A Simulator Study on Car User's Perceptions in Interaction with Autonomous Shuttles

Sagar Meda[1][a], Mario Ilic[2][b], Tanja Niels[2][c] and Eftychios Papapanagiotou[1][d]
[1] *Professorship for Intelligent, Multimodal Transport Systems, UniBwM, Neubiberg, Germany*
[2] *Chair of Traffic Engineering and Control, TUM, Munich, Germany*

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Abstract: This study integrates a driving simulator and microscopic traffic simulation tool to evaluate the impact of autonomous shuttles on driving behavior and safety in a university campus environment. Two scenarios were developed: one featuring a conventional shuttle and another with an autonomous shuttle, allowing a direct comparison of driver perceptions under identical conditions. Results show that perceived safety was higher for conventional shuttles (Mean: 5.909) compared to autonomous shuttles (Mean: 2.818), while stress levels remained consistent across both scenarios. These findings highlight critical human factors and challenges in integrating autonomous shuttles, offering empirical insights into their behavioral and safety implications in mixed-traffic environments.

1 INTRODUCTION

Technological advancements have significantly improved road and vehicle safety systems in recent decades, enhancing the overall safety and driving experience. However, human errors still hold a larger share of the causes of an accident. Accidents caused by human error continue to be a significant problem, resulting in serious injuries, fatalities, and substantial financial losses despite traffic laws and awareness efforts. A study by National Highway Traffic Safety Administration (2017) found that 94% to 96% of all vehicle accidents are due to human errors.

Human errors can result from various factors, such as driving while distracted or intoxicated, speeding, acting recklessly, lack of awareness and traffic law violations. Accidents are more likely to occur when the driver's focus is distracted from the road by activities like eating, using in-car entertainment systems, or talking on the phone. Similar to this, driving while intoxicated increases the likelihood of accidents by impairing judgment, coordination, and response times. Speeding is a common cause of accidents because it impairs a driver's capacity to react appropriately to unforeseen circumstances. Lack of awareness and education due to the introduction of new mobility options such as Autonomous Vehicles (AVs) also raises the risk and probability of accidents. A systemic approach is necessary for mitigating the issue of road safety and accidents caused by human error. This entails further research into the psychological and behaviour components of driving, improved education and awareness campaigns, and enforcing stricter regulations. Furthermore, by making up for human error and limitations, technological developments in vehicle technology, like advanced driver-assistance systems (ADAS), detection sensors and autonomous driving systems, can contribute to a safer driving environment, which potentially reduces road accidents and their related external costs.

AVs are one such option; they have already been driven on public roads. It has been observed that they adhere to local laws and traffic restrictions. Moreover, a study conducted by Bartneck et al. (2021) found that although the average human driver was seen to be driving at 70 Miles per hour (113 Kilometers per hour) on the Atlanta freeway, autonomous cars were found to be travelling below the posted limits. Thus realizing the benefits hosted by such mobility options. Further, the AVs possess superiority up to a certain extent based on the ability of the vehicle to perform any task under varying conditions.

However, the emergence of AVs could complicate the urban environment to an unprecedented degree, presenting both advantages and challenges for

[a] https://orcid.org/0009-0006-9227-8596
[b] https://orcid.org/0000-0003-2457-698X
[c] https://orcid.org/0000-0002-8530-0285
[d] https://orcid.org/0000-0002-8538-0326

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the modern world. The interaction between an autonomous vehicle and a conventional driver can be uncertain at times, and this might have an impact on driving dynamics and human perception abilities to a certain degree. Therefore, the increasing number of cities across the world should be innovative in the integration of intelligent mobility solutions into the existing urban traffic environment that would bgeable to meet the population's demands for efficient, safe, and sustainable transportation.

The study area considered for this study is the campus of the University of the Bundeswehr Munich (Universität der Bundeswehr München), situated in Neubiberg, Munich, Germany. It spans approximately 350 acres and plans to introduce an autonomous shuttle into the campus mobility ecosystem. While this initiative can significantly reduce environmental degradation, it also alters key behavioral, psychological, and human factors of driving. These factors include perceived safety, perceived stress, perception of the driving environment, and driver confidence, all of which are often challenging to conventional drivers. Therefore, the research questions of the paper are as follows: 1) To what extent does the introduction of autonomous shuttles in the study area impact human factors such as perceived safety, stress, perception, and driver confidence? 2) What is the quantitative relationship between perceived safety and perceived stress, and how does perceived safety influence driver stress levels?

This paper begins with a comprehensive literature review, followed by a detailed methodology outlining the data collection, experimental design, simulator setup, applied methods, and software used. The results and discussion present key findings in relation to the study's objectives. Finally, the conclusion offers an overall outlook and limitations of the study and suggests potential areas for future research.

2 LITERATURE REVIEW

The following sections will introduce key topics relevant to this study. The first sub-section introduces road safety and the leading causes of traffic accidents due to human errors. Further, the discussion will delve into the influence of autonomous shuttles on conventional driving behaviour and dynamics, with a particular emphasis on how these shuttles affect car driver's perceptions of safety and stress. In the final section, the use of driving simulators to study these behavioural shifts will be explored.

2.1 Road Safety and Accidents

The awareness of the traffic environment is vital; human factors, such as general perception of the surroundings, stress level, perception of safety, and confidence have a critical influence on a safer driving environment. Research by Sayed et al. (2022) emphasized the influence of environmental conditions and the importance of education and training to attain awareness. Study findings showed that a challenging traffic environment induces high-stress levels and increases driving errors. Further, points out that young male drivers have a low perception of risk correlating to accident rates.

Similarly, Xiao (2020) demonstrated that demographic factors, specifically age and gender, have a crucial role in influencing accident rates, largely due to differences in perception accuracy. Notably, Table 1 depicts various human factors as a cause of accidents. 90% of road fatalities out of 1.19 million incidents are seen in low and middle-income countries, primarily due to a lack of appropriate education, training and awareness (World Health Organization, 2023a). Additionally, Lee and Winston (2016) underscored that drivers experience heightened stress levels in situations where they feel a lack of control or low perception of safety and also highlighted behavioural implications, such as abrupt braking or quick lane change in response to increased stress levels.

2.2 Autonomous Shuttles

Autonomous shuttles possess numerous advantages in contrast to conventional buses, especially in metropolitan areas. A study by Bucchiarone et al. (2020) suggested that they could promote shared and integrated transportation, improve tourism experiences, and offer last-mile deliveries. In addition, Giese and Klein (2005) illustrated that these shuttles are an integral part of Intelligent Transportation Systems (ITS), which combines on-demand scheduling, cost-effective techniques and efficient usage of resources. Intelligent autonomous shuttles are able to transport a small amount of goods or a small group of passengers on their own. They can also independently navigate a passive track system and make decentralized operational decisions (Giese and Klein, 2005).

Further, Bucchiarone et al. (2020) emphasized how autonomous shuttles, specifically when deployed in designated lanes, have the potential to increase road safety, decrease emissions, and improve traffic efficiency. The case study results highlighted the potential of autonomous shuttles to serve hard-to-reach areas such as city centers, corporate headquarters, and

Table 1: Global Road Accident Data by Human Error Factors.

Human Error Factor	Key Statistics	Source
Limited Awareness	Globally, road traffic fatalities reach approximately 1.19 million annually, with human error, mainly perception and recognition failures, accounting for about 41% of incidents.	(World Health Organization, 2023a)
Stress Level	Limited perceived safety in environments with larger vehicles, intersections, and close-following traffic can increase stress, elevating heart rates and anxiety, which are linked to error-prone driving behaviors.	(Magaña et al., 2020; Tavakoli et al., 2023; Lee and Winston, 2016)
Distracted Driving	Distracted driving accounts for approximately 8-10% of global road fatalities, with a high prevalence of mobile phone use.	(World Health Organization, 2023a)
Speeding	Nearly 30% of global traffic deaths are attributed to speeding; each 1% speed increase raises fatality risk by 4%.	(World Health Organization, 2023c)
Fatigued Driving	Fatigue-related crashes cause significant global fatalities; fatigue equates to a 0.08% BAC impairment level.	(World Health Organization and National Sleep Foundation, 2023)
Impaired Driving (Alcohol/Drugs)	Driving under influence increases crash fatality risk up to 5x; alcohol impairment is a factor in around 15-20% of global fatalities.	(World Health Organization, 2023b)

hospitals, where traditional buses may face limitations and the potential possibility that autonomous shuttles will completely change urban transportation (Bucchiarone et al., 2020). However, Iclodean et al. (2020) pointed out the necessity to consider some of the legal frameworks and social aspects following the widespread use of autonomous driving as a public transportation method associated with it (Iclodean et al., 2020).

Nevertheless, there are still knowledge gaps about the usage of such newer mobility options. The lack of availability of a driver or an operator inside the vehicle might raise trust-related questions and show a low acceptance compared to conventional human-driven vehicles. Research by Aramrattana et al. (2022) found that when sharing the road with autonomous shuttles, several notable adaptations have been observed. First, drivers tend to adjust their following distance, often reducing the time gap during on-ramp scenarios but increasing it on highways when driving near autonomous vehicles (AVs). Furthermore, lane-changing frequency decreases, suggesting that conventional drivers become more conservative when driving alongside AVs. Similarly, a reduction in overall speed has also been observed (Aramrattana et al., 2022).

2.3 Simulator Studies

Driving simulators are crucial for many reasons, and they have great significance in research, training, testing, and decision-making concerning traffic actions. Simulators help to build models closer to reality and perform various experiments in a safe and controlled manner. A key advantage of driving simulator studies lies in their cost-efficiency compared to real-world vehicle testing. Physical vehicle testing often demands substantial expenses, particularly as vehicles may require tuning or modifications to suit each scenario. Since research typically encompasses multiple scenarios, incorporating various sets of test vehicles for each is not cost-effective. Moreover, conventional vehicles may not consistently perform as intended within controlled conditions, adding further complexity to accurate scenario-based testing. Additionally, there is a possibility for unlimited iterations without damaging or disturbing infrastructure and traffic flow. Wang et al. (2007) reviewed seven aspects in a study, which include driving behaviour studies, driver education and training, transportation infrastructure, medicine and therapy, ergonomics, intelligent transportation system, and administrative method and these aspects have been evaluated efficiently with the help of a driving simulator. Additionally, in therapy and medicine, driving simulators are used to evaluate and rehabilitate people with driving-related disabilities (Wang et al., 2007). Another study by Santiago-Chaparro et al. (2011) offered valuable insights into road safety audits using driving simulators. It proposes conceptual procedures to speed up and enhance safety audits by introducing programming and other software extensions that can significantly reduce time. However, this cannot be applied globally due to a factor called simulator sickness (Santiago-Chaparro et al., 2011).

Simulator sickness is an essential consideration in any simulator study. Symptoms caused by motion sickness include nausea, dizziness, headache and disorientation, which impact the participant's health. Ethical and legal considerations are necessary, and a comfortable experimental design must be modelled to minimize Simulator sickness. Numerous researchers refer to simulator sickness with different terms. For instance, Brown et al. (2022) calls it cybersickness, and Kennedy et al. (1993) terms it simulator sickness. Likewise, this study will make use of the term simulator sickness. When participants feel unwell or uncomfortable during the study, they might choose to leave, posing challenges in keeping them engaged for the duration of the research. Additionally, such unpleasant experiences can reduce their enthusiasm and willingness to participate, impact travel behaviour significantly and engagement levels within the study, and raise concerns about data quality and reliability. The cause of simulator sickness is still debated, and many hypotheses and theories have been discussed.

2.4 Research Gap and Contribution of this Study

Evaluating changes in driving dynamics and analysing the variations with human factors are pivotal for the integration of autonomous shuttles, which host many advantages over conventional options in the existing ecosystem. However, it is necessary to understand its impact and the fundamental changes required to accommodate such mobility options.

Garus et al. (2022) supports the fact that new mobility solutions are transforming road transportation, such as autonomous vehicles and have the potential to impact travel behaviour significantly. The researcher further points out that it is challenging to incorporate these changes into traditional models. The degree to which behavioural changes are taken into account determines how well the existing models perform (Garus et al., 2022).

Additionally, the experimental design should be optimized to eliminate any potential redundancy, ensuring maximum efficiency and precision in the data collection process. A study by Gold et al. (2018) proposed a taxonomy for testing scenarios in human factors research of Level 3 automated vehicles. Further, a study by Calvi et al. (2022) highlighted how spatial constraints, such as road layout, affect driving behaviour. For instance, in tighter spaces or areas with reduced lanes (e.g., from three lanes to one), the driver's behaviour shifts dramatically when following autonomous vehicles. Similarly, the study emphasized that traffic volume and spatial conditions are critical in the assessment of behavioural changes (Calvi et al., 2022)

In summary, this paper attempts to critically examine the impact of autonomous shuttles on conventional car drivers, considering human factors and their psychological dimension along with identifying relative behavioural changes. Further, the research seeks to have a closer view of some of these critical voids by focusing specifically on driver's perceptions concerning the new mobility option in the study area, as this will seemingly provide new knowledge and empirical facts to the field of ITS.

3 METHODOLOGY

This section discusses the overall design of the experiment. As mentioned earlier, the study aims to examine the impact of the introduction of autonomous shuttles on the driving behaviours of conventional car users in the study area. A static driving simulator and a qualitative survey questionnaire have been incorporated to investigate changes in the psychological responses of conventional car drivers when verbally informed about the presence of an autonomous shuttle in one of the scenarios. The survey was designed to comprehend traditional car driver's perspectives and readiness to drive with such mobility options. The results obtained by the qualitative survey were statistically analyzed to obtain cumulative and final results from all the test subjects.

3.1 Study Procedure

In this subsection, specific hypotheses of interest will be presented along with the design of the experiment to validate or discard the presented hypotheses.

The first hypothesis (H1) states that the presence of an autonomous shuttle in the study area environment will influence the physiological and behavioural aspects of conventional car users. Similarly, the second (H2) emphasises that perceived safety directly contributes to the levels of perceived stress in drivers.

The design of the experiment integrated a static simulator into this study to provide an immersive driving experience as shown in Figure 1, portrays a virtual environment of the study area that has been designed and developed using OpenDrive (Association for Standardization of Automation and Measuring Systems (ASAM), 2024) data to build a transportation network and related infrastructure. This data was gathered from an earlier survey conducted in 2015 by a private surveyor named *3D Mapping Solutions*.

Figure 1: Virtual Environment.

Similarly, traffic data has been collected and incorporated into the experimental design. The study area includes a camera-based traffic data collection system to collect and capture traffic statistics. Cameras have been installed in various locations on the campus to capture the movements of all vehicles and traffic participants. These cameras are installed at major intersections, entry-exit points, and other hot spots on campus.

Further, Figure 2 depicts the simulation unit incorporated in the study and Figure 3 illustrates the different software and tools employed in the design, such as DYNA4; it provides a platform to handle, access, modify and perform the experiment, further offers model configuration and scenario management to create, import or export models and attributes of Vehicle under Test (VuT) (Vector Informatik GmbH, 2024b). Similarly, CANoe is a versatile and essential software interface; it provides a thorough framework for creating, evaluating, and optimizing electronic control units (ECUs) and the complex network connections seen in automobiles. CANoe handles mechanical aspects of the simulator, which includes collision counter detection (Vector Informatik GmbH, 2024a). Likewise, Matlab (The MathWorks, Inc., 2024a) and Simulink (The MathWorks, Inc., 2024b) are core parts of the simulation setup that support CANoe operations in the background. The block models required to control the vehicle performance and simulator configurations were provided and handled with Simulink. Another powerful tool, SUMO, is a microscopic simulation tool that has been incorporated with the interface of DYNA4 to enable and control traffic demand in the virtual environment. Each of these applications performs specific tasks, and its integration facilitates a working simulator environment.

Figure 2: Simulator Setup - Hardware.

Considering the traffic volumes, road categories and traffic regulations inside the campus, a route has been selected from point A to Point B, which includes different road categories (main street and shared space) and traffic conditions and is also an important commuting route inside the study area. Figure 4 depicts the route selected along with camera locations. The red arrow mark indicates the starting point for the VuT. The total length of the route is 1.6 kilometres, including sections of the main street (red line) and shared path (blue line). As the name suggests, shared space can be used by all possible classes, such as cars, trucks, bikes, motorbikes, e-scooters and pedestrians. Vulnerable users hold the highest priority on such roads. It also includes some major intersections and a low-speed zone in front of Kindergarten.

The simulation experiment includes two scenarios: one with a conventional shuttle and another with the same shuttle presented to participants as autonomous. Both scenarios are otherwise identical, allowing comparison of responses based on the perceived automation level. Each of these scenarios has been designed to study the interaction between VuT and the respective shuttle. This study considered six categories of vehicles for other road users: cars, bicycles, e-scooters, motorbikes, pedestrians, and a bus, often termed a shuttle as far as the study is concerned.

3.2 Participants and Experimental Task

The preliminary stage essentially includes a briefing session of 15 minutes that lays out a general overview of the experiment and essential tasks expected from the participants. A total of 23 participants were involved in the study: 10 female and 13 male candi-

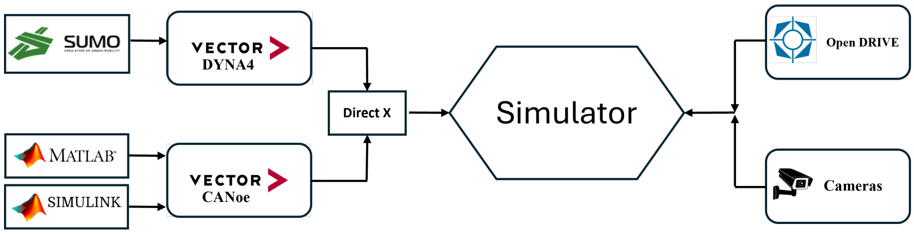

Figure 3: Simulator Setup - Data and Software Tool.

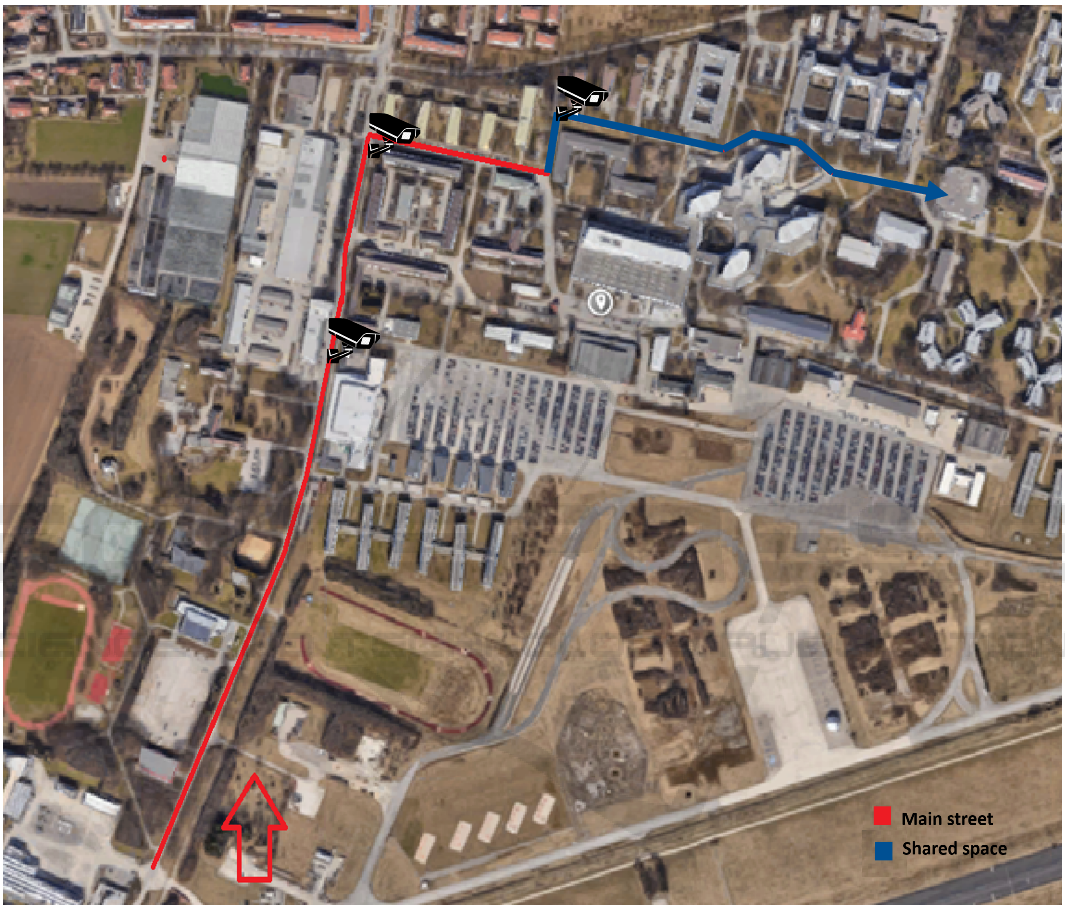

Figure 4: Route and Camera Location.

dates aged between 22 and 40 years with a mean driving experience of ten years (SD = 4.743). The pool of participants had different demographic backgrounds, consisting of nine nationalities, and everyone had at least a bachelor's degree.

Figure 5 narrates the procedures involved with the experimental tasks. In the first step, demographic details of the participants were acquired through a set of comprehensive demographic questionnaires. These surveys will be answered via an online tool, SociSurvey. The survey includes a declaration of consent, information about data protection, information about the simulator, and tasks to be performed.

Further, each participant will be trained in a specific training scenario to get acquainted with the dynamics of the simulator, followed by a simulator sickness questionnaire (SSQ) designed by Kennedy et al. (1993). The SSQ results are pivotal in assessing the participant's condition in regard to simulator sickness.

Once the test participants felt comfortable with the simulator, they were introduced to the testing scenarios. As Figure 5 depicts, participants were let to drive in Scenario 1 along with a conventional shuttle in the scenario. Similarly, in Scenario 2, before initiating Scenario 2, a piece of new information was given to the participants verbally *'This scenario is with the*

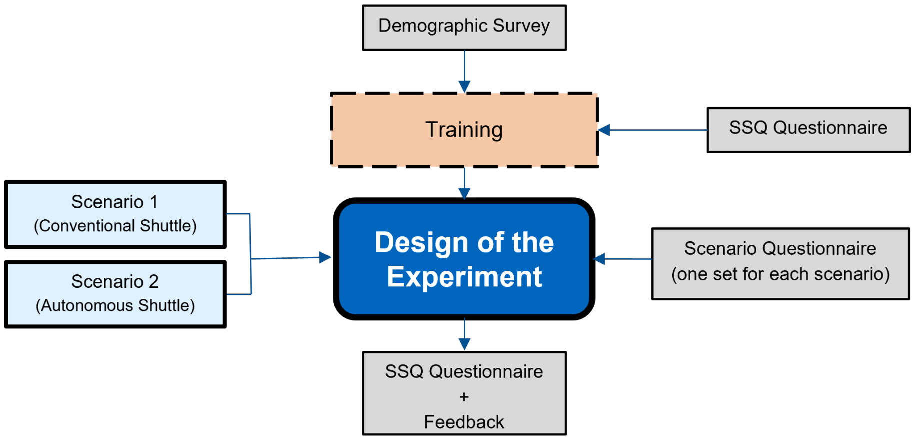

Figure 5: Flow Diagram - Experimental Phase.

Autonomous shuttle'. Additionally, participants answered a qualitative survey after each scenario run.

The scenario questionnaire (qualitative) is a series of structured questions to collect the participant's opinions and perceptions about operating the driving simulator in different scenarios. It had a particular emphasis on interactions with autonomous shuttles. Specific questions were designed to measure the perceived safety, stress levels, and ability to predict the behaviour of autonomous shuttles. In the end, SSQ has been exercised again to examine the degree of simulation sickness.

4 RESULTS AND DISCUSSIONS

This section presents the study outcome and data filtering procedures. The results should support or contradict the initial hypothesis on how the introduction of autonomous shuttles affects the behaviour of car drivers and safety. Further, to enhance the understanding of the results concerning both psychological and behavioural aspects focused in this study, the outcomes have been analysed and addressed in two sections.

4.1 Outcome Filtering

A collision counter has been incorporated as an indicator with a pre-defined reference limit; based on the sample size of test subjects, a boundary limit is assumed and defined. The assumptions were made considering historical results and an iterative testing procedure.

The collision counter is a simulator-inclusive signal that detects the number of collisions between VuT and the rest of the traffic in each scenario. This data is not hidden from participants. Any collisions between VuT and road users are instantly conveyed to the driver via a vibration signal on the steering wheel. The participants with more than two collisions per scenario were excluded from the dataset. However, only one participant was excluded from the results dataset due to erratic driving and high collision encounters. The remaining 22 participants were seen with zero or less than two collisions.

4.2 Statical Analysis of Qualitative Results

Mann Whitney U test, also known as the Wilcoxon rank-sum test, has been employed in the result analysis of this study. Mann-Whitney U test is a nonparametric statistical test used to determine if there are significant differences between two independent groups. It is particularly useful when comparing two groups with ordinal data or continuous data with a small sample size test that does not require normal distribution, making it appropriate for the study. Further, Equation 1 and 2 present the mathematical formulation of the Mann-Whitney U test, used to compare the two independent groups based on their rank sums.

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \tag{1}$$

Where:
U_1 is the Mann-Whitney U statistic for the first group,
n_1 is the number of observations in the first group,
n_2 is the number of observations in the second group,
R_1 is the sum of the ranks for the observations in the first group.

Similarly, for the second group, you can compute:

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \tag{2}$$

Where:
U_2 is the Mann-Whitney U statistic for the second group,
R_2 is the sum of the ranks for the observations in the second group.

As mentioned in the earlier section, this study emphasizes three key factors: perceived safety, perceived stress, and perception of the driving environment in regard to conventional car drivers in the study area. These factors are discussed in detail in the following subsections.

Perceived Safety

Safety corresponds to safety ratings opted by participants in regard to interaction with the autonomous or conventional shuttle, depending on the scenarios. The participants conveyed their opinions using the seven-star Likert scaling used in the scenario survey. Seven corresponds to higher safety, and one is relatively unsafe.

Figure 6 indicates that participants generally perceive higher safety when interacting with conventional shuttles compared to autonomous shuttles. The mean value for perceived safety is higher for conventional shuttles. Also, Table 4 indicates the descriptive statistics of two scenarios across 22 participants (N=22), suggesting the conventional car drivers felt comparatively safer (Mean: M = 5.909, Standard Deviation: SD = 1.151) while driving along with the conventional shuttle rather than an autonomous shuttle (M = 2.818, SD = 1.816). Even though the driving behaviour of the autonomous shuttle in the simulation environment is identical to the driving behaviour of the conventional shuttle. The only difference between the two scenarios is that the participants are informed beforehand that the shuttle is autonomous or conventional.

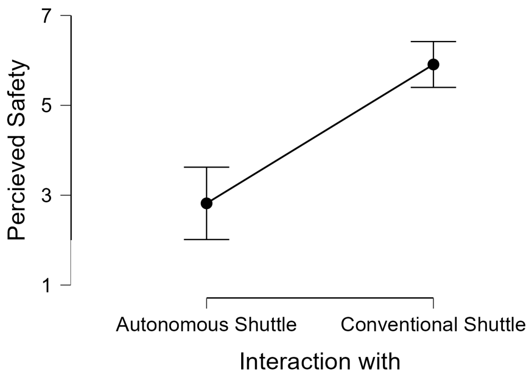

Figure 6: Perceived Safety of Conventional Car Drivers.

Table 2, displays U-statistics; It represents the sum of ranks for one of the two groups compared in the test and p-statistics; A p-value less than 0.001 indicates strong evidence against the null hypothesis, suggesting a statistically significant difference in perceived safety between the two groups. Further, the Mann-Whitney U test shows that the perceived safety is significant ($p = 0.001 < 0.05$). Therefore, this supports the first hypothesis (H1) of the study.

Table 2: Independent Samples T-Test for Perceived Safety.

	U	p
Perceived Safety	49.000	$< .001$

Perceived Stress

Another indicator used in this study is stress, which helps assess diverse study components. Perceived stress serves as a multi-dimensional unit influencing distinct aspects of transportation systems. Firstly, stress directly impacts driver behaviour. Heightened stress levels can impair decision-making, reaction times, and sustained attention, potentially compromising driving safety.

As shown in Figure 7, stress perceived by conventional users is similar in both scenarios. Further, the stress scores indicated by descriptive details for the scenario with the autonomous (M = 2.818, SD = 1.816) and conventional shuttles (M = 2.682, SD = 1.615) are relatively similar.

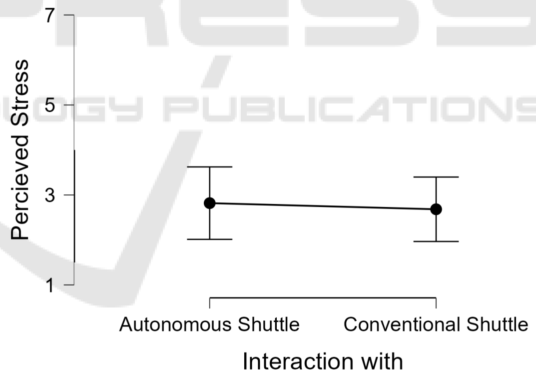

Figure 7: Perceived Stress of Conventional Car Drivers.

Additionally, in the Mann-Whitney U test, as shown in Table 3, the perceived stress does not differ significantly ($p = 0.981 > 0.05$) and also, perceived stress seemed not to influence the perceived safety to the same extent. Therefore, the hypothesis (H2) is rejected based on the previously chosen confidence level.

Table 3: Independent Samples T-Test for Perceived Stress.

	U	p
Perceived Stress	243.500	0.981

Table 4: Grouped Descriptive Values for Human Factors.

	Group	N	Mean	SD	SE	Coefficient of variation
Perceived Safety						
	Autonomous Shuttle	22	2.818	1.816	0.387	0.644
	Conventional Shuttle	22	5.909	1.151	0.245	0.195
Perceived Stress						
	Autonomous Shuttle	22	2.818	1.816	0.387	0.644
	Conventional Shuttle	22	2.682	1.615	0.344	0.602
Perception						
	Autonomous Shuttle	22	5.364	1.529	0.326	0.285
	Conventional Shuttle	22	5.727	1.518	0.324	0.265
Confidence of Driving with AVs						
	Male	13	4.462	0.519	0.144	0.116
	Female	9	3.556	0.882	0.294	0.248

Even though the factor of stress perception is statically insignificant, overall mean values (see Table 4) suggest a slight change in the behaviours of the car drivers as they tend to perceive rather in a different manner while interacting with the autonomous shuttle.

Perception

Perception corresponds to awareness of the surrounding traffic environment, which is a vital indicator of the psychological and behavioural aspects of this study. The acceptance of new mobility options and, therefore, the ability to understand the dynamics of these mobilities become a meaningful part of the campus transportation ecosystem is directly tied to user acceptance. When individuals perceive such vehicles and their operations as safe and reliable, adoption increases, and the integration into the existing transportation system proceeds smoothly.

As Figure 8 depicts, perceptions of both shuttle options, autonomous and conventional shuttles, are relatively similar. However, as shown by descriptive statistics in Table 4, the autonomous shuttle tends to be perceived slightly less (M = 5.364, SD = 1.529) by the car drivers as compared to a conventional shuttle (M = 5.727, SD = 1.518) within the exact same environment.

Furthermore, as shown by Table 5, the Mann-Whitney U test indicates that perception does not differ and is insignificant (p = 0.343> 0.05) with the chosen confidence levels. Therefore, perception as a factor leads to the rejection of the first hypothesis (H1) in the study.

Additionally, the survey results highlight the confidence levels of drivers when sharing the road with

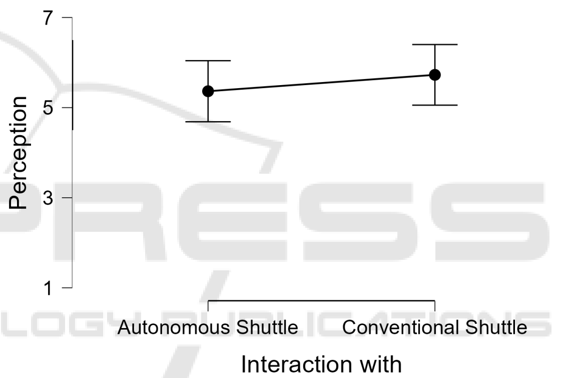

Figure 8: Perception of Conventional Car Drivers.

Table 5: Independent Samples T-Test for Perception.

	U	p
Perception	202.500	0.343

AVs in an urban environment. The demographic data of the participants provided valuable insights into these perceptions. After the data filtering, the result dataset contained 22 participants, consisting of nine female and 13 male drivers, who shared their views on driving alongside AVs.

Figure 9 illustrates that male drivers reported higher confidence when interacting with AVs in an urban environment, with an average score of M = 4.462 (SD = 0.592). In contrast, female drivers expressed lower confidence, resulting in a comparatively lower average score of M = 3.556 (SD = 0.294) under the same traffic conditions.

Further, Table 6 indicates the value from the Mann-Whitney U test. The difference between the

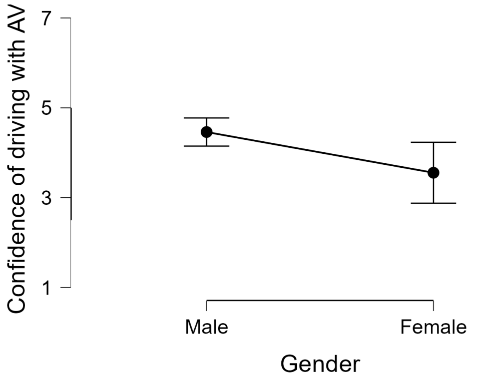

Figure 9: Confidence Levels of Conventional Car Drivers.

Table 6: Independent Samples T-Test for Confidence of Driver Interacting with AVs.

	U	p
Confidence of Driving with AVs	93.000	0.013

two groups is statically insignificant (p = 0.013> 0.05) given the confidence interval of 95%. Nevertheless, female participants expressed varied confidence across the rating scale, wherein the male drivers tended to report relatively higher confidence.

The findings of this research demonstrate, that perceived safety emerged as a key metric, reflecting the psychological and behavioral impacts of autonomous shuttles on conventional car drivers. The distinct differences in safety perceptions between autonomous and conventional shuttles highlight its central role in shaping driver interactions within mixed-traffic environments. While perceived safety was a primary focus, other interconnected factors, such as stress levels, driver confidence, and the perception of the driving environment, provided essential insights that enriched the analysis. Collectively, these aspects form a comprehensive framework for understanding how emerging autonomous technologies affect human factors, offering a foundation for a scalable framework for assessing human factors in similar experimental setups.

5 CONCLUSIONS AND FUTURE WORK

Overall, the introduction of autonomous shuttles is discussed, along with the crucial notion of integrating emerging mobility solutions into the driving environment of the study area as an essential component of the reshaping of mobility.

The study effectively demonstrates the influence of autonomous shuttles on driving behaviours, perceptions, and driver psychology. Findings revealed a significant reduction in perceived safety levels when drivers were informed verbally about the autonomous shuttle's presence, even though both scenarios were otherwise identical to each other. It also highlights that the perceived safety and perceived stress of a conventional car driver are not directly related to interacting with autonomous shuttles within the defined traffic environment.

Similarly, the variations across different human factors with different participants throughout the study clearly point out that human perceptions significantly impact driving, and deviations indicate the degree of perception change in reference to aggregated mean driving behaviours. Even though the result cannot be generalized to the whole driving community. The study, which was conducted effectively with 22 participants, resulted in slightly varied perceptions and lesser safety perception levels concerning autonomous shuttles. Nevertheless, no large-scale or fundamental issues have resulted in the introduction of autonomous shuttles on campus.

Though the study still has certain limitations, these can be tackled in future research designs with appropriate considerations. A much bigger sample size with varied demographic backgrounds might help in a deeper analysis of driving perceptions. Similarly, consideration of other human and psychological factors might provide a closer understanding of behavioural data. Detailed geometric data covering all aspects of road infrastructure on the campus will enhance visualization of the interaction between traffic and VuT. Further research direction includes the integration of vehicles-to-everything (V2X) communications units and connected simulators.

In conclusion, along with the results, the study offers a framework to design, develop and perform an experiment in regard to driving behaviours and survey procedures. The complete experiment is designed from scratch to study the impact of autonomous shuttles on the campus. The same experimental design can be adapted for further research with other vehicle types as well, considering appropriate and calibrated driving models. Additionally, the procedure discussed to carry out an experiment with participants considering various aspects, the study had established a comprehensive experiment design.

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