), 271-276. doi: https://doi.org/10.1016/j.apergo.2011.06.001

Wardman, M., Whelan, G., 2011. Twenty years of rail crowding valuation studies: evidence and lessons from British experience. Transport reviews, 31(3), 379-398.

Zuska, A., Więckowski, D., 2018. The impact of unbalanced wheels and vehicle speed on driving comfort. In Automotive Safety, 2018 XI International Science-Technical Conference (pp. 1-6). IEEE.