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Evaluation of a novel HMI to mitigate the effects of distraction under continuous mediation driving conditions

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Keywords: Distraction, partial automation driving, secondary task

1. Background

The increased prevalence of automation functions in partially automated vehicles (PAVs) relieves drivers from vehicle control tasks but not from their role as supervisors of the automated system or the driving task (Fisher et al., 2016). This supervision requires continuous mode awareness that might result in passive fatigue (May & Baldwin, 2009, Körber et al., 2015, Merat et al., 2019). Engagement with non-driving related tasks (NDRT) while driving under CM driving conditions may function as a countermeasure for passive fatigue, (Oron-Gilad, Ronen, & Shinar, 2008; Gershon et al., 2009), however, it might impair the hazard perception performance of young-experienced drivers (Zangi et al., 2022). These trade-offs between the benefits of using an NDRT as a fatigue countermeasure and the potential distraction it may cause received little attention. In light of this dilemma, the current study designed and evaluated a novel HMI concept that notifies the driver of an upcoming hazard and serves as preventive mediation. The objective was to examine whether the HMI preventive mediation concept assists in mitigating the effects of distraction during driving under CM while the engagement with NDRT.

2. Method

The Mediator HMI design had two primary functions: The first function convey the current driving mode to the driver to increase mode awareness and prevent mode confusion. The second function sought to prevent drivers from becoming distracted by notifying the driver of upcoming latent hazardous situations. The HMI used visual and auditory stimuli as the primary communication channels. The locus of interaction was the driver dashboard and the infotainment screen.

We used a visual WhatsApp-like message as an NDRT, that included objective details on several topics (e.g., changes in the train schedule), and provided several informative elements. Two questions followed the message presented one after the other (see Figure 1).

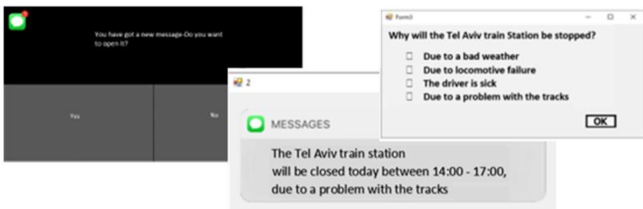

Figure 1 invitation to play WhatsApp (on the left) and an example of a question and answers.

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Twenty-six participants drove an RTI driving simulator under CM conditions in two driving sessions (20 min each), one week apart. Participants encountered 4 hazardous situations in each drive and had to handle them. During their drive, participants were purposely distracted by asking them to read informative WhatsApp messages and answer related questions. The hazard notification system was triggered prior to two of four hazards in each drive. In addition, the participants' eye movements were recorded throughout the experiment via Tobii Pro Glasses 2 head-mounted Eye Tracking System.

3. Results

Overall, the perceptions and attitudes of trust, safety, usability, and acceptance toward the mediator HMI were highly positive. Males tended to trust and adopt the automated system to a greater extent than females. However, females during their first drive were slightly more skeptical than males, but this difference diminished in the second drive due to increased female ratings. In terms of mental workload, we found that participants perceived the Mediator HMI as less mentally demanding during the second drive than the first, suggesting positive longer-term effects.

4. Conclusions

The HMI preventive concept assists in mitigating the adverse effects of distraction. The attitudes and perceptions toward the mediator HMI are positive, however, the system was 100% reliable. Future studies should examine less reliable HMIs and their effects on attitudes and perceptions. In addition, future studies should consider applying real-time detection and a human driver-based policy to reduce overreliance.

REFERENCES

Fisher, D. L., Lohrenz, M., Moore, D., Nadler, E. D., & Pollard, J. K. (2016). Humans and intelligent vehicles: The hope, the help, and the harm. *IEEE Transactions on Intelligent Vehicles*, *1*(1), 56-67.

Körber, M., Cingel, A., Zimmermann, M., & Bengler, K. (2015). Vigilance decrement and passive fatigue caused by monotony in automated driving. *Procedia Manufacturing*, *3*, 2403-2409.

May, J. F., & Baldwin, C. L. (2009). Driver fatigue: The importance of identifying causal factors of fatigue when considering detection and countermeasure technologies. Transportation research part F: traffic psychology and behaviour, 12(3), 218-224.

Merat, N., Seppelt, B., Louw, T., Engström, J., Lee, J. D., Johansson, E., ... & Keinath, A. (2019). The "Out-of-the-Loop" concept in automated driving: proposed definition, measures and implications. Cognition, Technology & Work, 21, 87-98.

Oron-Gilad, T., Ronen, A., & Shinar, D. (2008). Alertness maintaining tasks (AMTs) while driving. Accident Analysis & Prevention, 40(3), 851-860.

Gershon, P., Ronen, A., Oron-Gilad, T., & Shinar, D. (2009). The effects of an interactive cognitive task (ICT) in suppressing fatigue symptoms in driving. Transportation research part F: traffic psychology and behaviour, 12(1), 21-28.

Zangi, N., Srour-Zreik, R., Ridel, D., Chasidim, H., & Borowsky, A. (2022). Driver distraction and its effects on partially automated driving performance: A driving simulator study among young-experienced drivers. Accident Analysis & Prevention, 166, 106565. https://doi.org/10.1016/j.aap.2022.106565.

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What Mode is This? Exploring Which Elements of Visual In-vehicle HMI Designs Intuitively Indicate the Car Being in Assisted or Automated Driving Mode

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Keywords: mode awareness, visual HMI, intuitive design, benchmark, vehicle automation.

In vehicles with assisted and automated driving modes, humans and machines share the responsibilities of driving tasks and duties. However, these tasks and duties differ between modes. This means that at any moment during the journey, it should be unmistakably clear in which mode the car operates, i.e., at which level of automation. For human drivers, this is a prerequisite to be aware of who (car or human) has what responsibility. Manufacturers are increasingly developing visual Human Machine Interfaces (HMIs). This may come at the cost of consistency and compatibility between designs and could lead to mode confusion for the driver when confronted with different designs. Ideally, a certain level of standardisation is achieved amongst HMI designs to avoid mode confusion and human errors. Therefore, we 1) investigated what designs are currently being developed and 2) evaluated what elements affect the driver's intuitive decision on mode status.

To obtain an overview of the existing designs, desk research was performed, and car manufacturers were asked to share their HMI designs for assisted and automated driving modes. Commonalities and differences between designs were identified. Next, in an experimental study, different visual designs were tested to assess whether they are perceived as assisted or automated driving modes. First, to assess intuitive associations, participants were asked to indicate the automation level corresponding to the HMI shown as quickly as possible. For this, reaction time and response accuracy were measured. Through subsequent guided interviews, insight was obtained into which elements aided decision-making.

This research provides the state of the art regarding current HMIs for assisted and automated driving and identifies elements that affect drivers' intuitive decisions on mode status. Based on these findings, solutions are proposed to tackle issues in HMI design related to mode confusion and to provide input for Euro NCAP protocols.

Human-Centred Development of SAE-2 Automation for Truck Driving

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Keywords: truck driving, driver assistance systems, vehicle automation, human-centred design, headtracking, driver monitoring.

Background

Compared with passenger cars, automating driving functions for trucks and understanding related driver behaviour are considerably less advanced, potentially due to difficulties accessing relevant technology and subject matter experts (SMEs). Project HALC's (HighwayAssist with Lane Change) first objective was to develop the HALC system, which is an automation assisting truck drivers on highways. The system performs longitudinal and lateral control of commercial trucks, including lane changes. To optimally support truck drivers' interactions with the HALC system, we developed its functionality and human-machine interface (HMI) in close cooperation with SMEs. As an SAE level 2 (SAE International, 2014) type automation, the system may require drivers to resume control anytime. Thus, the second objective was to develop a monitoring system to ensure drivers' takeover readiness. The project's third objective was to understand better truck driver behaviour based on data collected within the project. This knowledge was then used to inform the HALC system's design and implementation.

Method

Informed by the daily operational needs of a trucking company, prototypical safety-critical events, and the capability of the available technology, 160 use cases were defined to specify how the automation should behave in specific traffic situations. Based on the use cases, (a) architecture and core functionality of both the automation and the driver monitoring system were derived, (b) a simulator experiment to explore truck drivers' behaviour in safety-critical situations was specified, and (c) a focus group to gather feedback regarding HMI solutions was planned.

The simulator experiment aimed at exploring how distracted truck drivers responded in case of silent automation failures and also served to collect parameters related to head and gaze orientation. The experiment's 4x2x2 design varied four safety-critical scenarios lasting about 15 min, which 27 participants holding at least a C1 driver's license (three female, 24 male; mean age = 42.5 years) experienced in two driving conditions (manual vs automatic) and two warning conditions (audio-visual warning vs no warning). Each participant conducted two scenarios in manual, distraction-free driving, whereas the two other trials required playing a game on a tablet computer while supervising the automation. Towards each scenario's end, participants had to intervene to prevent a safety-critical event from developing into a crash, with one condition simulating the automation failing without warning. During the initial training, participants were informed about this possibility.

The focus group was conducted with six professional truck drivers (two female, four male, mean age = 29.7 years) and integrated participatory design elements. The focus group aimed to receive feedback regarding the initial HMI concept and further understand drivers' information demands. After introducing SAE level 2 automation and the initial HMI concept, we demonstrated the HMI using a simulated driving scenario free of disturbances. Participants then answered questions to evaluate the HMI regarding strengths and weaknesses and, within a group discussion, were asked for potential improvements. Based on the drivers' suggestions, we immediately adjusted the HMI concept and repeated the question phase and the group discussion. This process was then repeated twice.

Results

The simulator experiment showed that the distraction exerted by playing the game could result in safety-critical incidents, even for highly skilled drivers. Some participants missed the critical safety situation entirely; others reported difficulty taking back manual control. We concluded that most collisions would have been avoided if drivers could not orient their heads away from the front view.

Informed by the experiment's results, we implemented a head tracking-based monitoring system to prevent complete aversions from traffic. Regarding the HALC system's lane change functionality, the results supported requiring drivers to initiate lane changes explicitly. They are only executed if no objects on the target lane have been detected and drivers have visually attended the rear-view mirror.

In addition to the lane change functionality, the HALC system integrates adaptive cruise control and lane centring. The results obtained from the focus group allowed for a holistic system design such that truck drivers perceive a single system instead of three separate functionalities.

Conclusion

Truck driving differs markedly from car driving due to vehicle size, braking and acceleration behaviour, and usually being part of a commercial operation. Under constant pressure to meet delivery times, drivers frequently experience long periods of monotony which are unpredictably interrupted by safety-critical situations. As such, drivers are substantially exposed to traffic-related hazards and appreciate technical systems lowering their workload and the risk of accidents. Designing and implementing such systems requires profound domain knowledge and an iterative development approach. The SMEs' support enabled us to obtain the qualitative and quantitative insights necessary for the human-centred design process. Transferring these insights into system functionality requires effort and flexibility, which should be considered during the project planning phase.

References

SAE International (2014). Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems (J3016).

Ergonomic study of an electric hand-truck for last 100-meter delivery service.

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Keywords: ergonomics, hand-truck, last 100-meter, lumbar-spine.

1. Background

Manual material handling tasks can result in musculoskeletal injuries, especially in the lumbar spine which account for a significant portion of work compensation costs (Marras, W. S. et al. 2000). This study aims to evaluate electric (e) hand-trucks that support workers in the last 100-meter distribution service and reduce the risk of musculoskeletal injuries. A literature and market study took place to identify the main functions of actuated e-hand-trucks. Three main functions were identified: uphill and downhill support, support for climbing sidewalks and stairs, and an actuated moving tray to avoid lifting weights. Already the positive effect of specific functions of e-hand-trucks was identified from other researchers (Lavender et al. 2023).

2. Method

An ergonomic study was conducted to evaluate these e-hand-trucks' functions. The study used the Tecnomatix Jack software and male and female mannequins with 50th percentile stature based on the (Donelson, S.M. et al. 1988). The simulations focused on the e-hand-truck's functionalities to assess their ergonomic features. The target weight of the e-hand-trucks was selected at 15 kg which according to (Stanton et al., 2004) is the maximum comfortable weight for lifting a box with 34cm width, similar to the width of the e-hand-truck, every 5 min from knuckle height to shoulder heigh for a 50th percentile woman. This way the e-hand- trucks can be safely loaded and unloaded to the cargo space of a truck.

3. Results

Simplified CAD designs based on a commonly available hand-truck in the market were used. The designs for the e-hand-trucks that can fulfil the identified functions in the literature were completed by adding the actuation system with an additional track-belt mechanisms and by also modifying certain geometric characteristics of the commercial hand truck. The results of the ergonomic study will be presented and discussed during the conference. Below are three photos from the functions of actuated e-hand-trucks.

Figure 1 Simulation of the three main functions: actuated moving tray for loading- unloading, traction wheels for uphill and downhill transportation, stair climbing

4. Conclusion

This research was motivated by the high incidence of musculoskeletal disorders among workers who perform manual material handling tasks, which can lead to significant work compensation costs. By designing e-hand-trucks that can reduce the risk of musculoskeletal injuries, this study aimed to improve workers' safety and efficiency in the last 100-meter distribution service.

5. References

Donelson, S.M. and Gordon, C.C. (1991). *Anthropometric survey of US Army personnel: pilot summary statistics*, 1988. Army Natick Research Development and Engineering Center.

Lavender, S. A., Charbonnet, J., & Sommerich, C. M. (2023). *Biomechanical assessment of alternative hand trucks for transporting heavy loads up and down stairs.* Applied Ergonomics, 110, 104010.

Marras, W. S. (2000). *Occupational low back disorder causation and control.* Ergonomics, 43(7), 880-902.

Stanton, N. A., Hedge, A., Brookhuis, K., Salas, E., & Hendrick, H. W. (Eds.). (2004). *Handbook of human factors and ergonomics methods*. CRC press.

AR Designs for eHMI – Communication between automated vehicles and pedestrians using augmented reality

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With the introduction of connected and automated vehicles (CAV) into the existing transport system, special attention must be paid to the interaction of these vehicles with the surrounding other road users (ORU). To meet this challenge, various solutions in the field of external human-machine interface (eHMI) have been developed in recent years. However, these are often visually perceptible eHMIs attached to a CAV's exterior. Here, the perceptibility of the information is highly dependent on the situation (e.g. lighting conditions, visibility, distance to the AV) and the signals can be difficult to adapt to the needs or preferences of the ORU in question. The present study investigates a new approach implementing interaction between CAV and ORU using augmented reality (AR). In an online video study, 94 participants evaluated different AR design variants for communication with a CAV from the perspective of a pedestrian. In addition to the subjective willingness to cross the road in front of a CAV, further data was collected on the subjects' perceptions of safety and mental workload. In addition, the AR design variants were compared with visual (light-based) eHMI solutions. The results showed a clear superiority of the AR design compared to a light-based eHMI.

Traffic Education Strikes a New Path – a Comprehensive Approach for all Types of School

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Keywords: traffic safety education, mobility, teaching materials, students.

1. Background

Traffic safety and mobility education is an essential part of the Safe System approach in European countries. Moreover, the educational objectives embedded in traffic safety and mobility education include the prevention of damage to the environment or someone's health. There is a commitment in Europe to provide this kind of safety education in schools at all levels. In Austria it is part of the curriculum for elementary schools. In secondary schools an interdisciplinary approach to mobility education is demanded but often not put into action. However, it is clear from both developmental psychology and traffic accident statistics that traffic safety education is particularly important after primary school. Therefore, a comprehensive approach is crucial in order to provide children and teens with the basic skills needed to participate safely and responsibly in traffic.

2. Method

To support teachers in this task, the Austrian Road Safety Board (KFV) aimed to offer an extensive mobility education concept and supporting materials to encourage and enable teachers to provide corresponding lessons with minimal effort. The resulting concept was based on developmental psychological principles, current traffic education findings and an analysis of both the mobility behaviour of students in primary and secondary schools and the latest traffic accident statistics.

The concept itself and some initial mock-ups of the teaching materials were tested in four focus groups involving teachers and students. According to both groups, the teaching concept was found equally suitable for both girls and boys and the use of role models was highly appreciated. However, the animated video clips, which were intended as an introduction to each topic, were not well received by both groups. Based on the feedback of both groups, the documents were adapted and finalised.

Lastly, a rollout plan and communication strategy were carried out based on the findings of a survey among federal and regional education authorities and teachers.

3. Results

In 2018 the methodological approach mentioned above gave birth to 'Risi & Ko' (referring to the German word for risk: 'Risiko'). Since then, the documents have been steadily expanded. With its flexible, modular approach and corresponding teaching materials, 'Risi & Ko' provides detailed lesson plans for different age groups and needs. The teaching materials released in 2019/20 for primary schools are structured according to each level of education. All content is based on the Austrian curriculum for traffic and mobility education which requires ten lessons in each school year from grades 1 to 4.

The teaching content for secondary schools is divided into four different topics: ‘risk and peer pressure’, ‘social skills and mutual respect in traffic’, ‘distraction in traffic’ as well as ‘different forms of mobility and their potential’. Depending on the occasion, the various lesson descriptions can be used in different subjects or within project days at school. This way, children and young people can acquire valuable strategies to increase both their personal safety in road traffic (for instance as pedestrians, cyclists, or public transport users) and the safety of other road users.

A key element of the Risi & Ko concept are five archetypal comic figures (see figure 1), each of which acts according to its given character. They serve as reference figures for the students, demonstrate different ways of adapting and reacting to traffic situations and allow for an active and critical analysis of different traffic safety and mobility topics.

These five characters are intended to accompany Austrian students from primary school until the end of their school careers. In this way, they develop in the illustrations in parallel with the students while their character traits remain the same.

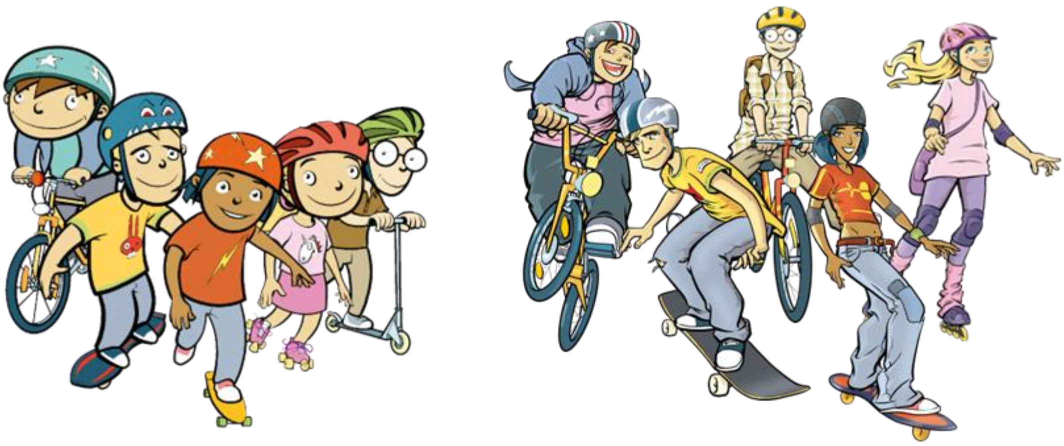

Figure 1 – Reference figures for primary and secondary school

In addition to teaching materials, workshops and other school activities were developed in order to allow students to look into certain traffic safety topics – for instance distraction or speeding – more thoroughly and with the help of extracurricular experts. All materials and activities are provided free of charge and are easily accessible via the website www.risi-und-ko.at.

4. Conclusion

With the support of federal and regional education authorities, the accomplished teaching materials were made available to a large number of schools. The Austrian Road Safety Board received very positive initial feedback from teachers. A formal evaluation of the actual use of the materials is scheduled to take place by the end of 2023.

One clear finding so far is that it is easier to raise interest among elementary teachers since there is no specific subject dedicated to traffic and mobility education in secondary schools. By now, the former has downloaded the digital version of the “Risi & Ko” materials around 3,000 times. In addition, about 4 out of 10 elementary schools in Austria are currently equipped with a hard copy version of the materials. Although the materials for secondary schools have been available for 2.5 years longer, only about 3 out of 10 schools have taken the opportunity to order them so far. It has been noted that secondary schools are often more inclined to outsource traffic- and mobility-related lessons to extracurricular experts. To meet this need, workshops and activities conducted by KFV experts are offered to all types of schools. For example, over 200 workshops on the topic of distraction were conducted in secondary schools in 2022, free of charge.

REFERENCES

ETSC. (2020). Key Principles for Traffic Safety and Mobility Education. European Transport Safety Council. https://www.trafficsafetyeducation.eu/wp-content/uploads/LEARN-Key-Principles.pdf

The Impact of Socio-economic and Health-related Characteristics and Built Environment on Meeting the Recommendations for Physical Activity in Israel

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Keywords: physical activity, walking, activity-oriented Infrastructure, healthy lifestyle.

1. Background

Regular physical activity (PA) serves as a primary and secondary prevention measure for numerous chronic diseases and health conditions and may reduce the risk for non-communicable mortality (Kruk, 2009; Warburton, Nicol & Bredin, 2006; WHO, 2020). According to the 2010 and 2020 guidelines of the World Health Organiation (WHO), the minimum recommended aerobic PA for adults is 150 minutes of moderate-intensity activity, or 75 minutes of vigorous-intensity activity per week, or an equivalent combination of moderate and vigorous intensity activities (WHO, 2020). Despite the importance of PA on a regular basis, a significant portion of the general population fails to comply with the recommendations, especially in industrialized countries, including Israel (Israel Center for Disease Control, 2017; WHO, 2020). An extensive worldwide review indicated on consistent association between participation in PA among adults and diverse socio-economic and health factors (such as health status) and environmental conditions (such as the presence of sidewalks and accessibility to sport facilities) (Choi, Lee, Lee, Kang & Choi, 2017). However, most of the studies among adults in Israel focused on examining the association between socio-economic and PA performance (Israel Center for Disease Control, 2017). The aims of the present study were: 1) Assessing the proportion of "sufficiently active" Israeli adults (according to the WHO's guidelines); 2) Presenting the most frequently reported physical activities (e.g. "outdoor walking"); 3) Identifying socio-economic factors, health-related characteristics and PA supportive environment level that predict "sufficiently active" lifestyle.

2. Method

A cross-sectional survey, the "PA in Adults-national survey", was carried out in 2016-2017. Self-reported data were collected by telephone interviews from a representative sample of 3,187 Israeli Jewish and Arab adults aged ≥21. The proportion of "sufficiently active" respondents and most frequently reported physical activities are presented by percentages. Two-tailed chi-square univariate analyses examined associations between socio-economic factors (gender, age, population group, education level and religiosity status), health-related characteristics (Self-perceived physical and mental health, current smoking status, vegetable and fruits consumption and body max index), PA supportive environment level (which was determined by the reported status of existence and accessibility of diverse facilities or activities at the residence place, e.g. "walking trails, bike paths, sport events etc.) and "sufficiently active" lifestyle. The statistically significant variables at the univariate analyses stage were introduced into logistic regression model for multivariate analysis in order to identify the predictors of "sufficiently active" lifestyle. SPSS software (version 28) was used and statistical significance was set at p<0.05.

3. Results

Less than a third of the respondents (29.8%) were "sufficiently active", 31.7% in men and 28.0% in women (p=0.024); 31.4% in Jews and 20.6% in Arabs (p<0.001). Similar rates (around 30%) of "sufficiently active" lifestyle were reported in both age groups, 21-49 and >50. The five most frequently reported physical activities were "outdoor walking" (52.9%), followed by "exercise for strengthening and shaping" (15.3%), "outdoor running" (12.1%), "gym" (8.5%) and "swimming" (8.5%). The following factors significantly predicted "sufficient active" lifestyle: being men (OR=1.27, p=0.016), being Jewish person (OR=1.48, p<0.001), being secular (OR=1.38, p=0.02), reporting on good physical health (2.70, p<0.001), avoiding smoking (OR=1.37, p=0.010), consuming ≥5 servings per day of vegetables and fruits (OR=1.68, p<0.001) and high level of PA supportive environment (OR=1.69, p<0.001).

4. Conclusion

A small portion (less than third) of Israeli adults adhere to "sufficiently active" lifestyle. "Outdoor walking" was the prominent and favored PA (around half of the respondents). Interventions targeted at increasing the proportion of physically active adults are warranted. While adoption of socio-economic characteristics that predict "sufficient active" lifestyle might be unattainable, the health characteristics and PA supportive environment predictors are partially modifiable factors and therefore can be embraced at an individual or community level. Understanding the role of the above predictors in compliance with physical activity may contribute to the development of improved policies and effective interventions in Israel. Intervention plans should focus on: 1) Increasing awareness to the importance of ahealthy and active lifestyle with emphasis on cultural aspects (e.g. tailoring appropriate programs for religious population); 2) Promoting plans for the expansion of activity-oriented infrastructure with an emphasis on accessible facilities aimed at enabling walking during leisure time and for transportation purposes.

References

Choi, J., Lee, M., Lee, J. K., Kang, D., & Choi, J. Y. (2017). Correlates associated with participation in physical activity among adults: a systematic review of reviews and update. *BMC public health*, *17*(1), 356. https://doi.org/10.1186/s12889-017-4255-2

Israel Center for Disease Control (2017). *Israel National Health Interview Survey INHIS-3, 2013-2015 – Selected Findings* (Report No. 374). Ministry of Health Israel. https://www.health.gov.il/publicationsfiles/inhis_3.pdf

Kruk, J. (2009). Physical activity and health. *Asian Pacific journal of cancer prevention: APJCP*, *10*(5), 721–728.

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *CMAJ: Canadian Medical Association journal*, *174*(6), 801–809. https://doi.org/10.1503/cmaj.051351

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WHO Guidelines on Physical Activity and Sedentary Behaviour. (2020). World Health Organization.

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Predicting Which Drivers Will Regularly Drive When Sleepy: Application of the COM-B Model

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ABSTRACT

Young drivers are overrepresented in sleep-related crashes suggesting that they are a high risk population who may benefit from interventions to minimise driver sleepiness. As sleepiness is a state which is impacted by lifestyle choices, countermeasures will only be effective if those at risk change their behaviour to address the problem. Within health psychology, the COM-B model states that Capability, Motivation and Opportunity all contribute towards behaviour. 458 participants, mean age 21.2 years (SD=3.8), 330 female 128 male, mean licensure 39.7 months (SD=38.2) completed a 74-item questionnaire about driver sleepiness. Two researchers independently categorised each survey item under one of the six COMB sub-headings, the 5 or 6 survey items which most strongly aligned to the COM-B, were selected for analysis. Structural Equation Modelling (SEM) identified twelve significant factors affecting sleep related driving behaviour. Higher level COMB areas (capability, motivation and opportunity) do not appear to affect behaviour, but prediction is found at the second level components. Physical capability was the greatest predictor of safe sleep related driving behaviour (1.747, p = .003) among automatic motivation, physical and social opportunity. Demographics impacted the model, e.g., gender has a significant impact on Physical capability (.833,p<.001), therefore guidelines for an intervention to mitigate driver sleepiness should consider tailoring material. Moreover, the model showed that interventions aimed at increasing belief that you or others could get in trouble with the police could reduce sleepy driving. Overall, the application of the COM-B model did not demonstrate a significant association with sleep-related driving behaviour, but specific components of the model provided some valuable insight.

Keywords: driver sleepiness, driver fatigue, young drivers, behaviour change, driver education, Structural Equation Modelling.

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1. INTRODUCTION

2.1 Background

This paper is concerned with young drivers, a population which is overrepresented in sleep-related crashes, suggesting they represent a high-risk group who may benefit from interventions aimed at minimising driver sleepiness. This can be seen in particular when comparing older and younger drivers (see, for example, Amponsah-Tawiah & Mensah, 2016; Lyon et al., 2020 and Watling, 2014). Sleepiness as an impairment state is influenced by a range of behavioural factors (e.g. sleep timing, caffeine use, etc) independent to driving behaviours. As such, it may be possible to reduce driver sleepiness by targeting these factors with behavioural interventions that address sleepiness in general, rather than only focusing on driving related behaviours.

The COM-B model is a behavioural change theory which is well-recognised within health psychology; it states that Capability, Motivation and Opportunity all contribute towards behaviour. The COM-B model was developed to determine what needs to change before a behavioural change intervention can be effective (Michie et al., 2011). It was developed as a means of offering more clarification and simplification of categorising factors which lead to certain types of behaviour and guidance for selecting appropriate interventions for behavioural change. The COM-B model has been applied successfully in a number of ‘real-world’ contexts in the past, particularly in the public health domain, e.g., improving hearing aid use (Barker et al., 2016); increasing rates of health tests (McDonagh et al., 2018); and improving stroke rehabilitation (Connell et al., 2015);. Significantly for this study, an RAC Foundation publication cited the COM-B model as a relevant example of a technique for use in road safety to decide on interventions for encouraging behaviour change in road users (Fylan, 2017).

The COM-B model highlights three types of factors which need to be present for any type of Behaviour (B) to occur. These are Capability (C), Opportunity (O) and Motivation (M). These three factors can each be further divided into two sub-categories to capture important distinctions (as shown in Figure 1). The interactions between these six components determine the type of behaviour which occurs.

Figure 1 – The COM-B Model

The COM-B model has a number of benefits; it is more intuitive and more structured than other behaviour change models (Mayne, 2018) and if the step by step process is followed carefully, a meaningful ‘theory of change’ can be achieved. The model is also able to incorporate ‘context very naturally’, where previously context was insufficiently theorised or investigated, despite the fact that the key to understanding behaviour is through its context (Michie et al., 2011).

2.2 Objectives

This paper uses an exploratory approach to determine if the COM-B model can be retrospectively applied to analysis of survey data in order to identify the elements which predict sleepy driving behaviour. Insights will be used to provide guidance for driver sleepiness interventions.

2. METHOD

A secondary analysis of data from a 74-item survey was completed. The purpose of the original survey was to identify factors which predicted self-reported regular driver sleepiness. The survey primarily consisted of a battery of previously validated survey materials. These included the Patient Reported Outcomes Measurement Information System (PROMIS) general health; sleep disturbance and sleep related impairment questions (Buysse et al., 2010); the Sleep Timing Questionnaire (STQ) (Monk et al., 2003); the Epworth Sleepiness Scale (ESS) (Johns, 1991); the Risk-Taking Index (RTI) (Nicholson et al., 2006); and the Sleep Practices, Beliefs and Attitudes Questionnaire (SPAQ) (Grandner et al., 2013). The survey also included basic demographic questions, and questions related to the respondent's experiences of driver sleepiness.

Participants were Queensland, Australia, based drivers who held a current open or provisional driving licence and drove regularly. As younger drivers are overrepresented in sleep related crashes (Armstrong et al., 2013), respondents were restricted to those aged 30 years and under. The final sample consisted of 467 respondents (27% male). The survey was promoted to both students and non-students; all respondents completed the survey online. Ethics approval for data collection was granted by QUT.

The secondary analysis for the current work considered the COM-B model of behaviour change (see Figure 1). The analysis sought to identify which aspects of the COM-B model most strongly influence driver sleepiness behaviour. Data were screened for appropriateness for modelling. Questions with categorical binary answers (no order meaning) were not considered. Two researchers independently categorised each survey item under one of the six COM-B sub-headings. Any disagreements were discussed until a common decision was reached. Once allocated the survey items which most strongly aligned to the COM-B were taken forward to be used in structural equation modelling. The final survey items used are showed in Table 1. The demographic factors of gender, age and months having held a driving licence were used in the model.
Sleep related driving behaviour was characterised by response to the questions:

- In the past 12 months have you fallen asleep whilst driving? Y/N
- Of the average number of journeys taken each week as the driver, on average, how many of these would be completed when you are feeling sleepy?

Table 1 – Survey items which were entered into structural equation model aligned to COM-B model sub-headings

Capability	
Physical Capability	*Psychological Capability*
-Total ESS (out of 24, higher = more sleepy) -When you are sleepy how impaired is your driving? (0 no impairment, 10 extreme impairment)	-When you are sleepy how well are you able to cope with boring tasks? (0 not able, 10 extremely able) -When you are sleepy how well are you able to cope with complex thinking? (0 not able, 10 extremely able) -When you are sleepy how is your mood affected? (0 more negative, 10 more positive)
Motivation	
Automatic motivation	*Reflective motivation*
-Do you read, watch TV, Eat or drink, work in bed? (0 not at all, 5 very often)	-Not enough sleep can lead to serious consequences (1 strongly agree, 5 strongly disagree) -My sleep is important to my health (1 strongly agree, 5 strongly disagree)
Opportunity	
Physical opportunity	*Social opportunity*
-Agreement with. Commute affects how I sleep, home responsibility affects how I sleep, work affects how I sleep (1strongly agree, 5 strongly disagree)	-If people drive sleepy how likely is it for people to get in trouble from the police? (1 not at all, 5 very likely) -If you drive sleepy how likely is it for you to get in trouble from the police? (1 not at all, 5 very likely) -If you were driving while you were sleepy, how much would you worry about getting in trouble with the police? (1 very much, 7 not at all)

Participants with more than 25% missing data were removed (9 removed). Any missing values for remaining participants were imputated. Exploratory factor analysis included:

- Pattern matrix check. If a variable does have various cross loadings (values in multiple columns), exclude until each category of the items loads to different factor.
- Variance check. At least 50% of variance should be explained by the factor solution provided.
- KMO check. Should be more than 0.5 (sampling adequacy of data).
- Reliability: Cronback alpha check (>0.5). Within a subcategory if one factor does not add anything beyond another (not an independent addition) then it should not go in the model.

3. RESULTS

Data from 458 participants, mean age 21.2 years (SD=3.8), 330 female 128 male, mean licensure 39.7

months (SD=38.2) were used in the analysis. The premise of the model is that the more capability, motivation and opportunity a person has, the safer their sleep related driving behaviour. The amount of sleep related safe behaviour a person has, influences the likelihood of driver sleepiness behaviours.

The final Model reported a Chi-square = 190.9, df=85, Comparative Fit index = 0.935 (to be a sensitive model CFI ≥0.9), Root mean square error of approximation (RMSEA) = 0.052 (RMSEA <0.08 considered valid), PCLOSE=0.342. Only statistically significant predictors remain in the model that is visually represented with the path diagram in Figure 2. It should be noted that standardised coefficients are reported on the path diagram.

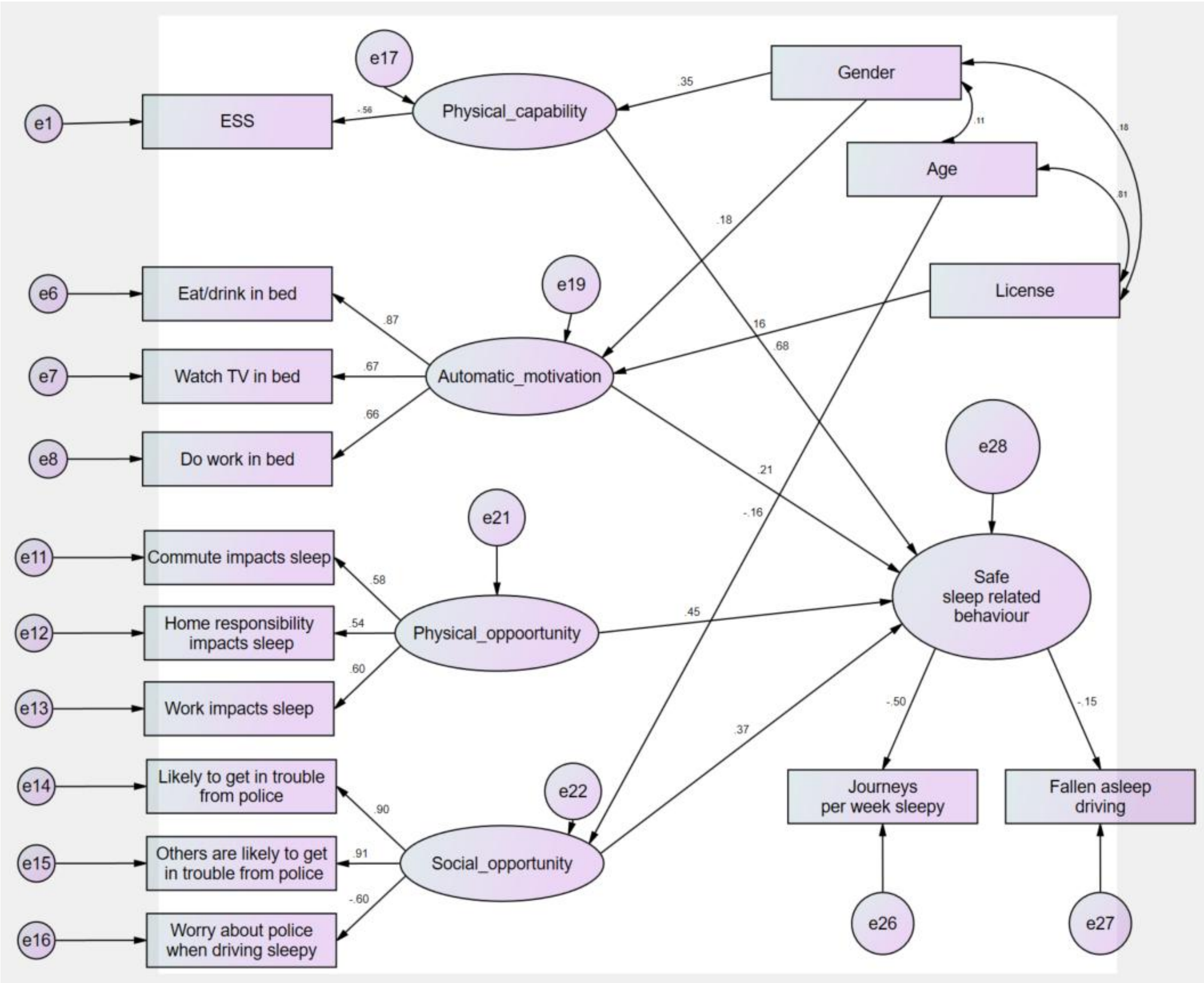

Figure 2 - SEM denoting factors affective safe sleep related driving behaviour, and driver sleepiness

The main outcomes from the model were:

- Physical capability was the greatest predictor of safe sleep related driving behaviour (0.68, p = .003). This was followed by Physical opportunity (0.45, p = .006) and Social Opportunity (0.37, p<0.001). Automatic motivation (0.21, p=.053, significant at 90% confidence level) appears to be less important than the others.

- Gender has a significant impact on Physical capability (0.35, p<.001) and automatic motivation (0.18, p<.001), both aspects are of greater influence for men. Men appear to have greater physical capability and automatic motivation. Having more physical capability and more automatic motivation leads to safer driving behaviour according to the model.
- Age had significant impact on social opportunity. The older the person, the less the social opportunity. Social opportunity is needed to inform good sleep related driving behaviour, and so driver sleepiness behaviour is more likely in older participants (-0.16, p<.001).
- Months held a licence had an impact on Automatic motivation, the longer the licence has been held (0.16, p =.002), the more the automatic motivation and therefore the safer the behaviour.
- Physical capability was only represented by ESS (only statistically significant variable). Higher levels of physical capability are correlated with lower ESS and less risky behaviour (-0.56, p<.001). NB. The sample had particularly high ESS (M=15.5, SD=3.8, Range 8 – 26, 84.9% ESS ≥ 12).
- Higher levels of automatic motivation are related to higher frequency of watching TV (0.67, p <.001), eating/drinking (0.87, p<.001) or working (0.66, p<0.001) in bed, and safer sleep related driving behaviour.
- A stronger belief in getting in trouble with the authorities when driving sleepy -yourself (0.90, p<0.001) or others (0.91, p<0.001)- is associated with greater social opportunity and therefore, with safer sleep related behaviour.
- Lower levels of worrying about the police (reverse scale-value in variable increases) when driving are related to a weaker person's social opportunity to act (-0.60, p<0.001), and in turn to less safer sleep related driving behaviour.
- A weaker belief that commuting (0.58, p<0.001), work (0.60, p<0.001) and home responsibilities (0.54, p<0.001) impact on sleep is associated with greater physical opportunity and therefore, safer sleep related behaviour. The belief that commuting impacts on sleep loads more strongly to physical opportunity compared to the work and home responsibility.
- In the model sleepy related behaviour was explained by the number of the trips when sleepy and on having fallen asleep whilst driving. The number of the trips proved to explain better sleep related behaviour (-0.50, p<.001).

4. Discussion

The higher-level COM-B areas (capability, motivation and opportunity) do not appear to affect sleep-related driving behaviour, however, prediction is found at a sub-area level. In other words, capability, motivation and opportunity do not act as mediating variables between the sub-categories and the behaviour. When developing interventions targeted at drivers most likely to drive when sleepy, it would be most beneficial to address the sub levels of physical capability, physical opportunity and social opportunity.

6

Gender, age and duration of licensure all had differing impacts on behavioural elements which predict sleep related driving behaviour. Similarly, sleep-related crashes statistics also demonstrate differences between demographics, with younger, inexperienced and male drivers all being overrepresented in sleep-related compared to non-sleep-related crashes (Armstrong et al 2013). It may be beneficial to tailor driver sleepiness interventions towards behavioural elements most relevant for each demographic group, e.g., aiming to increase physical capability and automatic motivation will likely have most benefit with female participants, as within this sample these aspects were greater for men. Automatic motivation increase was associated with longer licensure which provides some support for the potential benefit of graduated driving licencing in driver sleepiness management. For example, night-time driving restriction has been shown to reduce crash involvement of young drivers (Fell et al., 2011).

Identifying and targeting those with higher ESS could be beneficial as higher levels of ESS are correlated with reduced physical capability, thereby increased risking sleep-related driving behaviour. ESS is a widely used tool for quantifying trait sleepiness, however, validity at an individual (rather than group) level has been questioned (Kendzerska et al., 2014). Despite this, it may be useful for indicating those who may benefit from medical screening for obstructive sleep apnoea (Rosenthal et al., 2008).

Those who worry about the police when driving sleepy are less likely to do it. Therefore, increasing the belief that you and others could get in trouble with the police might be a mechanism by which to reduce sleepy driving. However, this is a complex issue to address as the police do not have a valid roadside test for driver sleepiness in the same way they do for drink driving. Nevertheless, even for drink driving, when random breath testing is possible, exposure to this police practice alone does not create intention not to drink drive (Freeman et al 2021).

In this analysis, it was possible to retrospectively apply the COM-B model as a theoretical grounding for SEM, however, it should be noted that the survey was not originally conducted with this purpose, therefore there are restrictions in the suitability for the data used in this analysis. Results should be considered indicative only. Further limitations include that some data was missing and had to be imputed, and the sample included more female than male participants, and a high mean ESS.

A key cause of sleepiness amongst young drivers relates to their specific lifestyle, that is, young adults are typically sleepier than older adults for example, because of chronic sleep loss (Smith et al., 2005). They, therefore, have a greater tendency to experience driver sleepiness (Lucidi et al., 2013; Guttman, 2013; Amponsah-Tawiah & Mensah, 2016; Watling et al., 2020). Since sleepiness is a state which is impacted by lifestyle choices, interventions aiming to reduce driver sleepiness will be most effective by targeting wholistic behaviour change to address overall alertness, independently from driving.

REFERENCES

Amponsah-Tawiah, K., & Mensah, J. (2016). The impact of safety climate on safety related driving behaviours. *Transportation Research Part F: Traffic Psychology and Behaviour*, *40*(Jul), 48-55. https://doi.org/10.1016/j.trf.2016.04.002

Armstrong, K., Filtness, A. J., Watling, C. N., Barraclough, P., & Haworth, N. (2013). Efficacy of proxy definitions for identification of fatigue/sleep-related crashes: An Australian evaluation. *Transportation Research Part F: Traffic Psychology and Behaviour*, *21*, 242-252.

Buysse, D. J., Yu, L., Moul, D. E., Germain, A., Stover, A., Dodds, N. E., ... & Pilkonis, P. A. (2010). Development and validation of patient-reported outcome measures for sleep disturbance and sleep-related impairments. *Sleep*, *33*(6), 781-792.

Connell, L.A., McMahon, N.E., Redfern, J., Watkins, C.L. & Eng, J.J. (2015). Development of a behaviour change intervention to increase upper limb exercise in stroke rehabilitation. *Implementation Science*, *10*, 34. https://doi.org/10.1186/s13012-015-0223-3

Fell, J. C., Todd, M., & Voas, R. B. (2011). A national evaluation of the nighttime and passenger restriction components of graduated driver licensing. *Journal of safety research*, *42*(4), 283-290.

Freeman, J., Parkes, A., Truelove, V., Lewis, N., & Davey, J. D. (2021). Does seeing it make a difference? The self-reported deterrent impact of random breath testing. *Journal of safety research*, *76*, 1-8.

Fylan, F. (2017) *Using Behaviour Change Techniques: Guidance for the Road Safety Community*. RAC Foundation. Retrieved April 13th, 2023, from https://www.racfoundation.org/research/safety/behaviour-change-techniques-guidance-for-the-road-safety-community.

Grandner M.A., Jackson, N., Gooneratne, N.S. & Patel, N.P. (2013). The Development of a Questionnaire to Assess Sleep-Related Practices, Beliefs and Attitudes. *Behavioural Sleep Medicine*, *12*(2), 123-142. https://doi.org/10.1080/1542002.2013.764530.

Guttman, N. (2013). "My Son Is Reliable": Young Drivers' Parents' Optimism and Views on the Norms of Parental Involvement in Youth Driving. *Journal of Adolescent Research*, *28*(2), 241-268. https://doi.org/10.1177/0743558411435853

Johns, M.W. (1991). A New Method for Measuring Daytime Sleepiness: The Epworth Sleepiness Scale. *Sleep*, *14*(6), 540-545. https://doi.org/10.1093/sleep/14.6.540

Kendzerska, T. B., Smith, P. M., Brignardello-Petersen, R., Leung, R. S., & Tomlinson, G. A. (2014). Evaluation of the measurement properties of the Epworth sleepiness scale: a systematic review. *Sleep medicine reviews*, *18*(4), 321-331.

Lucidi, F., Mallia, L., Violani, C., Giustiniani, G. & Persia, L. (2013). The contributions of sleep-related risk factors to diurnal car accidents. *Accident Analysis and Prevention*, *51*, 135-140. https://doi.org/10.1016/j.aap.2012.11.015

Lyon, C., Mayhew, D., Granié, M.-A., Robertson, R., Vanlaar, W., Woods-Fry, H., Thevenet, C., Furian,

G. & Soteropoulos, A. (2020). Age and road safety performance: Focusing on elderly and young drivers. *IATSS Research*. https://doi.org/10.1016/j.iatssr.2020.08.005

Mayne, J. (2018) *The Capabilities, Opportunities and Motivation Behaviour-Based Theory of Change Model*. [Unpublished working paper].

McDonagh, L.K., Saunders, J.M., Cassell, J., Curtis, T., Bastaki, H., Hartney, T. & Rait, G. (2018). Application of the COM-B model to barriers and facilitators to chlamydia testing in general practice for young people and primary care practitioners: a systematic review. *Implementation Science*, *13*, 130. https://doi.org/10.1186/s13012-018-0821-y

Michie, S., van Stralen, M.M. & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(1), 1-12. https://doi.org/10.1186/1748-5908-6-42

Monk, T.H., Buysse, D.J., Kennedy, K.S., Potts, J.M., DeGrazie, M. & Miewald, J.M. (2003). Measuring Sleep Habits Without Using a Diary: The Sleep Timing Questionnaire. *Sleep*, *26*(2), 208-212. https://doi.org/10.1093/sleep/26.2.208

Nicholson, N., Soane, E., Fenton-O'Creevy, M. & Willman, P. (2006). Personality and domain-specific risk taking. *Journal of Risk Research*, *8*(2), 157-176. https://doi.org/10.1080/1366987032000123856

Rosenthal, L. D., & Dolan, D. C. (2008). The Epworth sleepiness scale in the identification of obstructive sleep apnea. *The Journal of nervous and mental disease*, *196*(5), 429-431.

Smith, S., Carrington, M. & Trinder, J. (2005). Subjective and predicted sleepiness while driving in young adults. *Accident Analysis and Prevention*, *37*(6), 1066-1073. https://doi.org/10.1016/j.aap.2005.06.008

Watling, C.N. (2014). Sleepy driving and pulling over for a rest: Investigating individual factors that contribute to these driving behaviours. *Personality and Individual Differences*, *56*(1), 105-110. https://doi.org/10.1016/j.paid.2013.08.031

Watling, C.N., Shaw, L.M. & Watling, H. (2020). Sleep-impaired emotional regulation, impaired cognition, and poor sleep health are associated with risky sleepy driving in young adults. *Traffic Injury Prevention*, *21*(2), 133-138. https://doi.org/10.1080/15389588.2019.1710499

Developing Countermeasures to Improve Fitness to Drive in Professional Drivers

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Keywords: countermeasures, fitness to drive, medication, real world study, professional drivers.

1. Background

Professional drivers are at risk to be involved in a crash associated with an impairment (Talbot et al., 2016; Hanowski, et al., 2007). Working conditions, for example shift work, can lead to increased fatigue or stress (e.g. Åkerstedt et al., 2001) and alcohol, drugs (illegal/medicinal) increases crash risk (Romano et al., 2014). The PANACEA project[1] (2021-2024), aims to design and pilot a professional driver fitness to drive platform that combines technology measuring alcohol, drugs, fatigue and stress prior to a shift and fatigue during a shift and delivers post-trip countermeasures. This abstract will provide an overview of how the countermeasures addressing fatigue, stress, alcohol use and drugs were developed. The countermeasures will be listed, but results about their effectiveness and user acceptance are not yet available as trials are ongoing.

2. Method

A four-step process was undertaken to identify potential countermeasures. Step 1 involved conducting focus groups and interviews with professional drivers and manages to gain information about the impairments they viewed as most problematic. Step 2 involved a focused a literature review of the state of the art for countering impairments for professional drivers within the PANCEA use cases (fatigue/shift schedules and bus/shuttle drivers; stress in refuse drivers; licit/illicit drug use for PTWs) and behaviour change theories. Step 3, a feasibility exercise was conducted to create a short list of potential countermeasures. This took into account steps 1 and 2 as well as the technology available to the project. Finally, Step 4, countermeasures were selected to be fully developed and tested. Countermeasures were designed with a primary user in mind, either: the driver, employer or enforcement officers. Three types of countermeasures were considered: operational, delivered and actioned during a shift; tactical, delivered just after the shift with behaviour change to be applied to the

[1] The PANACEA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 953426.

next shift and strategic which are delivered following the shift and involve behaviour change both on and off shift.

3. Results

Nine countermeasures were developed that primarily addressed fatigue, stress, drugs and alcohol. For the driver: Stress Management (Operational), inform the driver about stress level and provides exercises to reduce; Fatigue Report (Tactical), information for the driver about their fatigue level that day; Fatigue Questionnaire (Strategic), assisting driver to assess and contextualise their fatigue and raise concerns with operator. For the operator: Fatigue alert (Operational), inform operator if critical fatigue state is reached; Licit drug debriefing (Strategic) support operator in conducting debriefing session with driver if legal drugs detected; Fatigue debriefing (Strategic), provide information to help coach/train drivers in sleep/fatigue management. For the Enforcer: Training material (Strategic), training in the use of newly developed alcohol (SENSEAIR) and drugs (LEITAT) detectors. A cloud-based system, connected to the PANACEA platform, was developed to deliver the countermeasures to drivers via an app and the operators via a website.

4. Conclusion and Next steps

Countermeasures developed and integrated in the PANACEA platform are designed to address the impairments and needs identified by the focus groups and interviews and literature review detailed above. These countermeasures will be tested in five pilots (April – Nov 2023) involving autonomous shuttle drivers, PTW riders, taxi drivers, refuse truck drivers, bus drivers and police officers. It is likely that some drivers/operators will not have the full experience of the countermeasures during the pilots. Focus groups and interviews will be conducted to demonstrate countermeasures not experienced and gain feedback. The focus groups will also be used to assess user acceptance and opinion on the countermeasures. These results will be used to generate recommendations for improvement of the countermeasure and PANACEA platform as well as assessing the potential impact of such a fitness to drive platform could be if deployed more widely.

REFERENCES

Hanowski, R. J., Hickman, J., Fumero, M. C., Olson, R. L., & Dingus, T. A. (2007). The sleep of commercial vehicle drivers under the 2003 hours-of-service regulations. Accident Analysis & Prevention, 39(6), 1140-1145

Talbot, R., Aigner-Breuss, E., Kaiser, S., Alfonsi, R., Braun, E., Eichhorn, A., ... & Hay, M. (2016). Identification of Road User related Risk Factors. SafetyCube Deliverable 4.1.

Romano, E., Torres-Saavedra, P., Voas, R. B. & Lacey, J. H. (2014). Drugs and Alcohol: Their Relative Crash Risk. Journal of Studies on Alcohol and Drugs, pp 1–9

Åkerstedt, T., & Kecklund, G. (2001). Age, gender and early morning highway accidents. Journal of sleep research, 10(2), 105-110.

Action-Meaning Networks - A Novel Methodology to Identify Unsafe Use of Driving Automation

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ABSTRACT

The transition from manual to automated driving holds the promise of safer traffic and numerous societal benefits. However, ensuring the safe usage of driving automation is crucial for realizing these promises and facilitating a successful transition. Introducing driving automation into vehicles presents challenges for drivers, often resulting in behavioural adaptations that undermine the anticipated advantages. Therefore, it is imperative to understand how drivers engage with driving automation systems (DAS) and the significance they attribute to them, as the meaning assigned to these systems significantly influences their usage.

This paper presents a novel methodology aimed at investigating the utilization of driving automation by examining both users' actions and the meaning they associate with the system during operation and organizing them into action-meaning networks. To illustrate this methodology, it was applied to take-over and hand-over requests, on a previously collected dataset from an on-road study. By employing this methodology, usage patterns were revealed, enabling the distinction of how drivers' actions and comprehension evolved over time and with repeated interaction. Additionally, unsafe actions and meanings associated with the interaction with the DAS were identified, highlighting potential hazards in long-term or alternative usage scenarios.

Based on the evaluation of the results, it is reasonable to conclude that this methodology has the potential to complement existing approaches. By uncovering usage patterns and associated meanings of users' interaction with DAS, it has the potential to facilitate the development of strategies to ensure safe usage and promote a positive user experience with such systems.

Keywords: driving automation, safety, users' understanding, meaning, actions, methodology.

1. INTRODUCTION

The transition from manual driving to automated driving promises a range of benefits for society, among them the promise of safer traffic (Spath et al., 2009). To sustain these promises and enable such a transition, safe usage of driving automation is critical. However, the introduction of driving automation into vehicles comes with challenges for drivers and may lead to behavioural adaptations that mitigate the benefits the systems may offer (MacDonald et al., 2018). Therefore, it is of significant importance to identify how drivers use driving automation systems (DAS) and what meaning they associate with them - seeing that the meaning we ascribe is believed to largely influence how we use a system (Krippendorff, 2005). In the context of driving automation, meaning has been identified to relate to the allocation, utilisation, operation and communication (Johansson, 2022).

In an attempt to address the aforementioned challenges, this paper describes a novel methodology to investigate the use of driving automation by identifying both users' actions and the meaning associated with the system during use. The approach used to achieve these results incorporates (1) two data collection methods, a think-aloud protocol, and video observations; (2) an analysis that structures the use of the driving automation systems into action-meaning networks.

2. METHOD

The following sections describe the data collection procedure and study setup, as well as introduce the proposed methodology, which was applied on the presented data set.

2.1 Data Collection & Analysis

The approach presented in this paper incorporates two data collection methods; (i) a *think-aloud protocol* (Charters, 2003), where users speak out loud while using a system, intended to elicit the users' interpretation process and meaning associated with the system; and (ii) *video observations*, intended to capture the actions perform when using the system.

The analysis consists of two parts that correspond to each of the two data collection methods used. The *first part* of the analysis focuses on identifying the actions that the users perform when interacting with the system. The actions are identified from the video data, and each action (within the predefined task) is organized into a diagram with a line connecting each action, resulting in a chart presenting actions in a sequence chart. If several users perform the same actions in the same order, it is indicated with a thicker line, corresponding to the number of users that performed the same actions in the same order. This results in a network of actions and procedural links after incorporating the data from several cases. The *second part* of the analysis focuses on the qualitative think-aloud data and aims to identify meanings associated with the system, e.g., interpretations of signals or status of the system, from the users' statements. These statements can occur during the task itself or just after, since during situations with high workload users may have difficulties verbalizing their thoughts. The meanings are then assigned to the procedural link that corresponds to the situation it refers to. Procedural links may need to be divided into several links if different meanings are associated with the same action. However, since the meanings users associate with systems are diverse, it may be necessary to group different similar meanings into themes, for the networks to not become too complex. Lastly, instructions given by the test leader – i.e. users not able to resolve the task on their own – should also be indicated on the procedural links in the network. The elements of the Action-Meaning Networks are summarised in Table 1.

Table 1 - Elements of the Action-Meaning Network

Element	Description	Visualization
Actions	The actions performed when using the system.	Circle with text describing the action inside.
Procedural links	The order in which the actions are performed.	The line between the circles, where the thickness of the line illustrates number of links.
Meaning	The task-relevant interpretations of the system.	Text - describing the meaning associated with the system - on the procedural lines.
Instructions	The instructions given by a test leader for users to resolve the task.	Triangle with text describing the content of the instruction given.

2.2 Use case

To illustrate the approach and assess the methodology on a use case, a dataset from a previously conducted on-road driving study was used. This paper will briefly explain the procedures of the study. However, more in-depth information about the setup of the study is found in Novakazi et al. (2021) and Johansson et al. (2021).

2.2.1 Procedure & Setup

The study was conducted in the San Francisco Bay Area and the participants experienced a supervised DAS and an unsupervised DAS, the latter was simulated through a WOz-approach, during rush hour traffic. For the purpose of this work, we have focused on the unsupervised DAS, specifically the hand-over and take-over situations. The DAS in focus was only available in congested traffic, with a max speed of 60 kph, on partially-to-fully-controlled access roads. Before the test runs, participants were presented with oral and written instructions about the capabilities and limitations of the system. Furthermore, video and audio data were collected and the test leader – sitting in the front passenger seat – reminded participants to verbalize their thoughts and if necessary, prompted them with questions.

2.2.2 Hand-over & Take-over

Hand-over – When the conditions of the DAS were fulfilled, the participants received a hand-over request (HOR) to take control of the car, signalled both audibly and visually through cues displayed in the instrument cluster. To activate the system the participants made a sustained press on two buttons on the left and right side of the steering wheel. When the system was active, the vehicle performed the dynamic driving task, and the participants were able to engage in non-driving-related activities.

Take-over - The participants got a take-over request (TOR) to resume manual control from the car through a visual and auditory prompt and pull on the seatbelt whenever the availability conditions were no longer fulfilled. If the participant did not take back the control within 10 seconds, the prompts escalated into a more urgent auditory and visual prompt and an additional pull of the seatbelt. To deactivate the system the driver performed the same procedure as when activating it; a simultaneous sustained press on two buttons located on the left and right side of the steering wheel.

3. RESULTS

The result from using the methodology is based on data from 12 participants, where each participant performed between two and five hand-over and take-over procedures, depending on the traffic conditions that they encountered. The networks that resulted from the analysis are different in character, both between and within the hand-over and take-over procedures, showing that participants acted in diverse ways and associated different meanings, even though the tasks were small and well-defined. An overview of the Networks is found in Figure 1.

Using the presented methodology, three main types of patterns were discerned: (i) Overall use patterns, (ii) Use paths, and (iii) Specific actions and meanings.

The general shapes of the networks represent the **general use patterns**, which differed in two accounts. First, the general use patterns differed between the hand-over and take-over procedures, where the hand-overs had simpler networks with fewer actions and procedural links than the corresponding take-over procedures, showing that the hand-overs were performed more similarly by participants. Second, the general use pattern differed depending on the order of the hand-over or take-over, becoming vertically thinner, showing that the participants' use of the system changed over time after repeated procedures, where more participants similarly used the system.

The second type of pattern **- use paths** – are the paths that are formed in the networks, which are visualizations of diverse ways users accomplish the task. One example is the three different use paths observed in the first hand-over procedure. Most participants are clustered in the middle use path, which is the expected sequence for activation. In contrast to these participants, the upper use path shows several more actions to accomplish the task in a trial-and-error approach. More alarmingly, the lower use path shows a participant that also used more actions but was not able to accomplish the task by themselves and needed instructions from the test leader two times during the procedure.

The third and last pattern is the **specific actions and meanings** that are possible to discern in the networks. They describe not only how participants acted (e.g., participant just grabs the steering wheel the first time they were supposed to take over the control), but also infer their occurrence (e.g., the signal was interpreted only as 'take action' rather than what specific action to take). Another example is that the meaning of the take-over notification changed for some participants from the first to the second time, from only 'take action' to 'take over'.

Hence, the analysis identified three different types of use patterns which reveal actions and procedures that were unsafe or could lead to unsafe situations, as well as meanings associated with the DAS that could lead to unsafe use over time.

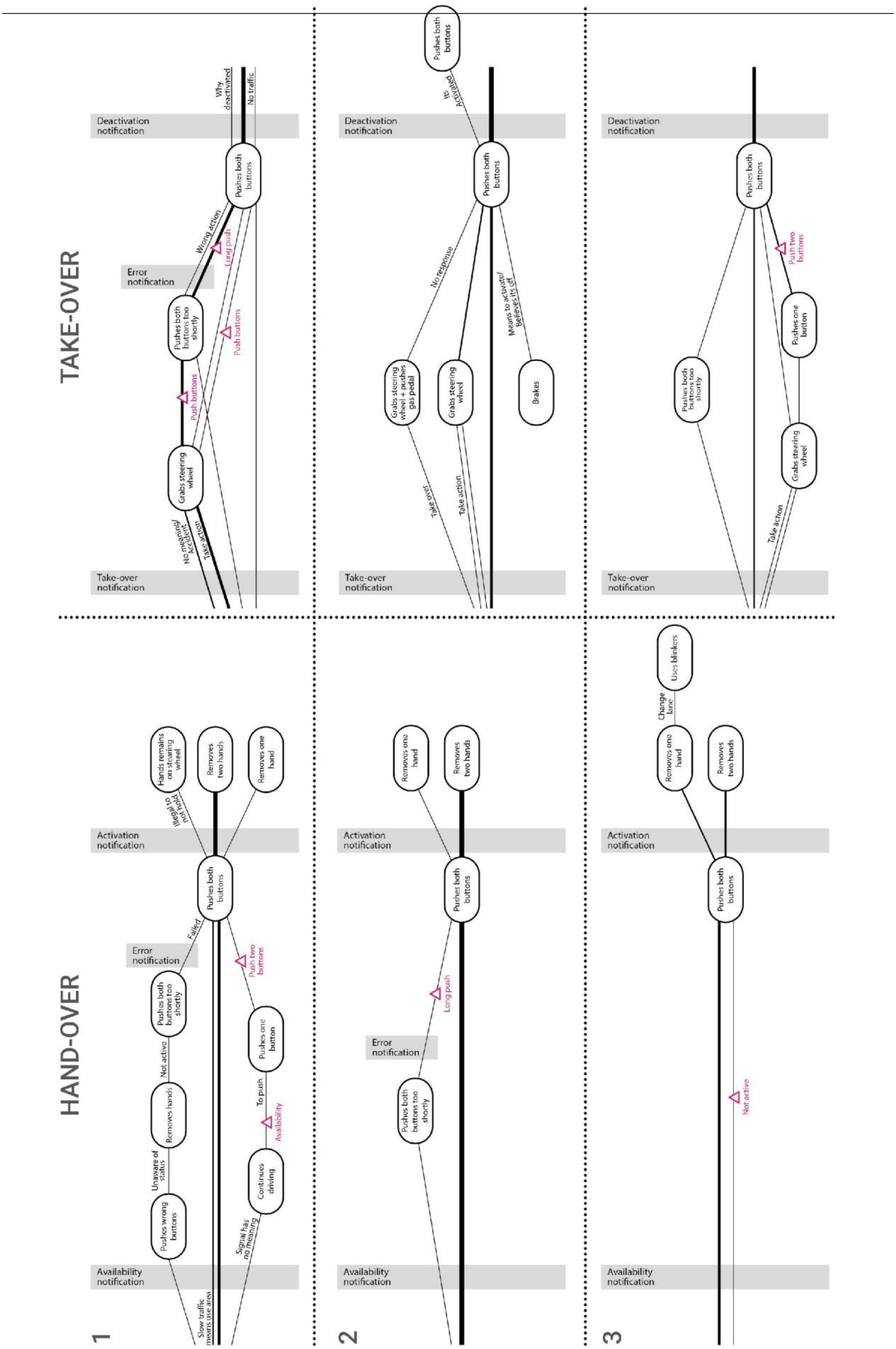

Figure 1 - Summary of the different Action-meaning networks.

DISCUSSION

After evaluating the available results, it seems reasonable to conclude that the Action-meaning network approach presents a promising complement to established methods. The ability to uncover patterns in the interaction with driving automation systems can aid in developing safe usage strategies and promoting the development and positive user experience of such systems.

Despite its potential benefits in identifying use patterns and related meanings, further improvements are required to optimize the methodology's effectiveness. The study used to test the methodology, included a think-aloud protocol and the test leader in the study posted questions to get the participants to verbalize their thoughts. Even with this procedure, it was sometimes hard to identify meanings associated with the driving automation system, showing that identifying meaning may be inherently difficult since all stimuli carry meaning, however, users may not be consciously aware and able to verbalize this. Nevertheless, the prompts appear to play a crucial role in eliciting verbalization of the meanings, but they should be more aligned with the purpose of this methodology rather than the one used in the investigated study.

Furthermore, a trade-off between the size and openness of the task investigated and the complexity of the resulting network may exist. The tasks chosen for this paper are small and well-defined, which resulted in networks that were not too complex to conclude from. However, when the task expands, such as the examination of the entire usage sequence, instead of only the take- and hand-over, the networks might become overly intricate, making it challenging to draw conclusions. This can pose a possible limitation and further exploration into this trade-off needs to be made.

Consequently, the next phase in methodology development would involve evaluating and refining it through application in a wider range of user studies. Additionally, future efforts should concentrate on categorizing the types of meaning and actions that potentially result in unsafe usage strategies applied by users of DAS.

REFERENCES

Charters, E. (2003). The use of think-aloud methods in qualitative research an introduction to think-aloud methods. *Brock Education Journal*, *12*(2).

Johansson, M., Mullaart Söderholm, M., Novakazi, F., & Rydström, A. (2021). The decline of user experience in transition from automated driving to manual driving. *Information*, *12*(3), 126.

Johansson, M. (2022). Making sense of making sense - exploring users' understanding of automated vehicles during use. Chalmers University of Technology, Sweden (PhD Thesis).

Krippendorff, K. (2005). *The semantic turn: A new foundation for design*. crc Press.

McDonald, A., Carney, C., & McGehee, D. V. (2018). V*ehicle Owners' Experiences with and Reactions to Advanced Driver Assistance Systems* (Technical Report). Washington, D.C.

Novakazi, F., Johansson, M., Strömberg, H., & Karlsson, M. (2021). Levels of what? Investigating drivers' understanding of different levels of automation in vehicles. *Journal of cognitive* *engineering and decision making*, *15*(2-3), 116-132.

Spath, D., Braun, M., & Bauer, W. (2009). Integrated human and automation systems. *Springer handbook of automation*, 571-598.

Exploring driver stress and the effects of breathing practice and guided mindfulness on stress relief

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Keywords: Driver, Stress, Remedies, Breathing, Mindfulness, Simulator.

1. Background

Previous research showed that driver stress is clearly identified as an important risk factor, with a notable impact on the cause of road accidents, but also of repeated incivilities. More than affecting safety, driver stress also affects well-being as evidenced by relationships between driver stress and negative emotions (e.g., anxiety, fear, or anger). Detecting and remedying driver stress are crucial functions to promote both well-being and safety especially due to the causal relationship between stress, negative emotions and poor driving performance. In this context, the current study seeks to identify relevant physiological indicators of stress while driving. A second goal is exploring the effects of potential remedies on driver stress. Stress was manipulated using three types of stressors that previously demonstrated their efficiency to induce stress (Gotardi et al., 2019; Pedrotti et al., 2014; Rendon-Velez et al., 2016; Wickens et al., 2015). These stressors were disruptive sounds, time pressure and social examination. Two stress remedies were also explored, including specific breathing training, and guided mindfulness while driving.

Mindfulness was described as “the act of paying attention to the present moment, with openness and acceptance” (Kabat-Zinn, 2005). When an individual reaches a mindfulness state, his/her “*thoughts and feelings are observed as events in the mind, without over-identifying with them and without reacting to them in an automatic, habitual pattern of reactivity*” (Bishop et al., 2004). In addition, various studies reported an advantageous effect of mindfulness on stress (Astin, 1997; Carmody et al., 2008; Creswell & Lindsay, 2014).

In addition, various researchers reported that specific breathing techniques can alleviate anxiety, everyday stress, depression, post-traumatic stress, and promote a state of calm alertness (Brown & Gerbarg, 2005). Such stress relief is based on the fact that controlling breathing patterns leads to changes in autonomic nervous system (ANS) functions, such as heart rate variability (Lehrer et al., 1999, Sovik, 2000)

2. Method

Participants. 66 participants took part in the driving simulator study. Twenty-nine were allocated to the experimental group that is the group that underwent stress manipulation and remedies for stress relief.

Twenty were assigned to the control group, which corresponds to the group that underwent stress manipulation without stress remedies. Finally, seventeen participants were included in the trained group, that is the group that experienced stress manipulation and stress, in addition to being trained to breathe at 6 breaths per minute.

Experimental design and procedure. After a training session, all participants completed three stress driving sessions, interspersed with three stress-free driving sessions. The driving sessions, varying from 5 to 8 minutes, are described below:

Stress driving. In the three stress driving sessions, stress was first manipulated by designing an unpredictable, high-traffic city environment. In order to maximize the chances of inducing stress, disruptive sounds, time pressure and social examination were included.

Free-stress driving. In contrast to stress driving sessions, the stress-free driving sessions were distinct between groups. While the stress-free driving sessions for the control group took place in a predictable, low-traffic, stress-free environment, the sessions for the experimental and trained groups included, in addition, an audio recording played during the driving. In this recording, participants could hear a woman's voice inviting them to pay attention to their driving environment and body sensations (e.g., breathing, body contact with the seat, steering wheel or pedals). This audio was intended to guide participants towards mindfulness, conducive to serenity and alertness.

In order to gauge driver stress, two methods were used: subjective (Likert scales of stress, anxiety, arousal and emotional valence) and physiological (heart rate, heart rate variability, and breathing rate).

3. Results

Difference across driving conditions. We assumed that drivers experienced more stress under stress driving conditions than under stress-free driving conditions (hypothesis 1). The results from the ANOVAs indicated significant differences between types of driving condition for a number of subjective and physiological measurements;

Subjective. Post-hoc tests confirmed our hypothesis that, in the stress conditions, subjective stress, anxiety and arousal are greater, and emotions more positive, than in the stress-free conditions (stress, $t = 14.29$, $p < .001$, 95% CI [1.091, 1.725], $d = 1.408$; anxiety, $t = 9.706$, $p < .001$, 95% CI [0.820, 1.426], $d = 1.123$; arousal, $t = 9.266$, $p < .001$, 95% CI [0.676, 1.197], $d = 0.937$; valence, $t = -6.965$, $p < .001$, 95% CI [-0.964, -0.480], $d = -0.722$).

Physiological. Pairwise comparisons reported that during the stress conditions, mean heart rate, SDNN/RMSSD, mean breathing rate are greater than in the stress-free conditions (heart rate, $t = 5.985$, $p < .001$, 95% CI [0.087, 0.194], $d = 0.141$; SDNN/RMSSD, $t = 2.338$, $p < .05$, 95% CI [0.028, 0.399], $d = 0.214$; breathing rate, $t = 8.978$, $p < .001$, 95% CI [0.514, 0.923], $d = 0.719$ (**Fig. 1**)). Conversely, LF power, HF power and RSA are both lower in the stress conditions than in the stress-free conditions (LF power, $t = -3.810$, $p < .001$, 95% CI [-0.447, -0.129], $d = -0.288$; HF power, $t = -3.258$, $p < .01$, 95% CI

[-0.327, -0.072], d = -0.199; RSA, t = -3.416, p < .001, 95% CI [-0.434, -0.105], d = -0.270).

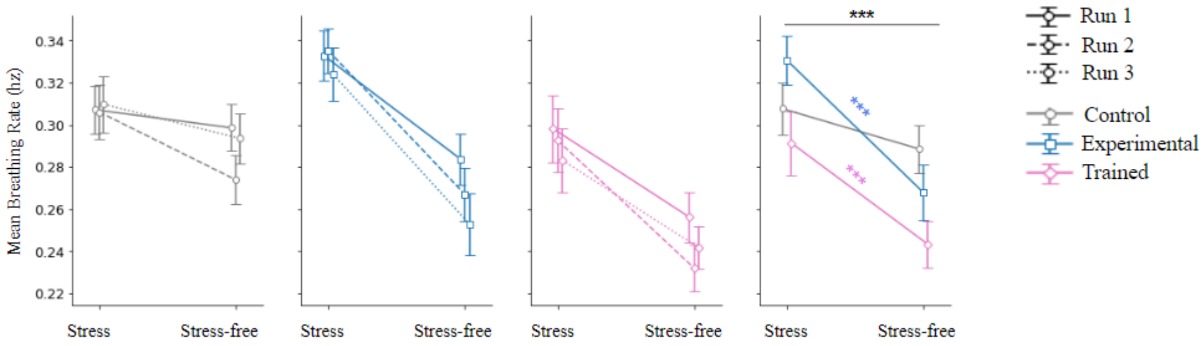

Figure 1 - Results of breathing rate in the groups (control, experimental, trained), across the driving conditions (stress, stress-free) and over time (run 1, 2, 3).

Difference in groups across driving conditions. We expected that changes in the groups would vary across driving conditions, and specifically that the groups who experienced guided mindfulness would be less stressed (hypothesis 2). The ANOVAs revealed a significant interaction between the main effect of the group and the main effect of the type of driving condition, for the physiological measurement, but not for the subjective measurement;

Post-hoc tests reported that, only in the experimental group, RMSSD, HF power and LF power are greater in the stress-free conditions than in the stress conditions (RMSSD, t = -3.780, p < .01, 95% CI [-6.316, -0.672], d = -0.189; HF power, t = -4.602, p < .001, 95% CI [-242.6, -49.07], d = -0.411; LF power, t = -5.286, p < .001, 95% CI [-903.6, -241.9], d = -0.583). In addition, pairwise comparisons indicated a decrease in mean breathing rate under free-stress *versus* stress conditions for both the experimental group (t = 8.882, p < .001, 95% CI [0.041, 0.084], d = 1.037) and trained group (t = 5.204, p < .001, 95% CI [0.020, 0.076], d = 0.793) (**Fig. 1**).

Difference in groups across driving conditions over time. We hypothesized that the group who did not experience guided mindfulness would be more stressed (hypothesis 2). The analyses reported a significant interaction between the main effects of the group, the type of driving condition, and time, for one physiological measurement: mean heart rate.

Post-hoc tests then revealed that, while the mean heart rate remained unchanged between the stress and stress-free conditions for the experimental and trained groups, it increased in the stress condition for the control group in both run 2 (t = 5.399, p < .001, 95% CI [0.999, 5.306], d = 0.289) and run 3 (t = 4.607, p < .01, 95% CI [0.536, 4.843], d = 0.247).

Finally, we assumed that breathing intervention training improves stress reduction and facilitates access to a state of well-being while driving (hypothesis 3). Howevere, there are no significant differences in the post-hoc tests that would support this hypothesis.

4. Conclusion

The results first indicate that a state of stress, induced by the use of different stressors, was successfully detected at the subjective and physiological levels. Second, they revealed that guided mindfulness helps to reduce stress at the physiological level. However, the results do not support the idea that specific breathing training, as conducted in this study, improves stress reduction during driving. Based on the first results, they could provide useful information both (1) for designing stress detection systems based on physiological indicators, and (2) for developing techniques to relieve stress while driving.

REFERENCES

Astin, J. A. (1997). Stress reduction through mindfulness meditation. Psychotherapy and psychosomatics, 66(2), 97-106. doi: 10.1159/000289116.

Bishop, Scott R., et al. "Mindfulness: A proposed operational definition." Clinical psychology: Science and practice 11.3 (2004): 230. doi: 10.1093/clipsy.bph077.

Brown, R. P., & Gerbarg, P. L. (2009). Yoga breathing, meditation, and longevity. Annals of the New York Academy of Sciences, 1172(1), 54-62. doi: 10.1111/j.1749-6632.2009.04394.x.

Carmody, J., & Baer, R. A. (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. Journal of behavioral medicine, 31(1), 23-33. doi: 10.1007/s10865-007-9130-7.

Creswell, J. D., & Lindsay, E. K. (2014). How does mindfulness training affect health? A mindfulness stress buffering account. Current directions in psychological science, 23(6), 401-407. doi: 10.1177/0963721414547415.

Gotardi, G. C., Polastri, P. F., Schor, P., Oudejans, R. R. D., Van Der Kamp, J., Savelsbergh, G. J. P., et al. (2019). Adverse effects of anxiety on attentional control differ as a function of experience: a simulated driving study. Appl. Ergon. 74, 41–47. doi: 10.1016/j.apergo.2018.08.009.

Kabat-Zinn, Jon. Coming to our senses: Healing ourselves and the world through mindfulness. Hachette UK, 2005.

Lehrer, P., Sasaki, Y., & Saito, Y. (1999). Zazen and cardiac variability. Psychosomatic medicine, 61(6), 812-821.

Pedrotti, M., Mirzaei, M. A., Tedesco, A., Chardonnet, J. R., Mérienne, F., Benedetto, S., & Baccino, T. (2014). Automatic stress classification with pupil diameter analysis. International Journal of Human-Computer Interaction, 30(3), 220-236. doi: 10.1080/10447318.2013.848320.

Rendon-Velez, E., Van Leeuwen, P. M., Happee, R., Horváth, I., van der Vegte, W. F., & De Winter, J. C. F. (2016). The effects of time pressure on driver performance and physiological activity: a driving simulator study. Transportation research part F: traffic psychology and behaviour, 41, 150-169. doi: 10.1016/j.trf.2016.06.013.

Sovik, R. 2000. The science of breathing–the yogic view. Prog. Brain Res. 122: 491–505. doi: 10.1016/s0079-6123(08)62159-7.

Wickens, C. M., Wiesenthal, D. L., & Roseborough, J. E. (2015). In situ methodology for studying state driver stress: A between‐subjects design replication. Journal of Applied Biobehavioral Research, 20(1), 37-51. doi: 10.1111/jabr.12029.

The Commuting Experience: An Analysis of Physiological and Experience Sampling Data During Multimodal Travel

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ABSTRACT

This study examines the influence of psycho-physiological factors on the commuting experience with public transport. While previous research mainly focused on travel time and cost, this study aims to explore three research questions: What are the common events during the commute? How does self-reported travel experience and cardiological data vary between different modes of transportation? How does context data, such as temperature, wind speed and acceleration affect the commuting experience? Ten participants were equipped with a wearable ECG sensor to collect cardiological and acceleration data, and an app to collect self-report and location data during their commute on three fixed routes. Participants were asked to report their stress levels, travel-related satisfaction, and travel-independent affect every 3.5 minutes. Specific events that influenced the commuting experience and the current mode of travel were also reported. In total, 294 events were reported during the study period. These events are categorized providing a basis for future studies. Self-report and cardiological data hint towards differences between modes, with the bus being the most stressfully perceived mode of transportation. Weak correlations between acceleration, stress and travel satisfaction, and between temperature and travel satisfaction were found. The study sheds light on common events during commuting and points towards differences in the commuting experience between modes and different contextual influences. The study provides a starting point for integrating psychophysiological aspects into mobility research.

Keywords: commuting, public transport, travel satisfaction, travel experience, stress detection

1. BACKGROUND

In 2019, the transport sector accounted for roughly 15% of total greenhouse gas emissions (IPCC, 2022), showcasing the importance of sustainable mobility transformations such as reducing motorized private transport and increasing the use of public transport. Commuting is an integral part of mobility, yet driving by car is the most common mode of transport for commuters in Germany (Destatis, 2016). Additionally, traffic congestion, air pollution, noise and lack of space, especially in inner cities, are commonly discussed issues related to private motorized transport (Gössling, 2020). Increasing the use of public transport is a promising way to address these issues.

To increase the number of commuters using public transport, its attractiveness needs to be improved. To date, the attractiveness of public transport was mainly evaluated along travel time and cost (Chowdhury et al., 2015). Despite their importance in influencing mode choice, psycho-physiological factors are often neglected (Castro et al., 2020). Commuting by public transport is generally perceived as an unpleasant activity, resulting in negative affect such as stress, while commuting by car results in less negative affect (Olsson et al., 2013). This likely contributes considerably to the low percentage of commuters using public transport. Previous scientific work has identified moderating variables such as time reliability, perceived control, travel duration, long waiting times or the number of transfers (Castro et al., 2020). Yet, most studies focus on subjective methods based on recall, which introduces a systematic bias and lacks objectivity. Consequentially, more research is needed to further a deeper understanding of the commuting experience, what influences it and how it can be improved.

2. OBJECTIVES

The present study contributes to the existing body of research by evaluating physiological, experience sampling as well as context data collected during multimodal commuting with public transport. In this way, it presents a real-world data collection integrating psychophysiological aspects into mobility research**.** The objective of this exploratory study is to evaluate the following questions: 1) What kind of events influencing commuting experience commonly occur during the commute, 2) how do self-reported commuting experience and cardiological data vary between different modes of transportation and 3) how do weather features and acceleration affect the commuting experience.

3. METHODS

3.1 Study procedure and design

The participants were first instructed to complete a questionnaire that included questions on demographics and everyday mobility behaviour. All participants travelled three different fixed routes by public transport with at least one transfer per trip and using at least two different modes of transport. Each trip started at home before work to ensure that the same time pressure is present as in a regular commute. The study was conducted from October until November 2022 in Brunswick, Germany.

3.2 Measures

While travelling, the participants were equipped with the ecgMove 4 sensor (Movisens GmbH, Karlsruhe, Germany), which collected cardiological data (heart rate (HR) and heart rate variability in terms of root mean squared difference of successive heart beats (RMSSD), which is calculated every 30s for a segment of 120s). Acceleration and activity data were collected once per second. The movisensXS app collected self-report and location data. During the trip, participants reported their stress level ("How stressed are you right now?"), travel-related satisfaction ("Please rate your current satisfaction with the journey.") and travel-independent affect ("How do you feel at the moment, independent of the journey?") every 3.5 minutes on a 10-point Likert Scale with low values representing low stress and high values representing high stress, or satisfaction, respectively. The 3.5 minutes interval in between questionnaires was selected to balance temporal resolution of the data and strain on the participant. After several test journeys, 3.5 minutes was selected as best suiting interval. The 10-point Likert scale was chosen to avoid the possibility of neutral answers and enabling a fine-grained reporting of the perceived stress. Simultaneously, they were asked if there had been any events that had influenced their commuting experience and what mode of transport they were using. In addition, the participants answered the questionnaire whenever something happened that changed their commuting experience. To report events, participants could choose from the categories *delayed vehicle*, *delayed start of journey*, *disturbance from people in the environment*, *overcrowded vehicle*, *style of driving*, *infrastructure problems*, *missed connection*, *cancelled journey* and *others*. These categories were chosen based on previous unpublished work. Finally, weather data was collected once per trip using the OpenWeatherMap API.

3.3 Participants

The study was conducted with 10 participants (4 female) aged between 24 and 39 years (mean age ≈ 28.7 years, standard deviation ≈ 4.5 years) who work at the German Aerospace Center. The majority of the sample lives in Brunswick, has a commute of 5-10km length and most commonly chooses an active mode of transportation such as taking the bike or walking, followed by public transport. Two participants had to be excluded from further analysis of cardiological data due to missing data and will only be used for the analysis of self-report data.

3.4 Data pre-processing and analysis

HR data missing due to motion artefacts were linearly interpolated for each participant, if less than 20 entries (corresponding to 20s) were missing. The HR data was then filtered using a Kalman filter to reduce noise and the resulting HR was z-transformed to account for interindividual differences. Lastly, the 60 data points for both the z-transformed HR and the RMSSD after a switch in activity from *active* (which includes walking or cycling) to *passive* (which includes sitting and standing) were removed because of the interindividual differences in the recovery times of the HR. Due to the small sample in the activity class *active* only HR and RMSSD data which were recorded within the *passive* activity class were analysed. This should ensure that any differences in physiological activation can be attributed to differences in experience and not physical activity differences.

Differences in self-reported commuting experience and cardiological data between different modes were examined based on mean stress ratings, satisfaction ratings, z-transformed HR data and RMSSD per respective mode per trip. For the evaluation of the impact of weather and acceleration on the commuting experience the features outside air temperature in °C, wind speed in m/s and the acceleration in multiples of earth gravity (1g = 9.81 m/s) were used. For all features and for the self-reported commuting experience the average value per commute was used and the Spearman Rank Correlation calculated for each combination of temperature, wind speed or acceleration and stress and satisfaction ratings. Because of the explorative nature of the study and the small sample size only descriptive analyses were performed.

4. Results

4.1 Common events during commuting

In total, 294 events were reported during the study period. The distribution of the events is displayed in Figure 1 on the left. The category *others*, which is not displayed, was selected 186 times by the participants, indicating that the initial categories were not representative of the events encountered by the participants. Therefore, a new categorisation system was developed based on the free text inputs describing the events in the category *others*. Concomitantly existing categories that describe similar experiences were merged, e.g., the events *delayed vehicle, missed connection* and *delayed start* are subsumed in the new category *delay*. The new categorisation system and the newly assigned distribution of events are displayed in Figure 1 on the right and examples for each category are displayed in Table 1. Note that the given examples are representative of the event category but not the only possible manifestation of events in the respective category. The event *delay* occurred most frequently with 85 occurrences.

Table 1 – Examples for each event category

Category	Example	Category	Example
Delay	The bus arrives 10 minutes later	On time	The destination is reached on time
Disturbing People	A person loudly listens to music	Discomfort	The bus is overheated
Style of Driving	The bus drives too fast and overruns potholes	Comfort	The passenger gets a comfortable seat
Infrastructure	The display with travel times is not working	Pleasant Surrounding	A nice sunset can be observed
Positive Interaction	A fellow passenger helps to find connecting train	Errands	The passenger buys groceries during the waiting time
Entertainment	The passenger reads a book	Others	The tickets get controlled

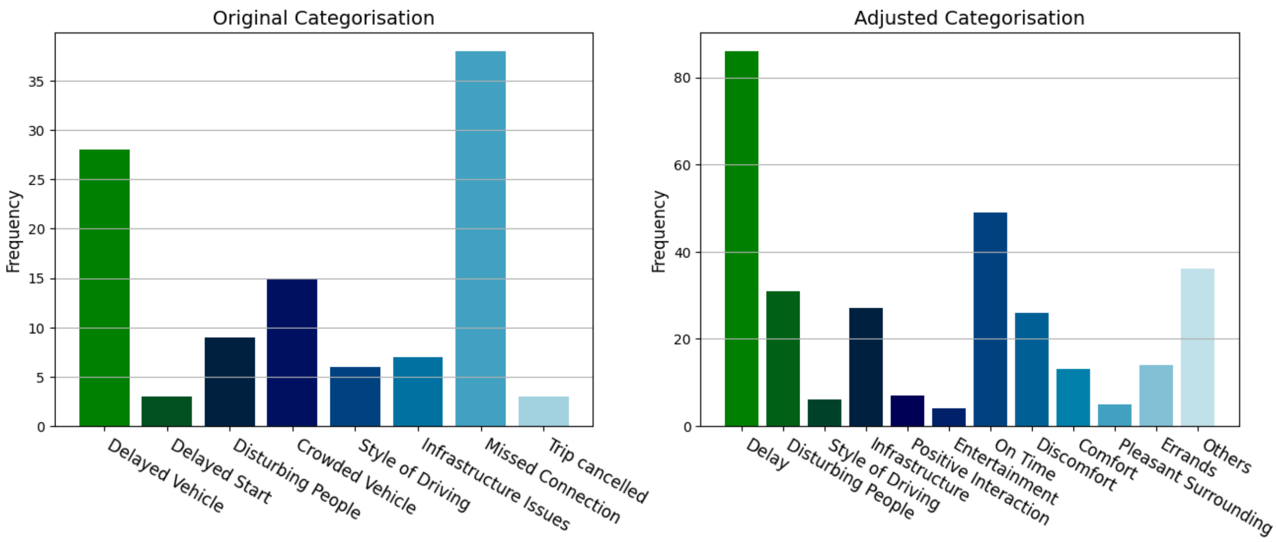

Figure 1 – The distribution of events during commuting

4.2 Differences in the self-reported commuting experience and cardiological data between modes of transportation

It was investigated whether the self-reported commuting experience and the cardiological data differ between different modes of transportation. The mean values per consecutive stay in the respective mode of transport are displayed in Figure 2. There was not sufficient cardiological data for the modes walking, waiting and tram likely due to motion artefacts. Thus, cardiological data was evaluated for the mode bus and train. The median stress rating was highest for taking the bus and lower taking the train. The satisfaction with travel in turn was low for all modes of transportation with no notable differences between modes in the median rating. The cardiological data revealed a comparable pattern to the stress ratings. Here, the mean z-transformed HR was slightly higher for taking the bus than for taking the train and the inverse relationship was evident for the RMSSD.

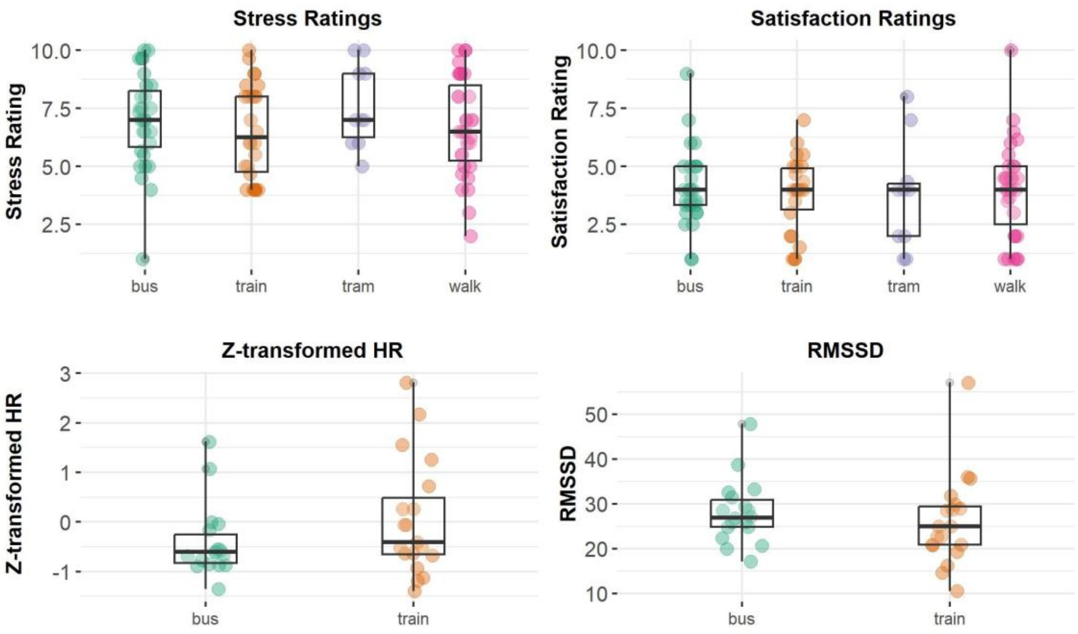

Figure 2 – Differences in subjective and cardiological data between different modes

4.3 Impact of weather features and acceleration on the commuting experience

No significant correlations were found, but weak positive correlations between the temperature and the satisfaction with travel (0.189), and also between the acceleration and the satisfaction with travel (0.208) were present. Furthermore, a weak negative correlation was found between stress and acceleration (-0.122).

5. DISCUSSION

The present study investigated the experiential aspect of commuting by evaluating cardiological, self-report and context data collected during multimodal commuting with public transport. Common events are reported and a categorisation system is suggested. The five most common events are *delay*, *arrival on time*, *disturbing people*, *infrastructural issues* and *discomfort*, with *delay* occurring by far most often. These findings indicate that commuting with public transport is characterised by negative events. Congruently generally high stress ratings and low satisfaction with travel ratings are observed. Yet, minor differences between both subjective and cardiological data, namely increases in HR and decreases in RMSSD are found, hinting towards that taking the bus is perceived as more stressful than taking the train. This underpins previous findings based purely on subjective methods (Lunke,

2020) with psychophysiological data. Contextual influences were also examined with acceleration weakly correlating with satisfaction and exhibiting a weak negative correlation with stress, potentially as a consequence of the negative influence of impedance during the commute. Outside temperature weakly correlated with satisfaction, likely due to the time spent outside during transfers or waiting. Thus, the findings hint towards multiple factors, like mode, events, weather and acceleration influencing the commuting experience.

Future research with more participants travelling the same route multiple times is needed to further disentangle the contribution of each factor influencing the commuting experience. Because of the multidimensional nature of the data, a particularly large dataset is necessary to accumulate enough data for each potential combination of e.g. event and mode. The present study offers a promising real-world study design enriching previous approaches with experiences sampling, physiological and context data on commonly used commuting routes. The tentative findings emphasise the necessity to collect multidimensional data to understand the commuting experience and to be able to link it to mobility choices. This work paves the way forward towards integrating travel experience into sustainable mobility transformations. By integrating the human factor into mobility research user-centred solutions can be designed that incentivise the use of sustainable mobility options.

REFERENCES

Castro, M., Guevara, C. A., & Jimenez-Molina, A. (2020). A methodological framework to incorporate psychophysiological indicators into transportation modeling. *Transportation Research Part C: Emerging Technologies, 118*, 102712.

Chowdhury, S., Ceder, A., & Schwalger, B. (2015). The effects of travel time and cost savings on commuters' decision to travel on public transport routes involving transfers. *Journal of Transport Geography, 43*, 151–159. https://doi.org/10.1016/j.jtrangeo.2015.01.009

Gössling, S. (2020). Why cities need to take road space from cars — and how this could be done. *Journal of Urban Design, 25*(4), 443–448.

IPCC. (2022). Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/9781009157926.012

Lunke, E. B. (2020). Commuters' satisfaction with public transport. *Journal of Transport and Health, 16*, 100842. https://doi.org/10.1016/j.jth.2020.100842

Olsson, L. E., Gärling, T., Ettema, D., Friman, M., & Fujii, S. (2013). Happiness and satisfaction with work commute. *Social Indicators Research, 111*(1), 255–263.

Statistisches Bundesamt. (2017). 68% der Erwerbstätigen fuhren 2016 mit dem Auto zur Arbeit [68% of employed persons commuted to work by car in 2016]. Retrieved May 30, 2023, from https://www.destatis.de/DE/Themen/Arbeit/Arbeitsmarkt/Erwerbstaetigkeit/im-Fokus-Pendler.html

Ensuring the safety of driver in automated vehicle: physiological detection of sadness and its regulation

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Keywords: sadness regulation, biofeedback, physiological detection

1. Background

Human mobility literature shows that emotions (e.g., the presence of ruminations related to sadness) observed during manual driving could be responsible for inattention episodes and will increase the risk of being involved in an at-fault accident (Lagarde et al., 2004). The impact of emotions on the driver's attentional state could be increased with the emergence of level 3 automation vehicles (i.e., cars requiring sporadic supervision of both environment and system by the driver). Indeed, the level 3 of automation can lead to under-activation that can hinder the mobilization of attentional resources (Young & Stanton, 2002) and have an impact on ruminations related to sadness. Therefore, the need to monitor, identify and regulate the drivers' internal states and in particular his/her emotions is crucial in terms of safety in case of take-over request or comfort. Despite this impact on the driver's attentional state or emotional comfort, few research works evaluated it with physiological parameters. To fill in this gap, the present study proposes to identify and remediate sadness during autonomous driving with a triangulation methodology (subjective, behavioral, and physiological data, see Gruberger et al., 2011).

2. Method

74 participants (mean age = 29.14 years, *SD* = 11.03, 41 women) were randomly assigned in one of the experimental conditions of mood (sadness vs control) and regulation (without or with haptic biofeedback). So, four groups were created: sad induction with regulation, (2) sad without regulation, (3) neutral with regulation or (4) neutral without regulation. The experiment is composed of two steps are participants are only seated in a simulated level 3 SAE vehicle and a step where participants drive in autonomous mode (see Figure 1): 1) a baseline session (i.e., the participant watches a movie for 5 minutes), 2) an induction session (i.e., the participant listen carefully to audios emotionally connoted: sadness or neutral for 4 minutes) and an autonomous mode driving session for 9 minutes; 3) with or without breathing exercise for 5 minutes,(i.e., a regulation session: participants had to adjust or no their breathing rhythm to the haptic signal sent by a smartwatch for 5 minutes). There were automated driving sessions without specific instructions succeeding of the induction and regulation sessions for 2 minutes: 1) driving session of induction and 2) driving session of regulation. During these experimental and driving sessions, we assessed physiological indicators (electrocardiogram, respiratory and electrodermal activity) and participants were asked to rate their subjective mood (i.e., happiness, sadness and anger) on a scale of 1 to 100 (i.e., 1= equals not at all; 100= extremely).

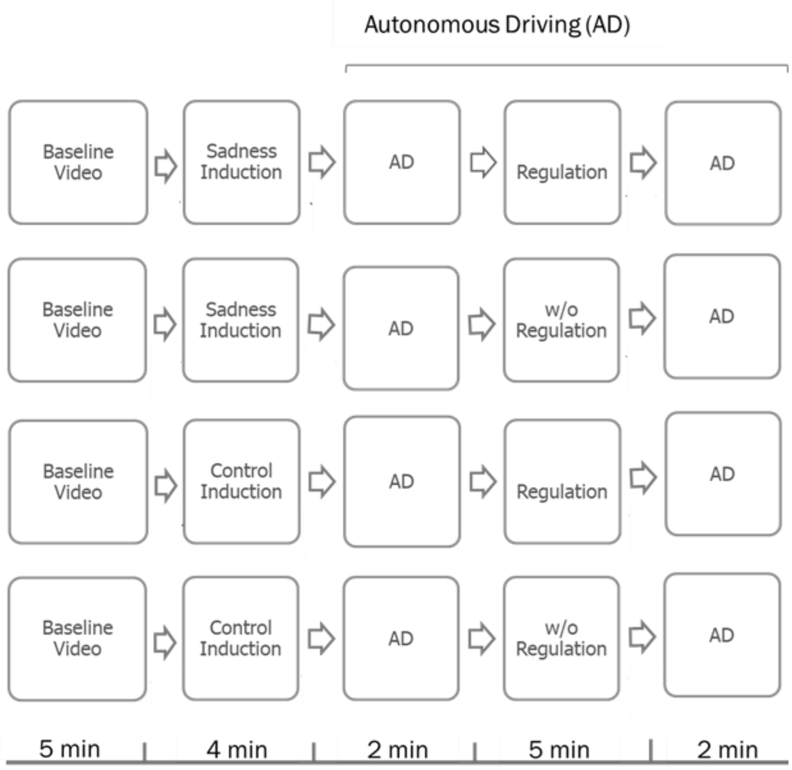

Figure 1: Illustration of the experimental design and the timeline of events

3. Results

Supporting the efficiency of induction and regulation, the result of 2 (mood: sadness vs control) × 2 (regulation: without vs with breathing exercise) × 3 (sessions: baseline, induction and regulation) mixed-model ANOVA for the subjective score was significant, $F(6, 140) = 9.380$, $p < 0.001$. After the induction, subjective sadness score ($M = 40.135$; $SD = 23.938$) increased in the sadness condition in contrast to the neutral condition ($M = 6.865$; $SD = 16.727$). After the regulation, only the score of the sadness no regulation group remained very high ($M = 9.375$; $SD = 4.250$ for sadness regulation group; $M = 19.571$; $SD = 3.709$ for sadness without regulation). In line with our preceding results on the efficiency of induction and regulation, a 2 (mood) × 2 (regulation) × 2 (driving sessions: driving session of induction and driving session of regulation) mixed-model ANOVA of sigh rate was significant, $F(3, 70) = 2.940$, $p < 0.05$. After the regulation, only the sigh rate of the regulation group increases very high. In addition to these results, a 2 (mood) × 2 (regulation) × 2 (driving sessions: driving session of induction and driving session of regulation) mixed-model ANOVA of respiration rate was trend, $F(3, 70) = 2.483$, $p = 0.068$. Furthermore, respiration rate was associated with the sadness subjective score in neutral ($r = 0.380$) and sadness condition ($r = -0.350$). A 2 (mood) × 2 (regulation) × 2 (driving sessions: driving session of induction and driving session of regulation) mixed-model ANOVA of cardiovascular reactivity (RMSSD) was significant, $F(3, 70) = 3.042$, $p < 0.05$. The regulation induces a decrease of cardiovascular reactivity and independent of the induction group. Currently, the statistical of EDA data of all participants is still ongoing.

4. Conclusion

The subjective score analysis revealed that both sadness groups were correctly induced in sadness as these participants gave higher scores on the sadness dimension. Moreover, these results indicated that the regulation technique used impacted the sadness felt. Supporting the effectiveness of the regulation, during the driving session of regulation, individuals of regulation group had an increase of the sigh rate and a decrease of cardiovascular reactivity after the breathing exercise. The chosen regulation technique has an impact on the different physiological responses and it seems to allow a return to the initial state of the participants. Therefore, this technique could counteract the negative effects of emotions while driving. These results are promising, sadness detection and its regulation could enhance comfort but also safety during autonomous driving.

REFERENCES

Gruberger, M., Ben-Simon, E., Levkovitz, Y., Zangen, A., & Hendler, T. (2011). Towards a Neuroscience of Mind-Wandering. *Frontiers in Human Neuroscience,* 5, 56. PMC.

Lagarde, E., Chastang, J.-F., Gueguen, A., Coeuret-Pellicier, M., Chiron, M., & Lafont, S. (2004). Emotional Stress and Traffic Accidents: The impact of separation and divorce. *Epidemiology*, 15(6), 762-766.

Young, M. S., & Stanton, N. A. (2002). Attention and automation: New perspectives on mental underload and performance. *Theoretical Issues in Ergonomics Science*, 3(2), 178-194.

Citizen-Centric Smart Mobility: Exploring Co-Creation Methods for Future Scenarios

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Keywords: urban mobility, co-creation workshop, smart cities, citizen-centred design, futures thinking

1. Background

Smart cities are urban areas supported by information and communication technologies (EC, 2020), which aim to provide sustainable, inclusive, and citizen-centric environments (OECD, 2020), i.e., focus on developing innovative technologies and services that enable citizens' well-being, quality of life, and environmental protection. Smart economy, smart governance, smart environment, smart mobility, smart people, and smart life are some of the themes that must be addressed in a smart city context (Kirimtat et al., 2020).

In the realm of urban mobility, many innovative technologies and services have already been developed to achieve a seamless and comfortable citizen experience. However, developing such artifacts does not always make them a smart solution, as not all of them consider the particularities of the population in a specific context. Measures to improve urban mobility must consider people's needs and perspectives and the diversity of a population (Vallet et al., 2020, p.2).

In addition, concepts like a 15-minute city, defined by the possibility of executing daily activities within a 15-minute route from one's home (Moreno, 2020), highlight the importance of active and micro-mobility, such as bicycles and scooters. Shared mobility plays a significant role in ensuring access to micro-mobility, and even ride-sharing, which can ultimately reduce personal vehicle ownership (Shaheen et al., 2016). However, it is essential to understand who the citizens are, their context, and how the city's culture, climate, and topography influence the built spaces in a collaborative process that considers these particularities (NACTO, 2018).

In this context, a significant question arises: How can co-design processes that involve citizens' needs and perspectives improve the development of smart solutions for urban mobility that contribute to sustainable, inclusive, and citizen-centric smart cities?

The paper’s objective is to present two co-creation workshop proposals to envision desirable future scenarios and define solutions to achieve them for urban mobility in Rio de Janeiro, using a citizen-centric approach and design tools for engagement and analysis.

2. Method

With the aim of seeking citizen-centred solutions for products, services and public policies regarding urban mobility, the two co-creation workshops were conducted, focusing on future scenarios. Both workshops were held online through a video meeting platform supported by design tools for engagement in the dynamics of the activities and in the creation of visual boards that were then analyzed.

During the first workshop, participants identified current mobility-related issues and expressed their desires for future short- and long-term scenarios. They were provided with contextual information, such as data, trends, and numbers, before individually creating ideal visions for their city's urban mobility in 2030 and 2050 on dedicated boards. Participants had the freedom to express themselves through text, images, or drawings. Following 20-30 minutes of individual work, everyone presented their boards, shared their wishes, and discussed the motivations behind their ideas, fostering group discussion.

In the second workshop, a method based on Backcasting approach was used to bridge the gap between the desires expressed in the previous workshop and the present. Participants were encouraged to question and identify key points to consider to achieve their future desires using a Sequential Question and Insight Diagram (SQUID Game) (Gray et al., 2010). This dynamic provided a tangible way for citizens to bring relevant solutions and inquiries about their needs and context.

3. Results

The first workshop's participants expressed their desires for urban mobility in Rio de Janeiro in both short-term (2030) and long-term (2050) scenarios. Their visions for 2030 emphasized aspects related to urban planning, with a focus on creating efficient micro-communities with a centerless city, aiming to reduce long-distance travel. They envisioned a more integrated public transportation system facilitated by information apps and an increased availability of shared and sustainable vehicles. Looking ahead to 2050, these desires were amplified by incorporating information and communication technologies. The participants envisioned "smart neighborhoods" and "technological micro-mobility," along with real-time connectivity between transport systems and smartphones for a safety mobility. Moreover, they proposed a diverse array of futuristic transportation modes, such as autonomous vehicles for long-distance trips, flying robot taxis that consider the city's topography, tramways for quick trips, and novel water transportation methods that account for the city's geography.

In the second workshop, citizens raised various concerns about the implementation of the desired systems and services. They highlighted the need for robust public policies and government accountability to ensure accessibility, safety, equity, and the well-being of commuters. Education on using public transportation and the role of citizens in shared systems were also discussed. Technical and operational aspects of the proposed technologies were important considerations. To address these concerns, participants suggested solutions such as offering discounts or loyalty programs to incentivize vehicle and ride-sharing, implementing laws and public policies for monitoring and accountability related to infractions and misuse of services, and imposing higher taxes or costs for individualized transportation options, among others.

The workshops provided valuable insights into the perspectives and aspirations of citizens regarding urban mobility in Rio de Janeiro. Notably, the short-term visions focused on resolving current issues without heavy reliance on digital technologies, whereas the long-term visions embraced more disruptive and technological solutions. The Backcasting approach employed in the second workshop facilitated a tangible path to achieve the citizens' desired future scenarios by identifying key points and strategies necessary for their realization.

4. Conclusion

In conclusion, the paper addressed the need for citizen-centric approaches in the development of smart solutions for urban mobility within the context of smart cities. The two co-creation workshops presented in the study proved valuable in understanding citizens' current challenges and desires regarding urban mobility in Rio de Janeiro. The workshops facilitated the identification of specific pain points, generated ideas for future scenarios, and encouraged participants to contribute tangible solutions and inquiries. Although engaging participants in such processes can be challenging, the use of visual and gamification resources proved effective in achieving the desired goals in an online activity.

REFERENCES

European Commission. (2020). Smart cities. Retrieved January 5, 2020, from https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

Gray, D., Brown, S., Macanufo, J. (2010) Gamestorming: A Playbook for Innovators, Rulebreakers, and Changemakers. O'Reilly Media.

Kirimtat, A., Krejcar, O., Kertesz, A., & Tasgetiren, M. F. (2020). Future Trends and Current State of Smart City Concepts: A Survey. IEEE Access, 8, 86448–86467. https://doi.org/10.1109/ACCESS.2020.2992441

Moreno, C. (2020). Vie urbaine et proximité à l’heure du Covid-19. Humensis. Retrieved from https://ideas.repec.org/p/hal/journl/hal-03259768.html

National Association of City Transportation Officials. (2018). Global Street Design Guide. New York. Retrieved from https://nacto.org/publication/global-street-design-guide/

Organization for Economic Co-operation and Development. (2020). Leveraging Digital Technology and Data for Human-centric Smart Cities. Paris. Retrieved from https://www.itf-oecd.org/data-human-centric-cities-mobility-g20

Shaheen, S., Cohen, A., Zohdy, I., & Kock, B. (2016). Shared Mobility: Current Practices and Guiding Principles Brief. California. Retrieved from https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf

Vallet, F., Puchinger, J., Millonig, A., Lamé, G., & Nicolaï, I. (2020). Tangible futures: Combining scenario thinking and personas - A pilot study on urban mobility. Futures, 117, 102513. https://doi.org/

10.1016/J.FUTURES.2020.102513

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Improving Transparency of a Highly Automated Shuttle's Minimal Risk Manoeuvre for Users by Internal Human-Machine Interfaces

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Keywords: human-computer interaction, highly automated vehicles, remote operation, explainable artificial intelligence (XAI), transparency.

1. Background

Vehicle automation may significantly improve safety, efficiency, and inclusive mobility services in future transportation. Although promising, there are still some challenges preventing vehicle automation from use. For example, highly automated vehicles (HAVs) struggle in new situations because the automation's machine learning (ML) algorithms are often unable to solve situations that are not part of their training data (T. Zhang, 2020). To solve this, the training data would have to include every possible situation an HAV might encounter. Since this is not conceivable, chances are that an HAV encounters a situation not yet incorporated in the AI's training data. This problem is known as the "Unknowable Unknowns Problem" (Koopman & Wagner, 2017). An approach to solve this issue is to incorporate a human operator in the automation system of HAVs. Different from ML algorithms, humans can quickly adapt to new situations and solve problems in them. Instead of being in the vehicle, the human operator can remotely support the vehicle, when necessary (Kettwich et al., 2021; W. Zhang et al., 2021). If an HAV encountered a problem it cannot solve on its own, it would trigger a so-called "minimal risk manoeuvre" (MRM) and stop. Then, it would inform a remote operator about the needed support. The remote operator would assist the vehicle by giving instructions on how to solve the issue at hand (Cummings et al., 2020).

So, in this case passengers taking a ride in an HAV would experience a driving situation without a driver. The remotely operated vehicle would occasionally stop for unknown reasons. This may cause uncertainty in the passengers because they would not be aware of what is happening and what is going to happen in the near future (Cummings et al., 2020; Meurer et al., 2020). Thus, the information given to passengers should take these uncertainties into account. Transparent design, which provides information about what a system does and how it does it, could help achieve this (Chen et al., 2014; Selkowitz et al., 2017). As a result, understanding should improve and uncertainty reduce. This information about what the automation is doing and why it is doing it can be example-based (Cai et al., 2019) or specifically about the AI's decision-making (Huff Jr et al., 2021). Previous research has shown that transparent design of HAVs is likely to increase passengers trust, understanding and subjective safety (Oliveira et al., 2020). To investigate the effect of transparent information on passengers' understanding, we conducted an experimental online study.

2. Method

To investigate this effect, we conducted an experimental online study with N = 22 participants. The participants were instructed to imagine themselves on board of a highly automated shuttle bus driving through Berlin Tegel to visit a friend. On its way, the shuttle bus encountered another car blocking the road and performed a MRM. Next, participants were shown pictures of five variants of an in-vehicle interface, i.e., internal Human-Machine Interface (iHMI), with different levels of information richness about the MRM, like delay time or cause of delay. The iHMI design aimed to increase transparency and therefore passengers' understanding. The map-based interface showed route and destination of the participants and of additional fictitious passengers. All passengers and their destination information were coded using animal-like emojis and visualized in pop-up windows. A separate popup window incorporated additional information on the MRMs as part of the iHMI. The MRM pop-up appeared where the shuttle bus was located on the map. After every variant, the participants had to answer eight questions regarding their understanding and perceived usability.

3. Results

Results show an improvement in user understanding with higher levels of information. From "No information" given (M = 2.86, SD = 1.18) to the highest level of information richness (M = 4.17, SD = 0.83), understanding scores improved significantly in a Bonferroni-adjusted post-hoc analysis (p = .002; M_{Diff} = 1.31, 95%-Confidence Interval [0.42, 2.2]). Usability ranged from M = 4.32 for "Low Information" to M = 5.15 for "High Information". Nevertheless, differences in Usability were not significant for a repeated measures ANOVA with a Greenhouse-Geisser correction, F(2.49, 52.18) = 2.70, p = .065.

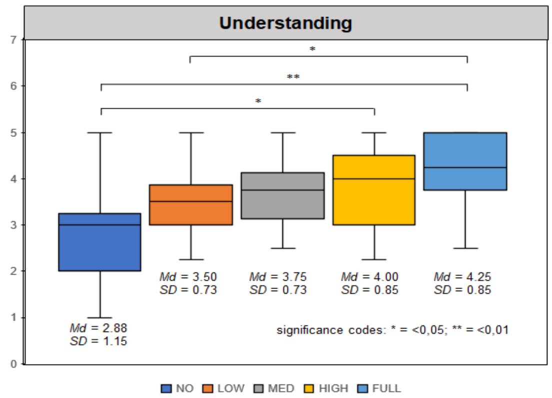

Figure 1 - Understanding between the variants

4. Conclusion

The study's results support the view that there is an effect of iHMI information richness regarding HAV's behaviour in MRMs on understanding. Higher levels of information richness perform increasingly better than lower ones. This effect is especially pronounced when comparing the highest level of information richness given and "No Information". However, the specific level of information richness should be given is still unclear. Also, we cannot rule out if informational needs are specific to situations since only one situation was examined. In addition, usability appears to remain unaffected by the amounts of information. This may point toward the conclusion that informational transparency does not impair usability. Overall, the study's results point towards transparency being a feasible way to improve passengers experience while using HAVs, especially in MRMs.

References

Chen, J. Y [Jessie Y.], Procci, K., Boyce, M., Wright, J., Garcia, A., & Barnes, M. (2014). *Situation Awareness-Based Agent Transparency*. Fort Belvoir, VA. https://doi.org/10.21236/ADA600351

Cummings, M., Li, S., Seth, D., & Seong, M. (2020). *Concepts of Operations for Autonomous Vehicle Dispatch Operations* (CSCRS-R9). https://rosap.ntl.bts.gov/view/dot/56823

Kettwich, C., Schrank, A., & Oehl, M. (2021). Teleoperation of Highly Automated Vehicles in Public Transport: User-Centered Design of a Human-Machine Interface for Remote-Operation and Its Expert Usability Evaluation. *Multimodal Technologies and Interaction*, *5*(5), 26. https://doi.org/10.3390/mti5050026

Koopman, P., & Wagner, M. (2017). Autonomous Vehicle Safety: An Interdisciplinary Challenge. *IEEE Intelligent Transportation Systems Magazine*, *9*(1), 90–96. https://doi.org/10.1109/MITS.2016.2583491

Meurer, J., Pakusch, C., Stevens, G., Randall, D., & Wulf, V. (2020). A Wizard of Oz Study on Passengers' Experiences of a Robo-Taxi Service in Real-Life Settings. In R. Wakkary (Ed.), *ACM Digital Library, Proceedings of the 2020 ACM Designing Interactive Systems Conference* (pp. 1365–1377). Association for Computing Machinery. https://doi.org/10.1145/3357236.3395465

Oliveira, L., Burns, C., Luton, J., Iyer, S., & Birrell, S. (2020). The influence of system transparency on trust: Evaluating interfaces in a highly automated vehicle. *Transportation Research Part F: Traffic Psychology and Behaviour*, *72*, 280–296. https://doi.org/10.1016/j.trf.2020.06.001

Selkowitz, A. R., Larios, C. A., Lakhmani, S. G., & Chen, J. Y [Jessie Y.C.]. (2017). Displaying Information to Support Transparency for Autonomous Platforms. In P. Savage-Knepshield & J. Chen (Eds.), *Advances in Intelligent Systems and Computing. Advances in Human Factors in Robots and Unmanned Systems* (Vol. 499, pp. 161–173). Springer International Publishing. https://doi.org/10.1007/978-3-319-41959-6_14

Zhang, T. (2020). Toward Automated Vehicle Teleoperation: Vision, Opportunities, and Challenges. *IEEE Internet of Things Journal*, *7*(12), 11347–11354. https://doi.org/10.1109/JIOT.2020.3028766

Zhang, W., Feltner, D., Kaber, D., & Shirley, J. (2021). Utility of Functional Transparency and Usability in UAV Supervisory Control Interface Design. *International Journal of Social Robotics*, *13*(7), 1761–1776. https://doi.org/10.1007/s12369-021-00757-x

The Co-existence of Autonomous Vehicles and Vulnerable Road Users - Raising Awareness of the Challenges Ahead

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Keywords: vulnerable road user; connected and autonomous vehicles; road intersections; crash data

ABSTRACT

Passenger vehicles equipped with advanced driver-assistance system (ADAS) functionalities are becoming more prevalent within vehicle fleets. However, the full effects of offering such systems, which may allow for drivers to become less than 100% engaged with the task of driving, may have detrimental impacts on other road users, particularly vulnerable road users, for a variety of reasons. Recent (2021) UK crash data was analysed to examine some challenging traffic scenarios that are prevalent and represent scenarios in which future connected and autonomous vehicles may be challenged in terms of safe manoeuvring. Road intersections are currently very common locations for vulnerable road-user accidents; traffic flows and road-user behaviours at intersections can be unpredictable, with many vehicles behaving inconsistently (e.g., red-light running and failing to stop or give way), and many vulnerable road users taking unforeseen risks. The challenges of unpredictable vulnerable road-user behaviour at intersections (including road users violating traffic or safe-crossing signals or taking other risks) combined with the lack of knowledge of CAV responses to intersection rules, could be problematic. This could be further compounded by changes to nonverbal communication that currently exists between road users, which could become more challenging once CAVs become more widespread.

Information on Capacity Utilization for Public Transportation: Useful for Passengers?

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ABSTRACT

Crowding in public transportation (PT) is a major challenge that has negative economic consequences for providers and negative psychological consequences for passengers. With more and more people using journey planner apps and the increasing availability of precise information on capacity utilization (CU) of PT, providing information on alternative, less crowded route options to passengers, is possible. In order to determine when, how and where the information on CU needs to be displayed and for whom it is especially useful for planning a trip, an online study was administered. An objective of the study was to investigate the use of journey planner apps among public transport users in more detail. In particular, the frequency and timing of app use for different trip purposes were investigated. Another goal was to identify under what circumstances public transport users perceive information on CU as useful. Results (N = 204) show that the frequency and timing of the use of journey planner apps differs depending on the trip purpose. People from metropolitan areas use journey planner apps less often than people from smaller cities. Trip purpose, duration of the trip, and service frequency have an influence on the perceived usefulness of information on CU. Important insights on the use of journey planner apps and the optimal conditions for the target group specific provision of information on CU could be gained with this study. The results can be used to derive strategies and recommendations for PT service providers.

Keywords: public transportation, passenger information, capacity utilization, usefulness.

1. INTRODUCTION

Overcrowded public transport (PT) is especially at peak times a widespread challenge in large cities. It is associated with several negative consequences for passengers and for transport companies. Frequent trips in overcrowded public transport lead to higher stress levels (Legrain et al., 2015), a lower safety and security perception (Cox et al., 2006), and overall diminished performance abilities (Evans & Wener, 2007). Transport companies experience economic detriments due to longer dwell times in stations and in consequence delays in the entire PT system (Yuan & Hansen, 2007). At the same time, in order to achieve the goal of a sustainable transport system, even more people need to switch from individual motorized transport to public transportation. Recently introduced measures, such as the 49-euro ticket in Germany, are expected to drive this trend. However, due to cost- and time-intensive implementation, the increasing demand for public transportation cannot be met with capacity extension alone, but must be predominantly carried out within the existing system. An approach to accomplish this is to provide passengers with accurate and reliable information on capacity utilization (CU) in advance of their trip directing them to lower-demand connections. Previous study results show that, in general, passengers are willing to adapt their PT usage behavior to current information about the trip (Drabicki et al., 2017; Kattan & Bai, 2018). However, no results about the user requirements of this kind of information are known to the authors.

A basic prerequisite for the desired change in PT usage behavior is that passengers perceive information on CU as useful. The various conditions under which PT journeys are made must be considered. Thus, the purpose of the trip, the length of the trip, and the service frequency of the mean of transportation are expected to influence the perceived usefulness of information on CU. The way this information is optimally provided is also relevant. Journey planner apps for PT are a widely used medium for providing passenger information and are used by most passengers (Islam et al., 2017). So, the usage behavior of these apps is of high interest. General frequency and timing of the use of journey planner apps for different trip purposes are relevant. Regarding the questions about the perceived usefulness of information on CU as well as the use of journey planner apps, it is expected that the local PT infrastructure also plays an important role. Metropoles - such as Berlin - are characterized by a variety of different modes of public transportation resulting in several route options for a specific journey. In contrast, in smaller cities, only one possible route option with much lower service frequencies is more likely. Accordingly, differences in frequency and timing of app use are expected between people from a large city and people from smaller cities.

Several objectives emerge for the present study. In order to investigate the requirements for a target group specific provision of information on CU, the perceived usefulness of these information will be analyzed depending on trip-specific and person-related factors. Questions regarding the use of journey planner apps are intended to provide insights into the optimal provision of the information. Furthermore, the general public transport usage behavior will be surveyed as an influencing factor. The results of people from Berlin will be compared with the results of people living in smaller cities.

2. Method

To answer the research questions, an online study via SoSci-Survey was conducted. The survey period was between November 2022 and January 2023. The questionnaire started with questions about the demographic characteristics of the participants such as gender, age, and the number of inhabitants of the place of residence. Furthermore, it was asked whether the persons came from the federal state of Berlin or Brandenburg. Based on this information, persons living in Berlin could be identified and thus the groups could be formed. This was followed by questions on PT usage behavior, the use of journey planner apps and the perceived usefulness of information on CU for different trip-specific factors. Questions regarding the frequency of PT use had to be answered on a 7-point scale from “on a daily basis” to “never”. For the frequency of the use of journey planner apps a 7-point Likert scale ranging from “for every trip” to “never” was used. Regarding the perceived usefulness of information on CU, participants rated a statement (e.g. information on CU are useful for me) on a 5-point Likert scale ranging from “I completely disagree” to “I completely agree”. Altogether, 204 people participated in the survey. Table 1 shows the demographic information of the sample split for people living in Berlin (PLB) and people living in smaller cities (PLSC).

Table 1 - Demographic information of the sample

	PLB	PLSC
N	85	119
Mean age (SD)	33.5 (12.7)	32.9 (13.8)
Gender		
male	58.8%	63.0%
female	35.3%	33.6%
divers	3.5%	1.7%
not specified	2.4%	1.7%

PLB = people living in Berlin, PLSC = people living in smaller cities

3. Results

3.1 Use of journey planner apps

Results show that participants used journey planner apps for most of their trips (*M* = 5.85, *SD* = 1.35). No difference was found between people who used PT once a week or less (*N* = 60) and people who used PT at least 3 times a week (*N* = 144). Comparing the results of PLB (*M* = 5.42, *SD* = 1.46) and PLSC (*M* = 6.16, *SD* = 1.16), PLSC showed a significantly higher usage ($p < .001$, *d* = 0.57).

Figure 1 shows Means and standard errors (*SE*) of the usage of journey planner apps for different trip purposes. It can be seen that journey planner apps were used more often for business trips, trips to appointments or leisure trips than for commuting trips or trips to run errands. For comparing the results of PLB and PLSC, two-tailed t-tests were conducted. After correcting for multiple comparisons problem with the Holm-Bonferroni method (Holm, 1979), a significant difference between the groups for trips to run errands was found (*p* = .009, *d* = 0.43).

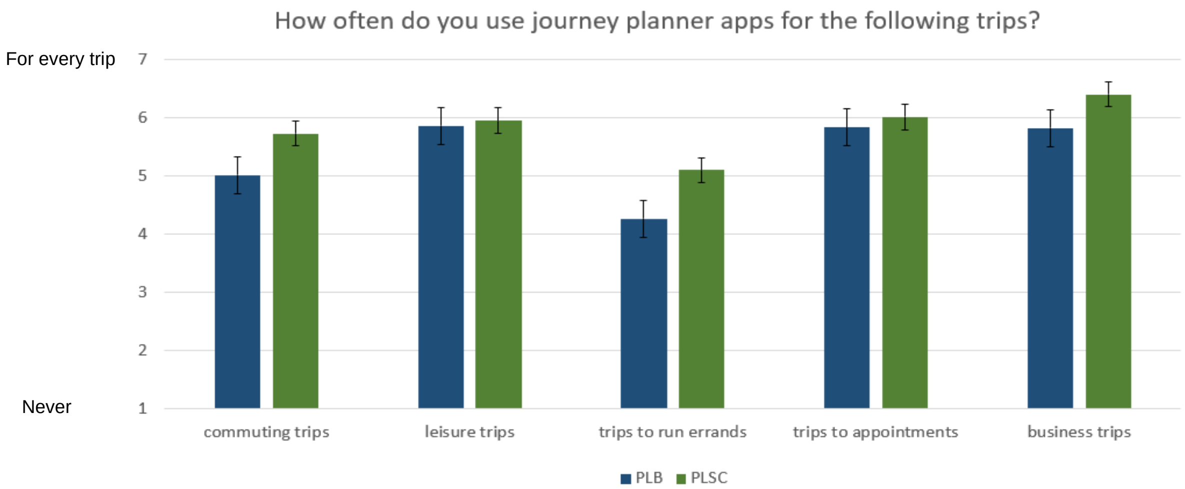

Figure 1 – Mean and *SE* of app usage for different trip purposes

For the timing of the app usage, participants stated, when they normally use journey planner apps for planning a trip. Table 2 shows the results.

Table 2 – Timing of usage of journey planner apps for different trip purposes*

	Less than 10 minutes prior to the trip		10-30 minutes prior to the trip		30 minutes – 1 hour prior to the trip		1-2 hours prior to the trip		More than 2 hours prior to the trip		More than 24 hours prior to the trip	
	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC
Commuting	32.9%	26.9%	32.9%	28.6%	22.4%	21.0%	5.9%	10.9%	17.6%	11.8%	12.9%	11.8%
Leisure	20.0%	22.7%	31.8%	28.6%	38.8%	24.4%	23.5%	15.1%	20.0%	16.8%	20.0%	21.8%
Run errands	31.8%	23.5%	32.9%	20.2%	18.8%	14.3%	7.1%	8.4%	4.6%	8.4%	5.9%	1.7%
Appointments	12.9%	14.3%	21.2%	13.4%	36.5%	23.5%	24.7%	13.4%	27.1%	19.3%	27.1%	24.4%
Business	10.6%	9.2%	11.8%	10.1%	10.6%	11.8%	11.8%	10.9%	16.5%	10.9%	41.2%	35.3%

*Multiple answers were possible, PLB = people living in Berlin, PLSC = people living in smaller cities

More than 60% of PLB and 40-50% of PLSC planned their commuting trips and trips to run errands only 30 minutes or less before the trip while connections for business trips and trips to appointments were checked by the majority of PLB and PLSC more than 24 hours in advance. PLSC plan their trips slightly earlier than PLB.

3.2 Perceived Usefulness of information on CU

In terms of the perceived usefulness of information on CU, a moderate to high approval of the statement "information on CU is useful for me" was found (*M* = 3.52, *SD* = 1.18). No differences between low (less than once a week) and high (more than once a week) frequent PT users were found. Comparisons between PLB (*M* = 3.61, *SD* = 1.20) and PLSC (*M* = 3.44, *SD* = 1.16) also showed no differences. Means and standard errors of the rating for different trip purposes are shown in Figure 2.

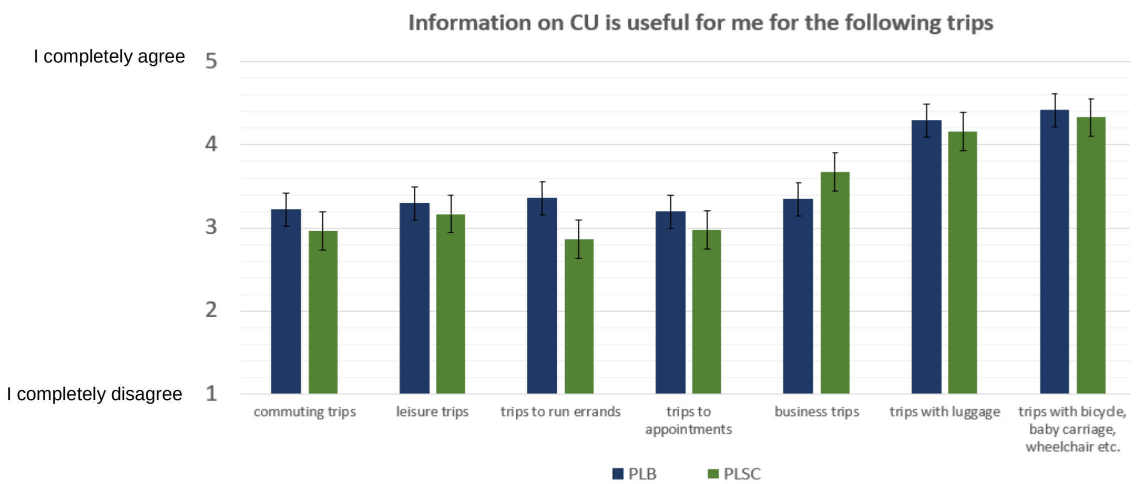

Figure 2 – Mean and *SE* of the perceived usefulness of information on CU for different trip purposes

Information on CU was rated equally useful for different trip purposes. Only for trips with luggage, bicycle, baby carriage, etc., it was rated more useful. Differences between PLB and PLSC were found for trips to run errands (p = 0.010, d = 0.41).

Regarding the trip duration, participants were asked to evaluate the aforementioned statement for eight different durations (Figure 3). Results of a one-way repeated measures analysis of variance (ANOVA) showed a strong significant main effect for PLB (F = 113.85, p < .001) and PLSC (F = 179.07, p < .001). After correcting with Holm-Bonferroni method, significant differences between PLB and PLSC with moderate to high effect sizes were found for all trip durations except "41-60 minutes" and "> 60 minutes" with higher values for PLB.

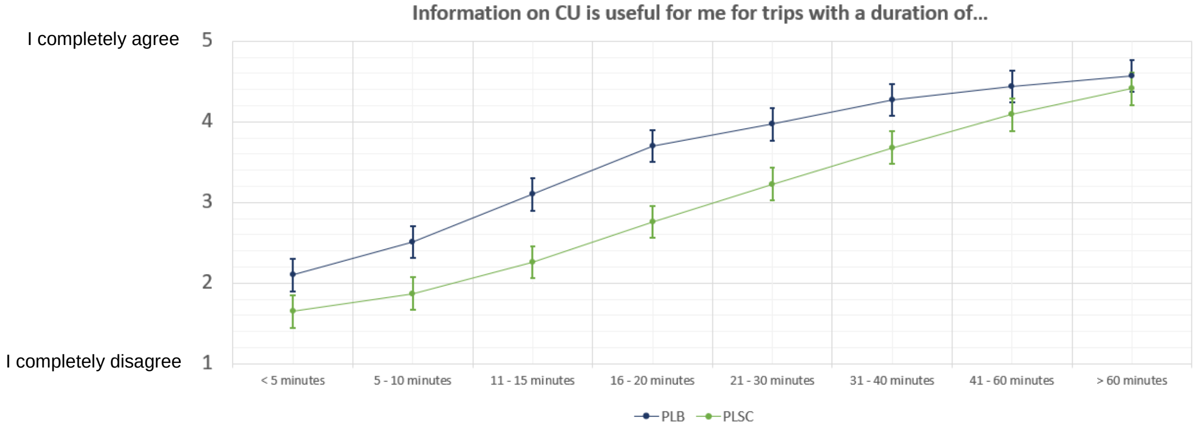

Figure 3 – Mean and SE of the perceived usefulness of information on CU depending on trip duration

In terms of service frequency, participants rated the perceived usefulness (Figure 4). A one-way repeated measure ANOVA was conducted showing a significant main effect for PLB (F = 8.68, p = .002) and PLSC (F = 44.82, p < .001). After correcting with Holm-Bonferroni method, significant differences between PLB and PLSC were found for "every 2-3 minutes" (p = .019, d = 0.35), "every 4-5 minutes" (p = .014, d = 0.37) and "every 6-10 minutes" (p < .001, d = 0.49).

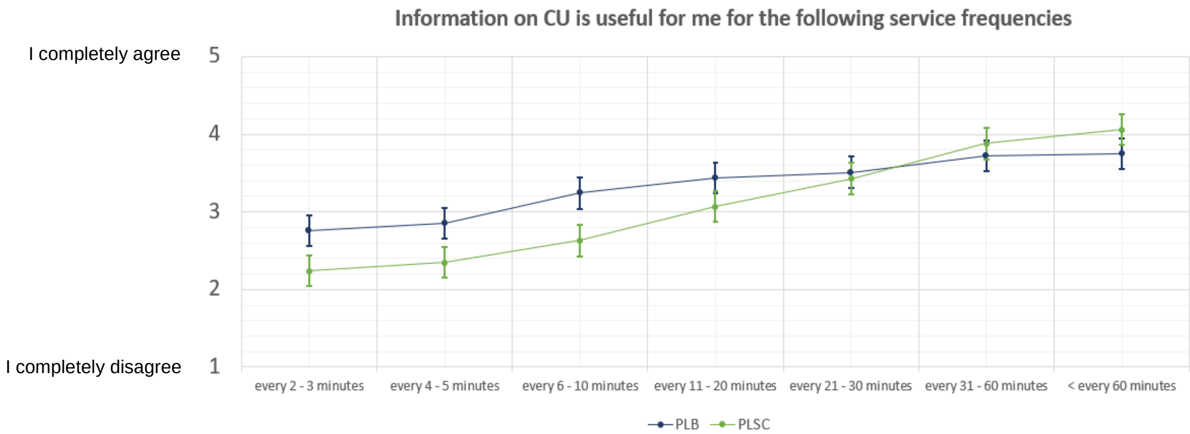

Figure 4 – Mean and SE of the perceived usefulness of information on CU depending on service frequency

Finally, participants were asked when they would need information on CU for different trip purposes. For commuting trips, leisure trips or trips to run errands, it is sufficient for most of the participants when the information is provided 10-30 minutes or even less in advance. For business trips, trips with luggage or trips with a wheelchair, bicycle etc. the information is needed more than 24 hours in advance. This is consistent with the results of the use journey planner apps. Large differences in the required timing of ICU can be found between PLB and PLSC. Over 60% of PLB need the information for commuting trips and trips to run errands less than 30 minutes before a trip. Over 60% of PLSC require the same information more than 30 minutes in advance. On the other hand, business trips or trips with luggage are planned more than 2 hours prior to the trip by only 30-40% of PLB, while more than 60% of PLSC need the information for these trips more than 2 or even more than 24 hours in advance.

Table 3 – Required timing of the provision of information on CU for different trip purposes

	Less than 10 minutes prior to the trip		10-30 minutes prior to the trip		30 minutes - 1 hour prior to the trip		1-2 hours prior to the trip		More than 2 hours prior to the trip		More than 24 hours prior to the trip	
	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC	PLB	PLSC
Commuting	17.6%	8.0%	41.1%	22.7%	17.6%	25.3%	11.8%	16.0%	2.9%	14.7%	2.9%	13.3%
Leisure	18.6%	4.2%	34.3%	31.6%	28.6%	22.1%	17.1%	15.8%	0%	14.7%	1.4%	11.6%
Run errands	23.5%	13.3%	42.6%	33.3%	16.2%	21.3%	10.3%	17.3%	4.4%	12.0%	2.9%	2.7%
Appointments	12.7%	7.1%	38.0%	14.1%	23.9%	27.1%	14.1%	24.7%	7.0%	15.3%	4.2%	11.8%
Business	6.1%	6.9%	28.6%	5.6%	16.3%	9.7%	16.3%	16.7%	6.1%	20.8%	26.5%	40.3%
Luggage	3.9%	3.1%	18.4%	6.1%	19.7%	10.2%	17.1%	15.3%	13.2%	19.4%	27.6%	45.9%
Wheelchair, bicycle etc.	3.2%	3.9%	14.5%	7.8%	24.2%	14.3%	24.2%	14.3%	9.7%	22.1%	24.2%	37.7%

PLB = People living in Berlin, PLSC = People living in smaller cities

4. Discussion

4.1 Conclusion

An online survey was conducted in order to gain more insight on the use of journey planner apps among public transport users. In particular, the frequency and timing of app use for different trip purposes were investigated. In addition, the perceived usefulness of information on capacity utilization depending on trip purpose was analyzed. As level of service differs between metropoles, such as Berlin, and smaller cities, comparisons between these two groups were administered. Results showed differences in frequency and timing of the use of journey planner apps depending on the trip purpose. People from a metropole (i.e. Berlin) use journey planner apps less often than people from smaller cities. Trip purpose, duration of the trip, and service frequency have an influence on the perceived usefulness of information on CU.

Overall, PLB and PLSC rated information on capacity utilization as useful. The information was perceived as more useful when travelling with luggage, bicycle, wheelchair, stroller, etc. Regardless of where people live, trip-specific factors may play a significant role in how useful the information is perceived. Nonetheless, results of service frequency also revealed differences in the perceived usefulness between PLB and PLSC. The information was significantly more important for PLB for service frequencies between two and ten minutes. The differences may result from the fact that service frequencies in smaller cities is generally not between two and ten minutes and are more likely to be operated in a less frequent manner. When the frequency of service is greater than every 30 minutes, PLSC perceive the information as slightly more useful as this service level may be the more common one in the area. The majority of PLSC also indicated (especially for commuting and running errands) that the information on CU is most useful more than 30 minutes in advance while the majority of PLB indicated the opposite. In general, when service frequency is between two and ten minutes, a delay or train cancellation does not affect the connection as it would when the train only runs every 30 minutes.

People from a metropolitan area, such as Berlin, use journey planning apps differently than people from smaller cities. It seems that because of the high service frequency, PLB do not need to use journey planner apps as often and as in advance as PLSC. Depending on where people live (i.e. frequency of service), the information is required at different points in time. At the moment, it is unclear whether passengers will use the information and choose a less crowded connection or whether the information is just used to be informed about upcoming travel experience. Further personal preferences (such as wanting a seat) and other factors need to be identified in order to provide relevant personal information that will motivate people to choose alternative routes.

4.2 Limitations

The mean age of our sample is ten years younger than the mean age of the German population resulting in a bias. Groups with a lower digital literacy, such as older persons, were less likely to participate in the survey. Therefore, little is known about older persons' needs with regard to information on capacity utilization as they may acquire such information further in advance and may need another device apart from a cell phone for receiving this information. In addition to providing surveys online, also offline versions need to be made available and groups with lower digital literacy acquired specifically. In addition, we did not ask participants whether they have any (permanent) physical or cognitive impairments/disabilities. It is also expected that persons with cognitive and/or physical impairments/disabilities may have different needs for the information on utilization rates. In order to design information on capacity utilization accessible and inclusive, needs and requirement of persons with special needs need to be collected and considered in the design and implementation process.

4.3 Outlook

Apart from studying the needs and requirements of persons with special needs, future research needs to investigate whether and to what extent people are willing to take a different connection that may be to another time, will take longer or will include more changes based on information on CU. This may depend on the trust in the accuracy of the information. It is expected that the point in time at which the prognosis was calculated has an effect on how reliable the information is perceived and whether people are willing to change their route. The general importance of the level of capacity utilization for passengers in comparison to other factors such as travel time or travel costs is also relevant. The effect of different levels of crowding, price categories, and trip durations on route choice behaviour of passengers may also be investigated. In addition to investigating whether and how passengers can be motivated to change their route choice, other strategies reducing the problem of overcrowded public transportation may be addressed. An idea is to inform passengers directly at the platform about the crowding levels of the oncoming train and to lead them to the doors with fewer passenger traffic. In this case real-time, crowding information is a promising way to optimize boarding and alighting and may result in an optimal distribution of passengers inside the vehicle.

REFERENCES

Cox, T., Houdmont, J. & Griffiths, A. (2006). Rail passenger crowding, stress, health and safety in Britain. *Transportation Research Part A*, 40, 244-258.

Drabicki, A., Kucharski, R., Cats, O. & Fonzone, A. (2017). Simulating the effects of real-time crowding information in public transport networks. *5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, Naples, Italy, 2017, pp. 675-680

Evans, G. & Wener, R. (2007). Crowding and personal space invasion on the train: Please don‘t make me sit in the middle. *Journal of Environmental Psychology,* 27, 90-94.

Holm, S. (1979). A Simple Sequentially Rejective Multiple Test Procedure. Scandinavian Journal of Statistics, 6, 65-70.

Islam, M., Fonzone, A., MacIver, A. & Dickinson, K. (2017). Modelling factors affecting the use of ubiquitous real-time bus passenger information, *5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, Naples, Italy, 2017, pp. 827-832.

Kattan, L. & Bai, Y. (2018). LRT passengers’ responses to advanced passenger information system (APIS) in case of information inconsistency and train crowding. *Canadian Journal of Civil Engineering*. 45(7), 583-593.

Legrain, A., Eluru, N. & El-Geneidy, A. (2015). Am stressed must travel: The relationship between mode choice and commuting stress. *Transportation Research Part F,* 34, 141-151.

Yuan, J. & Hansen, I. (2007). Optimizing capacity utilization by estimating knock-on train delays. *Transportation Research Part B*, 41, 202-217.

Exploring the User Preferences of Older Drivers for Car Interior Design Elements Based on the Semantic Difference Method

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ABSTRACT

As the demographic distribution of the population shifts, there has been a noticeable increase in the number of older drivers. Despite decades of research on this user group, current literature remains limited in exploring the emotional and aesthetic preferences of older drivers. The study reported in this paper endeavours to discover the specific preferences and needs of older drivers concerning car interior design by the Semantic Differential Method (SDM). To this end, 75 older drivers (aged 60+) completed a questionnaire, and rated 12 car interior designs according to their personal preferences using 18 Kansei word pairs. The data analysis methods employed included cluster analysis and principal component analysis (PCA). The cluster analysis identified the participants who shared similar emotional ratings. The PCA categorised 18 Kansei word pairs into six design factors: Comfort-related, Trends-related, Self-expression, Quality-related, Style, and Symmetry. The findings suggest that older drivers tend to emphasize Comfort-related and Trends-related design factors, which exhibit higher levels of positive emotional valence. For instance, the group of mainly women (and aged 70-79-years) expressed greater interest in comfort rather than style. Two other groupings, each emphasized psychological and physical comfort. In summary, this study provides pragmatic insights into the emotional and aesthetic preferences of drivers aged 60+ serving as a guide for age-friendly car interior design.

Keywords: older drivers, user preference, kansei engineering, semantic differential method, principal component analysis, cluster analysis.

1. BACKGROUND

For decades, numerous studies have shed light on the many physical and psychological challenges encountered by older adults when engaging in driving tasks. These challenges encompass various aspects such as visual, cognitive, negative emotional experiences and self-regulation (Anstey et al., 2005; Hill & Boyle, 2007; Meng & Siren, 2012). Simultaneously, scholars have observed that existing designs and technologies fail to adequately consider the needs of older drivers, as well as an insufficient market response (Meyer, 2014; Young, Koppel, & Charlton, 2017). Therefore, effectively addressing these challenges necessitates understanding and meeting the needs of older drivers.

Designing for users' needs poses a set of challenges. Users' needs go beyond functionality and usability and include emotional needs such as pleasure and self-esteem, which places greater expectations on designers (Jordan, 2010). However, personal emotions are highly subjective and difficult to measure (Helander & Po Tham, 2003). In this case, Kansei engineering (KE) has been widely recognized and applied as a tool to transform consumer psychological needs into perceptual design elements. Kansei means 'all emotions' in the Japanese context. Hence, KE involves collecting all emotional information (Kansei information) regarding users' interactions with a given product and transforming their psychological experiences into design elements through analysis, inference mechanisms, and expressive techniques (Nagamachi, 1999).

However, individual differences (e.g., age, gender, and personal experience) may lead to inaccuracies in Kansei information (Dong et al., 2021). Scholars have proposed various methods to address individual differences, such as basic emotion theories (Huang et al., 2012; Dong et al., 2021). Nevertheless, such methods may demand more participation time and workload, potentially leading to lower-quality questionnaires or participant reluctance (Gillham, 2008).

As a solution, this study proposes a methodology suitable for older participants that uses a single indicator, 'Positive-Negative,' for measuring and categorizing emotions. The cognitive theory of emotion posits that attribute of emotion, such as 'Positive' and 'Negative,' refer to evaluations of events that can be classified as 'Good' or 'Bad' (Arnold, 1968). Likewise, Peter et al. (2005) identified four primary types of emotional responses, including emotions, specific feelings, moods, and evaluations, each of which may involve positive or negative reactions. Consequently, ‘Positive-Negative' measurement could thus capture the perception and intensity of each semantic space or Kansei word by Likert scale (Figure 1), and reaching to the classification and comparison of individuals with similar emotional perceptions. In addition, it more user-friendly for older participants.

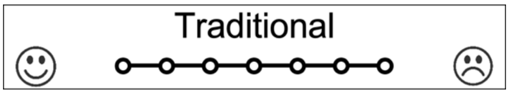

Figure 1 - Example of 7-point Likert scale based on the "Positive-Negative" indicator.

Therefore, this study aims to explore the aesthetic and emotional preferences of older drivers toward car interiors through KE and identify the differences in their needs based on emotional evaluation.

2. METHOD

2.1 Research Methods

This study uses KE Type I to determine older adults' emotional and aesthetic preferences for automotive interior design. This method is valued for its ability to quantify the correlation between user emotions and design factors (Nagamachi, 1995). The Semantic Differential Method (SDM) is a widely used technique in KE and emotional design, employing Likert scales to assess objects along a dimension between two antonyms (Huang et al., 2012). To ensure an effective evaluation process, the appropriate semantic space is necessary (Osgood et al., 1957). Therefore, after a comprehensive collection of influential words and three rounds of expert meetings, the researcher selected 18 Kansei word pairs (Figure 2). Meanwhile, following four expert meetings, this study selected 12 car interior designs from 147 images based on design style, the year of production, interior colour, etc (Figure 3).

'Traditional - Modern'	*'Sporty - Elegant'*
'Fashionable - Old-Fashioned'	*'Simple – Complicated*
'Warm - Cold'	*'Flashy - Plain'*
'Soft - Hard'	*'Relaxed - Tense'*
'Dark - Bright'	*'Passionate - Gentle'*
'Formal - Casual'	*'Delicate - Robust'*
'Symmetrical - Asymmetrical'	*'Accessible - Inaccessible'*
'Nostalgic - Futuristic'	*'Comfortable - Uncomfortable'*
'Conservative - Avantgarde'	*'Roomy - Cramped'*

Figure 2 - 18 Kansei word pairs extracted from 200 words.

Figure 3 - 12 selected car interior designs.

2.2 Data collection

The survey was conducted in October 2022 in the UK using non-probability sampling. Participants were selected based on age (60+ years), driving experience, and language proficiency (English). The questionnaire was distributed through various channels such as social media, and on-site locations. Based on the completion of the questionnaire, cognitive performance in completing the questionnaire, and the willingness to withdraw, this study obtained 75 valid questionnaires out of a total of over 250 questionnaires distributed. Among the respondents, 42.7% were female, and 57.3% were male. Almost half of the participants aged 60-69 were up to 49.3%, while 40% were aged 70-79 and 10.7% were aged 80 and above. All had at least 10 years of driving experience, and the majority currently owned a vehicle (96%). A total of 71 people reported still driving (94.7%), with only 4 people having given up driving (5.3%). Finally, 73 respondents answered the education question, with 12%, 8%, and 77.3% indicating secondary, further, and higher education, respectively.

Subsequently, Cluster Analysis (CA) was utilized to classify groups of participants with similar emotional assessments of Kansei words. The demographic characteristics of the five groups were as follows:

- Group 1 - N=14, Female (64.3%), 70-79 (50%), Higher education (N=13, 71.4%);
- Group 2 - N=15, Male (73.3%), 60-69 (73.3%), no age 80+, Higher education (N=12,80%);
- Group 3 - N=10, Equal gender, 70 -79 (70%), no age 80+, Used to drive (20%), Used to own a car (10%), Higher education (N=6,60%);
- Group 4 - N=20, Male (65%), 60-69 (55%), 70-79 (30%), Used to drive (5%), Higher education (N=19; 80%);
- Group 5 - N=16, Male (56.3%), Female (43.8%), 60-69 (50%), 70-79 (37.5%), Used to drive (6.3%), Used to own a car (6.3%), Higher education (N=14， 87.5%)

2.3 Data Analysis

Initially, Principal Component Analysis (PCA) was conducted to obtain the perceptions and assessments of car interior factors of the older driver group. The results of the analysis demonstrated six principal components (PCs), and each of the PCs was subsequently named with the support of an expert meeting (Table 1). In addition, the PCs explained rate of the total data (Total variance explained) determined its importance. The PCA Score was then calculated for the data, supported by the literature of Wold et al. (1987) and Eriksson et al. (2013), to obtain the scores of each car interior design for each PC (Table 2).

Table 1 - Six PCs extracted from PCA and features.

Principal Component	Semantic Dimension	Kansei word pairs	Total variance explained
PC 1	*Comfort-related*	*Comfortable - Uncomfortable, Soft - Hard, Relaxed - Tense, Warm - Cold, Accessible - Inaccessible, Roomy - Cramped*	20.995%
PC 2	*Trends-related*	*Fashionable - Old-Fashioned, Traditional - Modern, Futuristic - Nostalgic, Avantgarde - Conservative, Bright - Dark*	17.663%
PC 3	*Self-expression*	*Flashy - Plain, Passionate - Gentle*	10.476%
PC 4	*Quality-related*	*Delicate - Robust, Casual - Formal*	7.307%
PC 5	*Style*	*Simple - Complicated, Sporty - Elegant*	6.775%
PC 6	*Symmetry*	*Symmetrical - Asymmetrical*	5.163%

Table 2 – The score of twelve car interior designs in each PC

PCs	Car interiors											
	1	2	3	4	5	6	7	8	9	10	11	12
Comfortable-related	1.53	0.34	-1.60	1.22	-0.63	2.21	-1.95	0.77	-1.34	-0.80	0.19	0.08
Trend-related	-0.83	0.82	1.14	-1.80	0.35	0.78	1.18	-0.81	1.58	0.34	-0.25	-2.47
Self-expression	0.98	-0.06	-0.14	1.08	-0.13	0.13	-0.88	-0.35	0.64	-1.32	0.64	-0.58
Quality-related	-0.27	0.34	0.06	-0.11	0.55	0.18	-0.57	-0.26	-0.32	0.49	0.04	-0.13
Style	0.61	-0.84	-0.23	0.14	-0.69	-0.44	0.51	0.00	0.34	-0.01	0.30	0.32
Symmetry	-0.29	0.30	0.14	-0.02	0.35	-0.27	-0.30	-0.12	-0.24	0.09	0.05	0.31

Finally, a line graph (Figure 4) was formed based on the outcome of the CA and the emotional evaluation to depict the consensus and differences among distinct participant groups regarding evaluation of the car interiors.

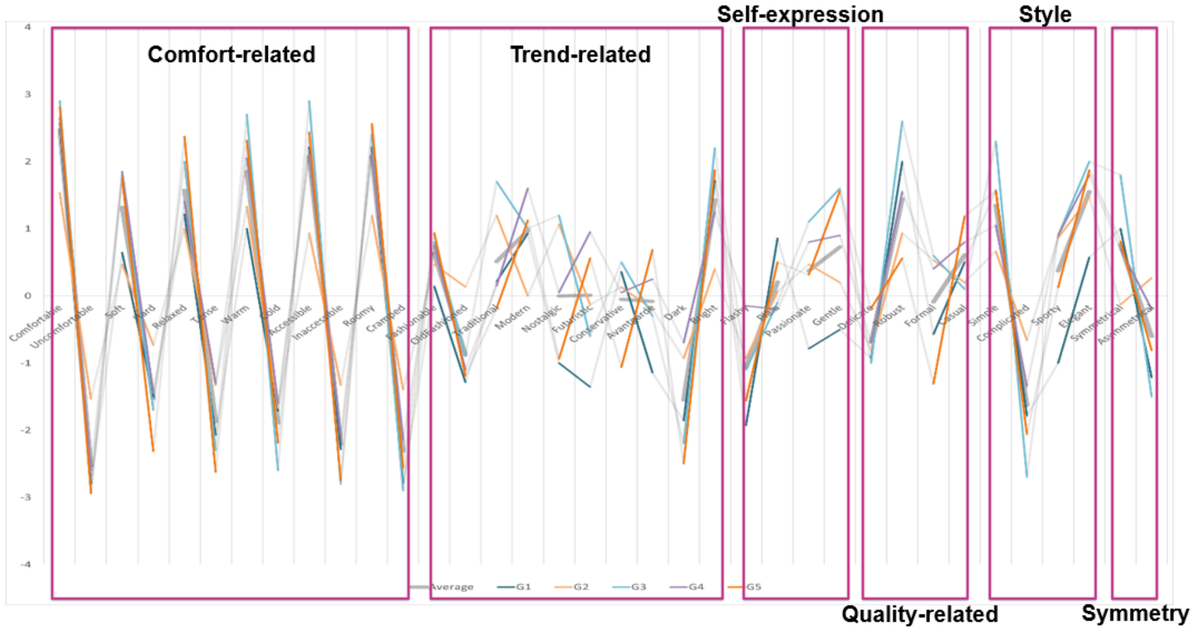

Figure 4 - The line graphs of the differences and commonalities in the emotional assessment between the five groups.

3. RESULTS

Based on the above information, it is clear that older individuals attach significant importance to *Comfort-related* factors. Comfort encompasses a wide range of emotional experiences, including contentment, tranquillity, and relaxation (Summala, 2007). Nevertheless, due to changes in mental well-being and cognitive capabilities, older adults encounter difficulty in experiencing intense positive emotions, such as comfort (Ready et al., 2017). Moreover, as a consequence of the physical limitations associated with the ageing process, older individuals are more prone to experiencing fatigue and facing challenges posed by inadequate ergonomic designs, such as achieving a comfortable driving position, and entering and exiting vehicles (Herriotts, 2005). These challenges could cause discomfort, and Zhang et al. (1996) pointed out that certain discomfort may be associated with pain, fatigue, soreness, and numbness. Therefore, in this research, older participants exhibited the highest consensus of evaluation of dimensions such as *'Soft - Hard', 'Warm - Cold', 'Accessible - Inaccessible'* and *'Roomy - Cramped'*, with some expressing a more emphasis on physical comfort (*'Soft - Hard'*) or psychological pleasure (*‘Relaxed – Tense’*).

Trend-related factors are the second important evaluation criteria for older people and influence their evaluation of comfort. Khalid & Helande (2004) and Marchegiani & Phau (2011) emphasized that familiarity plays an important role in shaping individual’s preferences and evaluations, which explains why products with nostalgic or retro cultural significance tend to captivate the attention of older individuals (Wu, 2019; Marchegiani & Phau, 2011). Furthermore, the impact of unfamiliarity with emerging technology during older people's evaluation processes cannot be overlooked. Meyer (2004) highlighted that older people might resist adapting to emerging designs and technologies, resulting in negative emotions or attitudes. Consequently, in this research, they are more likely to associate most past car interior designs (with lower *Trends-related* scores) with *'Comfortable'*, with Group 3 as a clear example.

The third PC, *Self-expression*, reflects older people's quest for certain emotions. Notably, certain scholars found that negative experiences can heighten older individuals' need for emotional expression, including self-esteem and autonomy (SafetyNet, 2009; Bright & Coventry, 2013). The findings reveal that delicate designs and colours, especially red, were associated with *Self-expression* in older adults. While vibrant colours tend to evoke higher emotional perceptions, warm and light colours resulted in higher *Comfort-related* ratings. Conversely, car designs 7 and 12, characterized by *'Hard'* and *'Cold'* styles, had lower *Self-expression* scores, which consequently impacted comfort ratings.

The fourth and fifth PCs are labelled *Quality-related* and *Style*. *Quality-related* factors refer to the environment and scene, while *Style* factors are the design style (e.g., *'Sporty'*). PC scores (Table 2) indicate a higher degree of relevance for evaluations in terms of *Quality-related* and *Style* factors. Older people tend to associate designs with lower *Style* and higher *Quality-related* scores with a sophisticated or business-oriented style. On the other hand, designs with higher *Style* and lower *Quality-related* scores showed prominent design styles such as *'Simple'*, *'Bright'*, and *'Sporty'*. Overall, designs associated with the former obtain higher comfort ratings.

The sixth factor identified in the analysis is *Symmetry*. The preference for *Symmetry* is related to personal aesthetics, and it appears that this factor is less perceived and expressed among older individuals. Thus, it shows a lower correlation with the other factors. Among the five clusters, only Group 3 demonstrated a slight emphasis on this factor.

4. CONCLUSION

In conclusion, this study reveals that older adults' primary evaluation criteria for car interiors are *Comfort-related, Trend-related, Self-expression, Quality-related, Style,* and *Symmetry*. In addition, emotional evaluation using CA showed that older adults with different emotional perceptions and expressions had varying perceptions of other factors. This study is significant because it identifies the preferences and evaluation criteria of older drivers for car interiors and provides a method for locating user groups and identifying individual preferences. These findings indicate that KE can potentially support designers with age-friendly car interior design.

REFERENCES

Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical psychology review*, *25*(1), 45-65.

Arnold, M. B. (Ed.). (1968). *The nature of emotion: Selected readings* (Vol. 12). Penguin.

Bright, A. K., & Coventry, L. (2013, May). Assistive technology for older adults: psychological and socio-emotional design requirements. *In Proceedings of the 6th international conference on pervasive technologies related to assistive environments* (pp. 1-4).

Dong, Y., Zhu, R., Peng, W., Tian, Q., Guo, G., & Liu, W. (2021). A fuzzy mapping method for Kansei needs interpretation considering the individual Kansei variance. *Research in Engineering Design*, *32*, 175-187.

Eriksson, L., Byrne, T., Johansson, E., Trygg, J., & Vikström, C. (2013). *Multi-and megavariate data analysis basic principles and applications* (Vol. 1). Umetrics Academy.

Gillham, B. (2008). *Developing a questionnaire*. A&C Black.

Helander, M. G., & Po Tham, M. (2003). Hedonomics—affective human factors design. *Ergonomics*, *46*(13-14), 1269-1272.

Herriotts, P. (2005). Identification of vehicle design requirements for older drivers. *Applied ergonomics*, *36*(3), 255-262.

Hill, J. D., & Boyle, L. N. (2007). Driver stress as influenced by driving maneuvers and roadway conditions. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(3), 177-186.

Huang, Y., Chen, C. H., & Khoo, L. P. (2012). Products classification in emotional design using a basic-emotion based semantic differential method. *International Journal of Industrial Ergonomics*, *42*(6), 569-580.

Jordan, P. W. (2010). Designing pleasurable products: An introduction to the new human factors. London: Taylor & Francis.

Khalid, H. M., & Helander, M. G. (2004). A framework for affective customer needs in product design. *Theoretical Issues in Ergonomics Science*, *5*(1), 27-42.

Marchegiani, C., & Phau, I. (2011). The value of historical nostalgia for marketing management. *Marketing Intelligence & Planning*.

Meng, A., & Siren, A. (2012). Cognitive problems, self-rated changes in driving skills, driving-related discomfort and self-regulation of driving in old drivers. *Accident Analysis & Prevention*, *49*, 322-329.

Meyer, J. (2004). Personal vehicle transportation. In *Technology for adaptive aging*. National Academies Press (US).

Meyer, J. (2014). Designing in-vehicle technologies for older drivers. *The Bridge*, *44*(3).

Nagamachi, M. (1995). Kansei engineering: a new ergonomic consumer-oriented technology for product development. *International Journal of industrial ergonomics*, *15*(1), 3-11.

Nagamachi, M. (1999, October). Kansei engineering: the implication and applications to product development. In *IEEE SMC'99 Conference Proceedings. 1999 IEEE International Conference on Systems, Man, and Cybernetics (Cat. No. 99CH37028)* (Vol. 6, pp. 273-278). IEEE.

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The measurement of meaning* (No. 47). University of Illinois press.

Peter, J. P., Olson, J. C., & Grunert, K. G. (1999). Consumer behavior and marketing strategy.

Ready, R. E., Santorelli, G. D., & Mather, M. A. (2017). Judgment and classification of emotion terms by older and younger adults. *Aging & mental health*, *21*(7), 684-692.

SafetyNet, (2009). Older Drivers. [online]. [Viewed 28/01/2022]. Available from: https://ec.europa.eu/transport/road_safety/system/files/2021-07/olderdrivers.pdf

Summala, H. (2007). Towards understanding motivational and emotional factors in driver behaviour: Comfort through satisficing. In *Modelling driver behaviour in automotive environments* (pp. 189-207). Springer, London.

Wold, S., Esbensen, K., & Geladi, P. (1987). Principal component analysis. *Chemometrics and intelligent laboratory systems*, *2*(1-3), 37-52.

Wu, T. Y. (2019, July). The Effect of Product Aesthetics on Older Consumers. In *International Conference on Human-Computer Interaction* (pp. 98-106). Springer, Cham.

Young, K. L., Koppel, S., & Charlton, J. L. (2017). Toward best practice in human machine interface design for older drivers: a review of current design guidelines. *Accident Analysis & Prevention*, *106*, 460-467.

Zhang, L., Helander, M. G., & Drury, C. G. (1996). Identifying factors of comfort and discomfort in sitting. *Human factors*, *38*(3), 377-389.

Preferences for new public transport options in a lignite mining area – an app-based qualitative usability approach

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Keywords: new mobility, participation, app, public transport, DRT, rural.

ABSTRACT

In rural areas, and particularly so in lignite mining areas, the structural change brought about new mobility patterns. Due to a lower density of local amenities and cuts in the supply of public transport options, these further fostered the hegemony of the automobile. Research on lignite mining areas shows that there is still need for further investigation particularly regarding mobility (Greiving et al. 2022). In order to make public transport a competitive alternative as compared to the private car, it is very important to identify the characteristics mobility options should have from a user perspective. Furthermore, it is of interest how available options are able to meet these preferences. A participatory workshop setting was used to discuss these aspects with five locals of different age, gender and mobility behaviour and test the usability of an app that displays new mobility options for public transport and lets users choose them. These new options comprise: on-demand bus, carsharing, shared electric bicycle, ride-pooling, and an automated ferry supposed to cross a former mining area that is being transformed to a big lake. Applying the method 'thinking aloud', we found that persons wish flexible, comfortable, fast, safe and cost-saving as well resource-efficient and environmentally-friendly transport options – partly confirming previous studies (Engeln & Schlag 2002). So far, participants prefer to either walk and use public transport, the bicycle or company cars. They stressed that the availability of transport options in terms of time and location is a huge problem. For instance, they can usually get easily to their leisure activities, however, in the evening on their way back, they cannot find suitable public transport options. Accordingly, participants said that in these cases they have to accept long waiting times, use their own car or organize a shared trip with people they know. Hence, among the proposed new options, on-demand shuttles and ride-sharing were associated with positive statements and expectations. Regarding cycling, participants said that thievery is a big problem and they pronounced several times the wish to carry their bikes on buses. Another workshop will have users test an existing navigation app's eligibility to display and let users choose among the discussed new options. Our preliminary results from the first workshop give some first implications on how public transport in rural areas could be improved. The presentation will show the results of both workshops in detail and discuss implications for public transport planning but also the methodological design.

REFERENCES

Engeln, A., & Schlag, B. (2002). ANBINDUNG: Mobilitätsanforderungen und Präferenzen. In: Schlag, B., & Megel, K. (Eds.). (2002). *Mobilität und gesellschaftliche Partizipation im Alter*. Stuttgart: Kohlhammer.

Greiving, S., Gruehn, D., & Reicher, C. (2022). The Rhenish Coal-Mining Area—Assessing the Transformational Talents and Challenges of a Region in Fundamental Structural Change. Land, 11(6), 826.

Effects of Rearward Displays in Highly Automated Shuttles on Following Traffic

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Keywords: automated driving, highly automated shuttles, external human-machine interface (eHMI), countdown timer, road safety.

Background. The use of shared automated vehicles (SAVs) is considered a promising concept to promote sustainability in transportation and is currently explored in many automated shuttle research projects. There is a consensus that SAVs need to be highly accepted for being successfully integrated into road traffic. However, since many SAVs drive at speed levels below 20 km/h, traffic flow may be substantially impeded. This may result in an increased potential of frustration for drivers in rear traffic, which might lead to negative effects on driving behaviour and road safety such as risky overtaking manoeuvres. **Method.** Therefore, an online video-based study was conducted to investigate how additional information (e.g., about the next stop and thus a safe opportunity for overtaking the SAV) is evaluated by following drivers and to what extent this improves the interaction with SAVs. In this context, different countdown displays on the SAV's rear window as external human-machine interface (eHMI) were investigated. As study material, video clips were created (using Unity 3D) displaying the perspective of manual drivers behind an SAV. In a repeated-measures design, countdown displays that differed in a) modality (time versus distance to the next stop) and b) updating frequency (1 Hz, 2 Hz, 5 Hz, versus 10 Hz) were examined and compared to a baseline condition without any countdown. **Results.** Results provide first insights regarding general acceptance as well as preferred modality, updating frequency, and initialization requirements of rearward eHMIs in SAVs. **Conclusion.** The information provided by additional eHMIs might increase transparency of upcoming SAVs driving manoeuvres for following traffic and could thus support road safety.

Infrastructure-based Automated Driving System and HMI for Mobilities

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Keywords: Automated Driving, LiDAR, Infrastructure-based, V2I Communication, Pattern Drawing

ABSTRACT

In recent years, there has been a growing interest in the use of LiDAR for automated mobility, and companies and research institutes around the world have been developing and demonstrating LiDAR-based object recognition using deep learning, which enables a higher level of recognition than conventional methods. In addition, point cloud data from LiDAR is effective in SLAM (Simultaneous Localization and Mapping) technology for self-position estimation and environment map production, and since point clouds can be acquired over a wide area and even at night, object detection technology can be used to develop assistive technology for automated driving. Therefore, the object detection technology is expected to be used for ADAS (Advanced Driver-Assistance Systems). In our laboratory, we have developed the autonomous mobility system shown in Fig. 1. However, LiDAR is an expensive sensor, and its use as an external recognition sensor in automobiles will inevitably increase the price, making it difficult to popularize automated driving.

Therefore, we believe that the introduction of an infrastructure-based system, as shown in Figure 2, in which LiDAR is not installed on the mobility side but on the infrastructure side and the status recognized by the infrastructure is provided to mobility via communication, will reduce the price of the automated driving system and enable the diffusion of the technology. In addition, the introduction of an infrastructure-coordinated system will make it possible to automate the operation of a greater number of mobility devices, and is expected to dramatically improve the safety of electric kick-skaters and other vehicles that are expected to become popular in the near future.

This research proposes a method to improve the recognition rate of target mobility and pedestrians using LiDAR installed on the infrastructure. The problem with moving LiDAR from mobility to infrastructure is that the high-density point cloud in front of mobility becomes lower. The object recognition rate in the point cloud goes down as the density goes down. Therefore, in this study, in addition to the conventional clustering of point clouds, tracking of feature points was introduced to prevent the recognition rate from decreasing. In addition, as an HMI that warns users of danger in an infrastructure-coordinated system, we also propose a system that draws warning patterns on the road surface from the infrastructure side using visible light lasers assuming that no devices are attached to the mobility vehicle.

Figure 1 – Automated driving mobility scooter

Figure 2 – infrastructure-based system

Road Junctions may cause problems for the safe co-existence of Automated Vehicle and certain Vulnerable Road Users

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Keywords: Vulnerable Road User, Autonomous Vehicles, Road Intersections, Crash Data

Background

The vision of a fully automated vehicle (AV) has excited the general public since Google won the US Defense Department's urban driving contest in 2007. Despite obvious challenges ahead, the pathway to full automation is accepted as being achievable and therefore has become the subject of much ongoing research. Adaptive driving support and information facilities may improve the driving experience enabling drivers to make better use of their time in routine situations, whilst automated traffic management offers the opportunity to manage the road infrastructure more efficiently providing improvements to mobility and the environment.

However, the forthcoming implementation of AVs on the roads is not without challenges. The full effects of offering such vehicles on the market, which may allow for drivers to become less than 100% engaged with the task of driving, may have detrimental impacts on other road users, particularly Vulnerable Road Users (VRUs) for a variety of reasons. To date, research on the interaction between AVs and VRUs has been limited to the technical aspects of detection and recognition of pedestrians, and cyclists by the vehicles, solely considered from the attitude of the vehicle (Vissers et al., 2016). However, Vissers et al. also noted that it is equally important to look at matters from the attitude of the VRUs. Will VRUs be able to effectively interact with AVs? As an example, would this affect their crossing decisions or their red-light compliance? And if so, in what way? Would they accept smaller gaps, or would they prefer larger safety margins? Would they be inclined to infringe traffic controls such as red lights more often or not? Also, through the transition period, with a combination of fully autonomous, partly autonomous and manually driven vehicles, will pedestrians be capable of differentiating between these vehicles, and would they adjust their behaviour accordingly? Furthermore, during the transition there is likely to be a large fleet of partially autonomous vehicles on the road, and these vehicles may suddenly hand back control to the human driver if they encounter a situation for which they are not programmed to handle.

In this study, recent (2021) UK crash data was analysed to examine some challenging traffic scenarios that are prevalent and represent scenarios in which future connected and autonomous vehicles may be challenged in terms of safe manoeuvring. Road intersections are currently very common locations for VRU crashes; traffic flows and road-user behaviours at intersections can be unpredictable, with many vehicles behaving inconsistently (e.g., red-light running and failing to stop or give way), and many VRUs taking unforeseen risks. The challenges of such unpredictable VRU behaviour at intersections (including road users violating traffic or safe-crossing signals or taking other risks) combined with the lack of knowledge of AV responses to intersection rules, could be problematic. This could be further compounded by changes to nonverbal communication that currently exists between road users, which could become more challenging once CAVs become more widespread. This paper therefore aims to highlight possible traffic scenarios which are likely to be problematic for the VRU group in future interactions in traffic with Avs.

1. Method

GB national collision data (known as STATS19) was used to assess the extent of the VRU (Pedestrian and Cyclists only) casualty problem. Data from the years 2016 to 2021 were analysed. STATS19 is a national road collision database founded on collision records completed by the Police in the event that a collision occurs on GB roads. To be included as a collision record within the database, the collision must be reported to the Police and should involve human injury or fatality to at least one road-user. The STATS19 data collection form involves detailed information about the collision including date, location, and road conditions together with information about the vehicles and casualties. Whilst an overview analysis is conducted and published by the UK Department for Transport, this study includes additional analysis of the data.

2. Results

1. Pedestrians

According to the STATS19 database, there were 122,961 pedestrian casualties from 2016 to 2021. Of these, 2,551 (2.1%) were fatally injured.

Table 1 – Pedestrians - Collision Partners by Crash Severity

	Fatal		Serious		Slight		Total	
	N	%	N	%	N	%	N	%
Passenger Car	1,469	57.6	26,404	73.3	63,054	74.7	90,927	73.9
Truck	277	10.9	578	1.6	876	1.0	1,731	1.4
Light Goods	166	6.5	2,276	6.3	5,161	6.1	7,603	6.2
Motorcycle	66	2.6	1,472	4.1	3,665	4.3	5,203	4.2
Pedal cycle	15	0.5	771	2.1	1,686	2.0	2,472	2.0
Bus/coach	119	4.7	1,288	3.6	2,835	3.4	4,242	3.4
Other	61	2.4	661	1.8	1,815	2.2	2,537	2.1
Multi-vehicle	378	14.8	2,575	7.1	5,293	6.3	8,246	6.8
Total	2,551	100	36,025	100	84,385	100	122,961	100

Table 2 –Junction Type for Cyclist Collisions

Junction Type	Fatal	Serious	Slight	All
Crossroads	7.9%	8.6%	8.1%	8.2%
T, Y or Staggered	25.6%	32.1%	31.6%	31.6%
Multi-exit junction	0.9%	1.4%	1.5%	1.4%
Other junction	3.9%	5.2%	5.4%	5.3%
Roundabout	2.5%	2.8%	2.9%	2.9%
Mini roundabout	0.5%	0.9%	1.1%	1.0%
Slip Road	1.6%	0.6%	0.5%	0.6%
Private driveway	1.5%	1.9%	2.2%	2.1%
No junction	55.5%	46.3%	45.5%	45.9%
Not Known	0	0.3%	1.1%	0.8%

2. Cyclists

According to the STATS19 database, there were 103,983 cyclist casualties from 2016 to 2021. Of these, 654 (0.63%) were fatally injured.

Table 3 – Cyclists- Collision Partners by Crash Severity

	Fatal		Serious		Slight		Total	
	N	%	N	%	N	%	N	%
No other vehicle	101	15.4	2,020	7.7	2,650	3.4	4,771	4.6
Passenger Car	301	46.0	19,082	72.8	61,518	79.8	80,901	77.8
Truck	89	13.6	454	1.7	810	1.1	1,353	1.3
Light Goods	51	7.8	1.918	7.3	5,549	7.2	7,518	7.2
Motorcycle	6	0.9	420	1.6	1,425	1.8	1,851	1.8
Pedal cycle	4	0.6	380	1.4	587	0.8	971	0.9
Bus/coach	14	2.1	367	1.4	1,031	1.3	1,412	1.4
Other	23	3.5	492	1.9	1,212	1.6	1,727	1.7
Multi-vehicle	65	9.9	1,097	4.2	2,317	3.1	3,479	3.3
Total	654		26,230		77,100		103,983	

Table 4 - Junction Type for Cyclist Collisions

Junction Type	Fatal	Serious	Slight	All
Crossroads	10.1%	9.7%	10.6%	10.3%
T, Y or Staggered	21.1%	35.8%	37.7%	37.1%
Multi-exit junction	0.9%	1.2%	1.3%	1.2%
Other junction	2.8%	4.0%	4.5%	4.4%
Roundabout	4.3%	10.9%	11.6%	11.4%
Mini roundabout	0.3%	1.9%	2.3%	2.2%
Slip Road	0.8%	0.6%	0.7%	0.7%
Private driveway	1.1%	3.2%	3.4%	3.3%
No junction	58.7%	32.2%	26.5%	28.1%
Not Known	0.0%	0.5%	1.4%	1.2%

It is important to examine the nature and circumstances of VRU collisions and consider key "scenarios" for such collisions. Tables 2 and 4 show the percentage of collisions occurring at, or not at intersections in collisions of all injury severities. As can be seen in table 2, approximately 45% of pedestrian collisions occur at junctions/road intersections compared to approximately 55% of collisions not at intersections. For cyclists as shown in table 4, the equivalent figures are 41% at an intersection/junction compared to 59% not at a junction/intersection. The term 'intersection' includes several types of road intersections including signalized and non-signalized road intersections, roundabouts, etc. (although the data do not allow satisfactory discrimination on signalized versus non-signalized intersections). However, with over 50% of collisions for each VRU road-user types occurring at locations remote from intersections, these may involve pedestrians crossing at random points on the roads away from designated crossing facilities. The key issue here is that unsignalized intersections present unique challenges for CAVs since they often require decision-making and predictions about safe manoeuvring in relatively congested traffic environments.

3. Conclusions

The current study has explored collision data from GB to look at the potential influence of junctions on collisions. The main findings from the study are as follows:

- Vulnerable Road Users make up over one-half of fatally injured road users in Great Britain
- Intersection crashes involving VRUs are very common. Almost 50% of crashes occur at an intersection of some type
- Crashes at both signalized and non-signalized intersections may diminish when Autonomous Vehicles become widespread as such vehicles are more likely to adhere more stringently to road rules and regulations and will therefore give the VRU more certainty regarding safe crossing opportunities:
- However, there may still be challenges ahead based on both the CAVs and the VRUs understanding each other's code of conduct on the roads whilst considering unpredictable behaviour, particularly at intersections.

Other non-intersection road locations may also present challenges and there is scope for understanding and defining the various 'edge-case' scenarios where potential problems may manifest themselves.

4. References

Vissers, L., Van der Kint, S., Van Schagen, I., & Hagenzieker, M. (2016). Safe interaction between cyclists, pedestrians, and autonomous vehicles. What do we know and what do we need to know? Report R-2016-16. The Hague, SWOV Institute for Road Safety Research.

Morris, A: Wilson, C; Ma, R; and Thomas, P (2022) Driving Ahead – Some Human Factors Issues Related to Future Connected and Autonomous Vehicles. In Human Body Interaction edited by Michele Zannoni and Roberto Montanari, Fondazione Bologna University Press, ISSN 2385-0515; ISMN 979-12-5477-165-5, ISBN on-line 979-12-5477-166-2

Morris, A, Haworth, N, Filtness, A, Nguatem, D-PA, Brown, L, Rakotonirainy, A, Glaser, S (2021) Autonomous vehicles and vulnerable road-users—important considerations and requirements based on crash data from two countries, *Behavioral Sciences*, 11(7), 101, DOI: 10.3390/bs11070101.

Age, Group Travel, and Communication Device Use: Impact on Information Sampling in Pedestrians and Cyclists

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Keywords: attention, information sampling, crossings, group behaviour, communication device.

1. Background

Research indicates that children aged between 4-11 have varying abilities to sample information, being attentive, and detect hazardous situations in traffic (Whitebread & Neilson, 2000; Zeedyk, Wallace & Spry, 2002). Further, research reveals that young children are more prone to risk-taking compared to older children (Barton & Schwebel, 2007), even though younger children can reach the same level of competence with sufficient training (Whitebread & Neilson, 2000). Studies examining information sampling in young cyclists have yielded similar findings, revealing that children tend to perceive situations as less dangerous compared to adults. However, no age-related differences in visual search and hazard localization were found (de Geus, Vlakveld, & Twisk, 2020).

Few studies have been conducted in real traffic environments to validate these findings and examine how both children and the traffic environment can be adapted to create a safe environment. Thus, a field study was conducted, which demonstrated that the presence of other road users tends to influence information sampling and that this was cofounded with the children's age (Odéen, 2022). In turn, we expanded the study to explore how group behavior affects information sampling in traffic.

Studies confirming the results of the field study have shown that pedestrians alter their attention to traffic when walking in a group, regardless of their familiarity (Chinn et al., 2004; Simmons, Caird, Ta, Sterzer, & Hagel, 2020). Further, several studies have demonstrated that as group size increase, the odds of looking at traffic decrease compared to pedestrians walking alone (Lanzer & Baumann, 2020; Pešić, Antić, Glavić, & Milenković, 2016). This behavior may stem from either "following the crowd" or distributing responsibility for attention (Chinn et al. 2004; Harrell, 1991; Lanzer & Baumann, 2020). Similar strategies have been observed among peloton cyclists in groups.

When conducting this observational study, it was considered that it would inevitably suggest that some of the people observed are using mobile communication devices such as telephones and headphones. Therefore, this aspect is also included in the study. Previous research indicates that the use of handheld phones reduces the likelihood of looking left and right before crossing the street, whereas the use of headphones does not have the same effect (Simmons et al., 2020). Pedestrians texting are less attentive to their surroundings at crossings, and individuals engaged in phone conversations also exhibit less cautious behavior (Horberry et al., 2019; Ralph & Girardeau, 2020). However, there is no direct evidence that this impacts pedestrian safety, as compensatory strategies may be employed.

The main objective of this study was to investigate how group configurations, modes of transportation, and communication device usage affect visual information sampling in children and adults in traffic.

2. Method

A total of 898 active road users were observed at 14 different intersections on 18 occasions. A researcher used a bicycle equipped with two inconspicuous action cameras to film the intersections, capturing a view of pedestrians and side roads. Recordings were made in the morning before school started, ranging from 5 to 30 minutes depending on school traffic density. All locations were situated near schools for different age groups and had sidewalks. Four of the locations had separate bicycle lanes or combined pedestrian and bicycle paths. Seven locations were four-way intersections, and seven were three-way intersections. Motorized traffic at all locations was low and calm. The observations were then data coded using Observer XT16 (Noldus, Wageningen, NL). By identifying group memberships, five distinct interaction types were discerned, elaborated in Table 1.

Table 1 - Description of the division of formal and informal groups

Type of company	**Member of …**		**Comment**
	formal group	**informal group**	
alone	no	no	
strictly formal group	yes	yes	everybody in the group belongs to the same formal group and travels in physical proximity of each other
strictly informal group	no	yes	everybody in the group does not belong to a formal group
mixed group	either	yes	everybody in the group belongs to the same informal group, with some people belonging to (a) formal group(s)
distanced from company	yes	no	travelling with a physical distance, but obviously belonging together (e. g. a child travelling ahead of a parent with another child)

3. Results

The study revealed that group membership significantly influences individuals' visual sampling approach (walking: chi-square(4) = 20.6, $p < .001$; cycling: chi-square(4) = 16.3, $p = .003$). Formal groups demonstrate stronger collaboration (walking sampling rate: 78.7%; cycling: 64.9%) compared to informal groups (walking sampling rate: 88.7%; cycling: 71.4%). Table 2 provides the individual non-sampling percentages for the other group types.

Table 2 – Group size range and number of groups per type, the individual non-sampling rate for each group type, and the distribution of groups per type depending on whether all, some or no people in the group did any visual sampling other than from forward.

Walking			Individuals sampling information (percentage)	How many per group looked around?		
	# people in group	# groups per type		all group members	some group members	none
informal	2-5	36	88.7 %	25 (69.4 %)	11 (30.6 %)	
mixed	2-16	25	85.4 %	15 (60.0 %)	10 (40.0 %)	
formal	2-7	55	78.7 %	35 (63.6 %)	17 (30.9 %)	3 (5.5 %)
total	**2-16**	**116**	**84.0 %**	**75 (64.6 %)**	**38 (32.8 %)**	**3 (2.6 %)**
Cycling						
	# people in group	# groups per type		all group members	some group members	none
informal	2-5	23	71.4 %	12 (52.2 %)	8 (34.7 %)	3 (13.1 %)
mixed	2-5	4	28.6 %	1 (25.0 %)	1 (25.0 %)	2 (50.0 %)
formal	2-4	17	64.9 %	9 (52.9 %)	4 (23.5 %)	4 (23.5 %)
total	**2-5**	**44**	**63.6 %**	**22 (50.0 %)**	**13 (29.5 %)**	**9 (20.5 %)**

For difference in information sampling in age groups, the comparison was limited to walking groups only comprising either young or old individuals. There was no significant difference in non-sampling behavior between individuals in these two groups. Regarding usage of communication devices, pedestrians walking alone tended to exhibit higher non-sampling percentages when interacting with a hand-held device (18.8% non-sampling) compared to not using any device (5.0%) or using earphones (4.3%; chi-square(2) = 5.19, p = .075) (see Table 3).

Table 3 - The frequency of observation occasions per group type, age and usage of communication device

Pedestrian	Communication device			Age (# and % young)
	No	Ear-phones	In hand	
alone	159	46	16	15 (6.8 %)
strictly formal group	134		2	36 (26.5 %)
strictly informal group	76	34	5	1 (0.9 %)
mixed group	111	11	8	6 (4.6 %)

distanced from company	7			1 (14.3 %)
total 609	487	91	31	49 (9.7 %)

Bicycle	**Communication device**			**Age (# and % young)**
	No	**Ear-phones**	**In hand**	
alone	145	22		8 (4.8 %)
strictly formal group	37			9 (24.3 %)
strictly informal group	44	12		2 (3.6 %)
mixed group	12	2		
distanced from company	3			3 (100 %)
total 277	241	36		22 (7.9 %)

However, non-sampling rates did not significantly differ when walking with earphones in an informal or mixed group (11.1%) compared to walking alone (4.3%; chi-square(1) = 1.47, p = .226). Holding a device while walking in an informal or mixed group showed a trend of increased non-sampling (46.7%) compared to walking alone with a hand-held device (18.8%, chi-square = 2.76, p = .097). The use of earphones had no discernible effect on visual information sampling.

4. Conclusion

Group membership significantly influences individuals' information sampling approach. Formal groups demonstrate stronger collaboration compared to informal groups. There was no significant difference in non-sampling behavior between young and old individuals in walking groups. Pedestrians walking alone tended to have higher non-sampling percentages when using a hand-held device. The use of earphones did not affect visual information sampling. Overall, these findings highlight the importance of group dynamics and device usage in understanding individuals' behavior in traffic. When studying these factors, it is crucial to consider the interplay between group composition, age, and phone/earphone usage in real-world settings.

REFERENCES

Barton, B. K., & Schwebel, D. C. (2007). The Roles of Age, Gender, Inhibitory Control, and Parental Supervision in Children's Pedestrian Safety. Journal of Pediatric Psychology, 32(5), 517-526. doi:10.1093/jpepsy/jsm014

Chinn, L., Elliott, M., Sentinella, J., & Williams, K. (2004). Road safety behaviour of adolescent children in groups (TRL599). Retrieved from https://trl.co.uk/uploads/trl/documents/TRL599.pdf

de Geus, E., Vlakveld, W. P., & Twisk, D. A. M. (2020). Peer distraction: an experiment to assess impact on adolescent and adult cyclists' hazard perception. Journal of Transportation Safety & Security, 12(1), 66-81. doi:10.1080/19439962.2019.1591554

Harrell, W. A. (1991). Precautionary Street Crossing by Elderly Pedestrians. The International Journal of Aging and Human Development, 32(1), 65-80. doi:10.2190/4xne-wcbc-g9ty-ngyg

Horberry, T., Osborne, R., & Young, K. (2019). Pedestrian smartphone distraction: Prevalence and potential severity. Transportation Research Part F: Traffic Psychology and Behaviour, 60, 515-523. doi:https://doi.org/10.1016/j.trf.2018.11.011

Lanzer, M., & Baumann, M. (2020). Does crossing the road in a group influence pedestrians' gaze behavior? Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 64(1), 1938-1942. doi:10.1177/1071181320641467

Odéen, M. (2022). The attention demands of school routes - the role of age, traveling together, and mode of travel. unpublished report. Cognitive Science. Linköping University. Linköping.

Pešić, D., Antić, B., Glavić, D., & Milenković, M. (2016). The effects of mobile phone use on pedestrian crossing behaviour at unsignalized intersections – Models for predicting unsafe pedestrians behaviour. Safety Science, 82, 1-8. doi:https://doi.org/10.1016/j.ssci.2015.08.016

Ralph, K., & Girardeau, I. (2020). Distracted by "distracted pedestrians"? Transportation Research Interdisciplinary Perspectives, 5, 100118. doi:https://doi.org/10.1016/j.trip.2020.100118

Simmons, S. M., Caird, J. K., Ta, A., Sterzer, F., & Hagel, B. E. (2020). Plight of the distracted pedestrian: a research synthesis and meta-analysis of mobile phone use on crossing behaviour. Injury Prevention, 26(2), 170. doi:10.1136/injuryprev-2019-043426

Whitebread, D., & Neilson, K. (2000). The contribution of visual search strategies to the development of pedestrian skills by 4-11 year-old children. British Journal of Educational Psychology, 70(4), 539-557. doi:https://doi.org/10.1348/000709900158290

Zeedyk, M. S., Wallace, L., & Spry, L. (2002). Stop, look, listen, and think?: What young children really do when crossing the road. Accident Analysis & Prevention, 34(1), 43-50. doi:https://doi.org/10.1016/S0001-4575(00)00101-9

Human Operator Task Modeling for Decision Support Systems in Railway Control Rooms: a Review

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Keywords: Decision support systems, Task Modeling, Railway, Control Room

Decision support systems (DSS) are aimed at supporting human decisions in different industrial applications [1]. They are based on the task knowledge and will to provide the user with all the information needed to make the best decision, and to suggest the best one according to a predefined optimization criteria [2]. It is an interesting hypothesis having that, knowing the user, the task and the context of use, a set of HMI strategies could be designed to support the human execution of each type of task at best [3] [4] [5]. Such HMI strategies would be chosen by the DSS: they would be based on the knowledge of the task the DSS is modeled upon and chosen according to the contextual hints about the current task execution [6]. Railway Control Rooms represent a challenging application domain for DSS. Indeed, today they are the object of important investments for the increase of the automation usage within them and the optimization of human performance is gaining increasing momentum, as different European project initiatives can witness [7]. DSS can play a strategic role in this process. As stated before, the core knowledge that is leveraged is represented by the train controller task in this case [8] [9]. The research question proposed and considered in this work is how such knowledge is modeled and made operational to this aim at best the state of the art. Indeed, human operator procedures in rule books are not usually described in a machine-readable way and need to be analyzed by a human factors perspective to feed the DSS with the needed information, and this activity, besides requiring human factors experience, represents a mandatory step to do towards the path towards an increased and safer automation integration [10]. To the aim of understanding how to approach such activities at best, a survey of the literature about task modeling and decision support in control rooms is provided with the identification of the most promising and effective methodologies and open challenges.

References

[1] Jao, C. (Ed.). (2010). Decision support systems. BoD–Books on Demand.

[2] Johnson, H., & Johnson, P. (1991). Task Knowledge Structures: Psychological basis and integration into system design. Acta psychologica, 78(1-3), 3-26.

[3] Paternò, F. (2004). ConcurTaskTrees: an engineered notation for task models. The handbook of task analysis for human-computer interaction, 483-503.

[4] Knisely, B. M., Joyner, J. S., Rutkowski, A. M., Wong, M., Barksdale, S., Hotham, H., ... & Vaughn-Cooke, M. (2020). A cognitive decomposition to empirically study human performance in control room environments. International Journal of Human-Computer Studies, 141, 102438.

[5] Yun, Y., Ma, D., & Yang, M. (2021). Human–computer interaction-based decision support system with applications in data mining. Future Generation Computer Systems, 114, 285-289.

[6] Power, D. J., & Sharda, R. (2007). Model-driven decision support systems: Concepts and research directions. Decision support systems, 43(3), 1044-1061.

[7] D'Ariano, A. (2009). Innovative decision support system for railway traffic control. IEEE Intelligent Transportation Systems Magazine, 1(4), 8-16.

[8] Litra, M. (2014). Decision Support System for Assisting in Rail Traffic Management. vol, 3, 188-204.

[9] Alyoubi, B. A. (2015). Decision support system and knowledge-based strategic management. Procedia Computer Science, 65, 278-284.

[10] Lindblom, J., & Laaksoharju, M. (2022). A roadmap for UX in rail: Changing tracks in train traffic research. In 51st NES Conference: Work Well-Ergonomics in an unpredictable world, Uppsala, 23-25 October 2022 (pp. 51-58). Nordic Ergonomic Society (NES) & Uppsala University.

Using existing collision data to understand the possible injury risk associated with non-orthogonal seating positions while undertaking non driving related tasks.

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Keywords: Autonomous Vehicles, Seating, Collisions, Injury, Real world data.

1. Background

Since the 1950s, when initial concept drawings of autonomous vehicles were first presented, the idea that the occupants could sit how they desired has become a mainstay in the evolution of interior design. This concept has great merit as it allows occupants, and drivers in particular, to use the vehicle interior space more effectively, opening up the ability to use driving time for other non-driving related tasks (NDRT). Novel seating positions may bring with them concerns over occupant protection, especially if some collision risk, such as rear impacts, remain latent in the transport system

Rear collisions are one of the most common collision types, with approximately 400,000 occurring each year in the UK, this accounts for 27% of all reported collisions (DfT, 2018) and approximately 75% of all injury claims (RTA assistance, 2020) which leads to high medical/rehabilitation costs.

Most injuries from rear impact are soft tissue injuries and are commonly grouped under the 'whiplash' heading. Although whiplash is not a defined medical term it encapsulates a large proportion of crash related cervical spine injuries (Eck, 2001). The full extent of whiplash injuries are likely to be substantially higher to that published, with some studies suggesting up to 84% underreporting (Freeman, 2020).

Cervical spine injuries may persist and may be further influenced by seating preference if more freedoms are allowed through design. Studies have shown that detail changes in seating parameters, for example, head restraint location (Viano, 2002), seat back design (Warner, 1991), rear seat occupants and female occupants (Krafft, 2003) all variously influence the rates of occupant cervical spine injuries, however no research has considered seat angles away from the mean longitudinal centreline.

Driven by the sheer quantity of insurance claims (550,000 in 2019/20 in the UK, (DfT, 2021)), many studies have focussed on identifying a limit of harmlessness for rear end collisons, although this threshold is still disputed, the evidence does suggest that velocity change as low as 10km/h may lead to soft tissue injuries. (Castro, 1997)

Currently, Non-orthogonal seating positions, such that differ from a vehicle's traditional, longitudinally aligned seating arrangement, are not possible with any production vehicle, however a simulator study conducted on an autonomous vehicle buck within the Human Factors Research Laboratory at Loughborough University, showed that given total freedom, participants adopted a wide range of seat positions and associated postures whilst conducting NDRTs (Wilson, 2021). This study aims to provide evidence to inform the safety case for allowing these postures in autonomous driving.

2. Method

The study used real world collision data from the Road Accident In Depth Study database held by the UK Department of Transport. In depth data was used as it provided much more detail compared to the UK national police reported dataset (STATS19), while remaining broadly representative of the national picture, albeit with a focus on more serious and fatal collisions.

Angled seating positions do not currently exist within the collision data. Instead collisions were selected where an angled principal direction of force was evident. This angled force replicated the occupant kinematics for standard seating orientations that would be seen in AVs if the seat was angled by up +/- 60 degrees from the mean longitudinal vehicle plane.

Four stratified searches were conducted to identify collisions where angled directions of force, and subsequent occupant kinematics would reflect the postulated AV situation. A detailed case review process was undertaken on 154 cases with a final dataset of 79 cases available for detailed examination.

Variables extracted for use in the analysis included detailed injury information and injury contacts, crash reconstruction metrics (Delta-V, impact speed), vehicle damage information and a full text description of the collision.

3. Results

Data indicates that the severity of injuries, collision velocities and the types of injury contact for non-orthogonal impacts are very similar to orthogonal impacts. The change in velocity (Delta-V) for all non-orthogonal impacts examined are around the lower threshold for injury occurrence, although these remain within the expected range from the literature. Mean Delta-V are 11.5km/h for non-injury collisions and 13.5km/h for slight injury collisions. Further detailed examination of speed against injury is not possible due to very small numbers of more serious collisions, however when plotted an observed correlation is identified, however this is subject to low case number effects.

The primary injury and mechanism are non-contact (‘whiplash’) cervical spine injuries, with few (n=2, 2.5%) serious or fatal injuries. Where these do occur the intrusion of vehicle structures and direct contact with these stiff structures is the primary injury mechanism, this is also in line with the existing literature on more serious injuries from rear impacts. For injury contacts, no observed differences were identified between the non-orthogonal collisions and orthogonal collisions.

4. Conclusion

Injury data shows that even with angled impacts up to 60 degrees from the mean longitudinal vehicle axis, the injury risk, in terms of severity, is relatively low, particularly when compared to the injury pattern for orthogonal rear impacts which exhibit a number of similarities to angled impacts. Similalry there is little evidence to suggest that non-orthogonal impacts increase the rate of injury which remained low within the sample (40% of the collisions resulting in no reported injury).

Although there is much work to be done with respect to restraint and airbag design for AVs, this study suggests that angled seat positions are perhaps low risk. This finding also suggests that current seat and head restraint design is effective in situations that are non-optimal for their designed performance, such as when the direction of collision force increases up to 60 degrees.

The study is limited by the small sample size and more work is needed to determine peak acceleration and duration which is not captured through real world data but does have an impact on injury rates.

5. References

Warner, C. Y., Stother, C. E., James, M. B., Decker, R. L. (1991). Occupant protection in rear-end collisions: role of seat back deformation in injury reduction. Journal of passenger cars, Vol. 100, Section 6, 2018–2039.

Krafft, M., Kullgren, A., Lie, A., Tingvall, C. (2003). The risk of whiplash injury in the rear seat compared to the front seat in rear impacts. Traffic Injury Prevention, Vol. 4, issue 2, 136–140. https://doi.org/10.1080/15389580309862

Viano, D. C. (2002). Role of the seat in rear impact crash safety. SAE international.

Eck, J, C., Hodges, S, D., Humphreys, S, C. (2001). Whiplash: a review of a commonly misunderstood injury. The American Journal of Medicine, Vol. 110, issue 8, 651–656. https://doi.org/10.1016/S0002-9343(01)00680-5

Freeman, M, D., Leith, W, M. (2020). Estimating the number of traffic crash-related cervical spine ijuries in the United States: an analysis and comparison of national crash and hospital data. Accident analysis & Prevention, Vol. 142, https://doi.org/10.1016/j.aap.2020.105571

Go Law solicitors Limited. (July 2013). Accident statistics. https://toptests.co.uk/driving-statistics/

Gov.uk. (2012, Jan 31). Road accident and safety statistics. https://www.gov.uk/government/collections/road-accidents-and-safety-statistics

Castro, W, H., Schilgen, M., Meyer, S., Weber, M., Peuker, C,. Wörtler, K. (1997). So ”whiplash injuries” occur in low-speed rear impacts?. European Spine Journal, Vol. 6, 366-375. https://doi.org/10.1007/bf01834062

Wilson, C., Gyi, D., Morris, A., Bateman, R., Tanaka, H. (2021) Space Utilisation and Comfort in Automated Vehicles: A Shift in Interior Car Design? Comfort Congress 2021 Proceedings.

Applying the Driver Reliability and Error Analysis Method – Lessons Learnt

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Keywords: Crash causation, systems approach, road traffic crashes, DREAM

Road traffic crashes and the resultant injuries and fatalities are an international issue and therefore road safety research aimed at preventing crashes has huge potential impact. A key first step in preventing crashes is to identify the factors that contributed to them. Crash causation has been a focus of studies for many years and a variety of methods have been developed. One such method is the Driver Reliability and Error Analysis Method (DREAM). DREAM is a systems-based method that enables chains of contributory factors to be identified relating to a specific crash and also for these chains to be aggregated to indicate patterns in groups of crashes. Unlike other tools based on systems methods such as AcciMap, DREAM chains take into account the order of contributory factors in time. For example fatigue appears earlier in contributory factors chains than factors that are more specific to the particular crash such as missed observations. In the years since its first development a number of analyses of DREAM have been conducted. These analyses have demonstrated the scope and versatility of the method as well as some limitations. For example, the method can be used to identify causation patterns in specific types of crashes, e.g. a vehicle leaving its lane, or used to compare crash causation among two groups of drivers, e.g. PTW riders and their collision partners. These analyses have also allowed some best practice to be identified that can be applied when conducting DREAM analyses. This includes the importance of defining the groups of focus and using both DREAM diagrams and descriptive statistics in interpreting and comparing results between groups of interest. Further lessons learned from DREAM analyses and best practice will be discussed as well as the potential future role of DREAM as vehicles become increasingly automated.

Trendline: Towards a Common Approach for Using Road Safety Performance Indicators in Europe

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Keywords: road safety, performance indicators, Europe, methodology.

1. Background

The European Commission (EC) has put forward a new approach to the European Union's (EU) road safety policy for the decade 2021-2030, highlighting the need of setting new interim targets and establishing a range of road safety performance indicators for road safety at European level. The indicators are referred to as "Key Performance Indicators" (KPIs) and are directly related to factors that contribute to road crashes and injuries.

The EC has made grants available for developing and applying a common methodology for the collection of the KPIs in the EU. In a first project "Baseline", 18 EU Member States participated. This project ended at the end of 2022; the reports were published in March 2023. A successor project "Trendline" started at the end of 2022. 25 EU countries are fully engaged in the project; four more European countries act as an observer. Trendline is coordinated by SWOV Institute for Road Safety Research in The Hague (The Netherlands).

Both Baseline and Trendline start from 8 KPIs which have been defined by the European Commission, following consultation of experts and representatives of EU Member States (EC, 2019). These eight KPIs are associated with speeding, driving under the influence of alcohol, distracted driving, wearing helmets, wearing seatbelts and using child restraint systems, vehicle safety, safety or roads, and post-crash care.

2. Method

For each of these KPIs, a methodology for data collection and analysis was initially developed in the Baseline project by a group of European experts, considering the best national practices observed in the EU. These methodologies have been reviewed and somewhat adapted during the early stages of the Trendline project, taking into account the experience gained in Baseline. The adapted versions will be available on the Trendline website from mid-2023 onwards. Most of the measurements and observations will take place in autumn 2023 and spring 2024.

In Trendline some new experimental indicators and complementary methods have been identified, following a consultation process involving all Member States:

- Driving under the influence of drugs
- Share of 30km/h road lane lengths in urban zones
- Red-light negations by road users

- Compliance with traffic rules at intersections
- Helmet wearing of PMD riders
- Self-reported risky behaviour
- Attitudes towards risky behaviour
- Use of lights by cyclists in the dark
- Enforcement of traffic regulations
- Alternative speeding indicators.

For each of these indicators a methodology will be developed and subsequently data collection and analysis will take place at limited scale in order to test the feasibility and reliability of the method.

In Trendline there will be more emphasis on the use of the KPIs in policy monitoring activities. A Policy Integration Advisory Committee (PAC) has been established that will reflect on how KPIs could be used in the policy process, will collect best practices, and will formulate recommendations to the European Commission and the Member States.

3. Results

The results of the Baseline project are documented in a series of reports that are available from the Baseline website. At the moment of submitting this abstract, the methodologies for the eight standard KPIs in Trendline have been reviewed and the selection process for new experimental indicators was completed. Most EU Member States will deliver values for 5 to 7 KPIs. First results on Trendline will become available early 2024.

4. Conclusion

The Baseline and Trendline projects show that it is possible to develop and apply methodologies for road safety performance indicators that are common, transferable and comparable across different countries. The data collected is a basis for monitoring and evaluating the road safety progress at national and EU level over the decade 2021-2030 and will facilitate the formulation of targets at European and national level. It will also support decision makers in deciding on the most appropriate measures to be taken to improve road safety.

References

Website Baseline: https://baseline.vias.be - Website Trendline: https://trendlineproject.eu

European Commission (2019). Commission staff working document EU road Safety Policy Framework 2021-2030 - Next steps towards "Vision Zero". SWD (2019) 283 final.

Silverans, P., & Vanhove, Sophie (2023). Baseline conclusions and recommendations. Baseline project, Brussels: Vias institute."

European Commission (2022) Road Safety Thematic Report – Road Safety Performance Indicators (RSPIs). European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport.

Coloured Street Designs for More Attention – Testing a New Road Safety Measure

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ABSTRACT

International studies suggest that measures such as coloured street designs can help to increase the attention level of all road users and reduce vehicle speeds in urban areas. However, such studies lack formal evaluation.

Therefore, a pilot test was carried out to determine the effects of coloured road markings on the attention and speeding behaviour of drivers[1]. Two road sections were selected in order to test two different types of design. Both sections were located in 40 km/h zones. As part of the evaluation, speed measurements, traffic observations and online surveys were conducted, each before and after the designs had been applied.

Results show that the number of drivers exceeding the speed limit of 40 km/h was reduced by 4 to 7%. Furthermore, the average speed was reduced by 1-2 km/h, equivalent to the effects of radar speed displays. Thus, the effects on speed behaviour achieved by such designs can be considered positively.

In addition, a positive effect was found in the interactions between pedestrians and drivers. 13% of those surveyed (n=114) believe that car drivers now stop more often for pedestrians than before.

The initial results are very promising. Any habituation effects will be assessed in a follow-up study in spring 2023.

Keywords: colour, road markings, speeding behaviour, evaluation.

1. BACKGROUND

In urban areas, public spaces are often geared towards motorised road traffic and are thus not very attractive for walking. Firstly, this can be explained by the existing infrastructure which does not cater for the needs of pedestrians. Secondly, speeding in urban areas makes pedestrians feel unsafe.

[1] The pilot test, which was financed by Radland Niederösterreich GmbH and carried out by the Austrian Road Safety Board (KFV) in cooperation with con.sens mobility design, took place as part of the Lower Austrian road safety campaign "Schenk mir einen Augenblick" (meaning: give me a moment).

Simple measures such as coloured street designs can increase the attention of all road users and reduce vehicle speeds. Individual international examples suggest a positive effect of coloured designs on road safety (National Association of City Transportation Officials, 2016; Leku Studio, 2020; City of Vienna, 2013). In Austria, too, colour design elements have already been used in pedestrian zones and residential streets.

However, both internationally and nationally there are hardly any published evaluation results available.

Therefore, a pilot project was carried out in a small town in Lower Austria in autumn 2022, in order to identify the possible effects of coloured road markings on road users.

2. OBJECTIVES AND METHODS

The pilot tests had two main objectives:

- to evaluate the effects of the coloured road makings on the speeding behaviour of drivers
- to evaluate the effects of the coloured road makings on the attention of road users

Based on the findings, recommendations for the application of coloured road markings in local communities should be developed.

In the course of a preliminary study, two possible road types for the use of coloured designs were deemed suitable. Typology 1 should correspond to the character of a main through-road (two-way street with one lane per direction, predominantly linear, longitudinally oriented movement pattern of road users). Typology 2 was defined as intersections within secondary road networks (diffused movement pattern of road users). Depending on the respective typology and based on the existing literature, a variety of design options were developed. These were examined and a design was selected that was suitable for both typologies. A triangular shape was assumed to be the most appropriate. In addition, and regardless of the type of paint application, there must be good grip on the road surface. In order to test the two different designs two road sections were selected according to the described typologies above. Both sections were located in 40 km/h zones. The section for typology 1, which is situated on a straight two-way street, measures 250 meters in length and has a roadway width ranging from 6.5 to 7.0 meters. The selected intersection is located in the vicinity of a school centre, with two pedestrian crossings running along the edge of the intersection plateau. The intersection plateau is elevated and has a steep slope to the north.

With design 1 a visual narrowing of the road should be achieved. Design 2 was intended to increase the attention of road users.

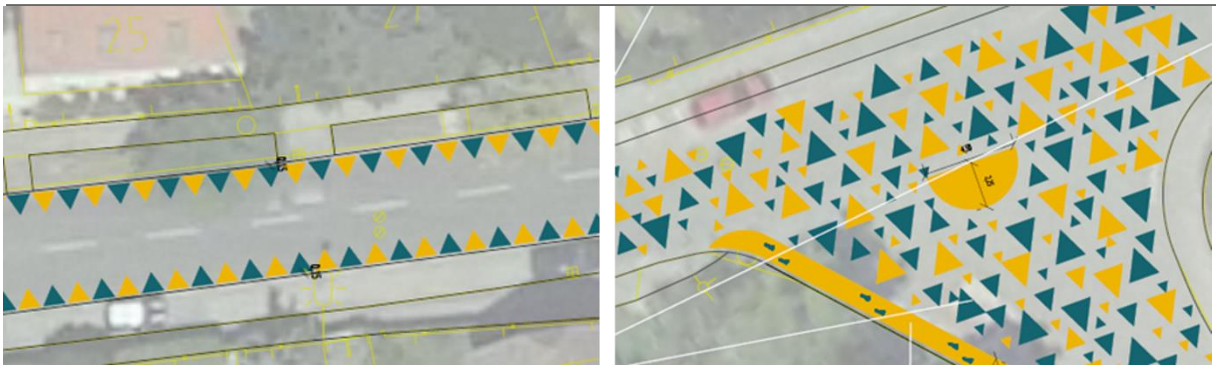

Figure 1: Design 1 (left), Design 2 (right)

In order to evaluate the effect on the behaviour of car drivers and on vulnerable road users, a before-and-after study design was chosen. The before measurements took place in June 2022 and the after measurement in October 2022. The conducted measurements and surveys were:

- Before and after speed measurements by a radar detector
- Before and after measurements of traffic volumes (including cyclists)
- Before and after observations of pedestrian walkways (by video recording)
- Before and after online survey of residents on their subjective perception of the applied designs

Driving speeds on the main through-road were measured at a single point located in the middle of the road section, on the intersection at two points, roughly 30 m before and after on of the pedestrian crossings. The data was collected with radar sensors that continuously measure the speed and length of each passing object. The duration of the measurements was one week before and after the installation of the colour markings.

The speed measurements examined the overall traffic flow and compared the speed patterns of all vehicles before and after the implementation of the road markings. This was done by calculating three key factors: (1) V85[2], (2) V50[3], and (3) the percentage of vehicles exceeding the speed limit.

3. RESULTS

The online survey included a sample of 230 (before) and 245 (after) persons. Regarding the subjective perception of speed, in the before survey more than a third of the respondents stated that most drivers

[2] The V85 speed, or the 85th percentile speed is the speed that 85% of drivers do not exceed, and 15% of the drivers do exceed.

[3] The V50 speed, or the 50th percentile speed is the speed that 50% of drivers do or do not exceed.

were speeding in both typologies. The conducted chi-square test shows that after applying the coloured designs at both locations, significantly fewer people believe that the driving speeds are too fast. In both typologies the proportion of respondents who think most drivers are too fast dropped by 12% and 17% respectively (see figure 2).

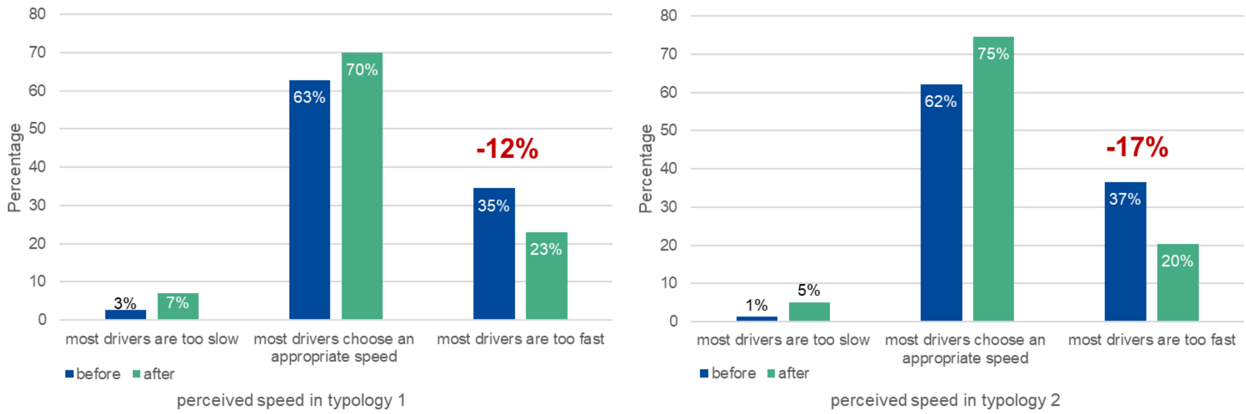

Figure 2: Perceived speed in both typologies

Furthermore, the proportion of those who believe that vehicles now stop for pedestrians more often or consistently has increased by 13% (typology 2). According to the respondents there were less conflict situations between road users after the application of the markings in both typologies.

All road users' perception of safety increased in the area of typology 1, whereas at the crossing (typology 2) the perception of safety of cyclists decreased slightly. However, it should be noted that the sample size of cyclists (n= 24) was very small.

To determine the speed behavior, the traffic volumes were initially determined at both locations. The pre-measurements on the main trough-road detected a total of 50,700 vehicles, while the post-measurements detected 52,700 vehicles. The average daily number of vehicles was 8,200 on weekdays and 5,300 on weekends. The difference in average daily number of vehicles by measurement phase ranged from 0 to 200.

Regarding the intersection, the pre-measurements detected a total of 10,100 vehicles, while the post-measurements detected 12,000 vehicles. The average daily number of vehicles was 1,700 on weekdays and 1,100 on weekends. The difference in the average daily number of vehicles between the two measurement phases ranged from 0 to 200 as well.

After the application of the road markings the speed measurements show a slight reduction in speed at both locations. At the main through-road (typology 1) a reduction of the V85 by 1 km/h was recorded. Within the intersection area (typology 2) the V85 was reduced by 2 km/h.

The evaluation also found that proportion of vehicles exceeding the speed limit of 40 km/h dropped by 6% in typology 1, and 7% in typology 2 (see figures 3 and 4).

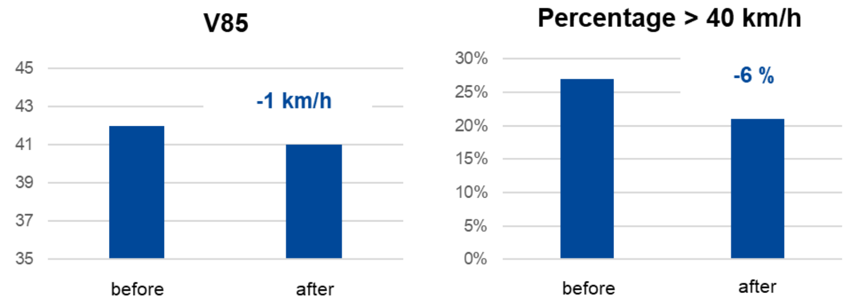

Figure 3: Speed reductions - typology 1

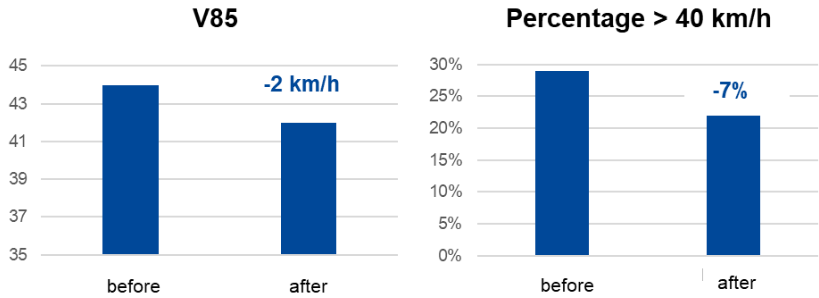

Figure 4: Speed reductions - typology 2

In order to further evaluate the reductions achieved, the measured speed was compared to Austrian average speed levels in 40 km/h zones (V85). At both locations, the speeds driven were already significantly lower than average before the application of the road markings.

According to a study by the Austrian Road Safety Board (KFV)[4], motor vehicle drivers in Austria drive at an average speed of 46.8 km/h (v85) in 40 km/h zones. At both study sites, the recorded speeds were already significantly below this average value at the pre-measurement time (typology 1: 42 km/h, typology 2: 44 and 41 km/h, respectively). With the coloured markings, a further reduction in speed could be achieved (typology 1: 41 km/h, typology 2: 42 and 39 km/h, respectively).

With Mobile Speed Displays, an average speed reduction of 1-3 km/h can be achieved in 40 km/h zones (Malin & Luoma, 2020; Trimmel et al., 2009). The extent of the reduction largely depends on the speeds driven prior to encountering the display. In areas with a lower average speed exceeding the legal limit, a Mobile Speed Displays may have little to no impact on driving speeds. Therefore, speed reductions of 2 km/h achieved with coloured markings can be considered as promising alternative.

[4] KFV survey (2021). Around 11 million measurements at 110 sites.

4. IMPACT

In order to support interested municipalities in the implementation of similar projects, guidelines were compiled. These describe the key points to be considered in the use of coloured markings including the potential costs and the corresponding approval process.

Within a working committee of the Austrian Research Association for Roads, Railways and Transport (FSV) the results of the pilot project were presented and discussed. It is now being considered to include criteria for the use of coloured road markings in an upcoming road safety directive concerning traffic calming measurements.

A second evaluation will be carried out by the end of 2023 to determine whether the post-evaluation effects can also be identified after a longer period of time. To guarantee the comparability of the results, the survey design will correspond to that of the previous evaluations.

5. REFERENCES

City of Vienna (2023, May 8). *Wirkungsanalyse flächiger Radwegmarkierungen in Wien.* Wien. Retrieved May 8, 2023, from https://www.wien.gv.at/verkehr/radfahren/analyse-markierte-radwege.html

Leku Studio. (2020). *Guia de Diseno para la Transformacion sostenible del Espacio Publico de Valencia*.

Malin, F. & Luoma, J. (2020). Effects of speed display signs on driving speed at pedestrian crossings on collector streets. Transportation Research Part F: Traffic Psychology and Behaviour, 74, 433-38.

National Association of City Transportation Officials. (2016). *Global Designing Cities Initiative. Global Street Design Guide*. Island Press. https://nacto.org/publication/global-street-design-guide/

Trimmel, P. et.al. (2009). Schwerpunktprogramm NÖ 2008 - Geschwindigkeitsüberwachung mit vorlaufender Aufstellung mobiler Tempoanzeigeanlagen (MTA). Durchgeführt im Auftrag des Amtes der NÖ Landesregierung Abteilung ST7 – Autobahnen und Schnellstraßen.

The assessment of riders' perception of the safest riding positions in simulated urban environments

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Keywords: Urban micro-mobility, electric scooter, safety perception, decision-making, route selection.

Extended Abstract

1. Background

Micro-mobility has become increasingly popular in dense urban as an alternative mode of transportation to private cars and buses due to its flexibility, time-saving capabilities, economic benefits, and low emissions (Ensor et al., 2021). However, previous studies have found that safety concerns hinder its widespread adoption (Gössling, 2020). Micro-mobility involved casualties on the sidewalk more than on the road, while the micro-mobility riders' casualties on the road are more severe than on the sidewalk (Wachtel & Lewiston, 1994). This contradiction about where micro-mobility riders should ride has been debated for decades. Previous research has shown that personal and road environmental factors influence riders' riding patterns. To our knowledge, we need to study further how riders' demographic, riding experience, skills, and knowledge about riding laws interact with road environment characteristics to influence their safety perception and attitudes toward safe riding positions, attitude, and feeling and how these factors interact with road environments to influence their decisions of the safest riding positions. This study aimed to measure their personal factors, experiment with riders' decision-making in the simulated urban environment, investigate how personal and environmental factors influenced their judgment on the safest riding positions, and work out the decision-making framework.

2. Method

This research designed twenty scenarios that simulated Israeli-typical urban road environments (VR-Forces). Thirty-three participants (half males and half females) were invited to the eye tracking lab and sat about 70 cm from a computer screen. Participants were asked to move a virtual figure of an e-scooter ride representing the participant in the simulated environment using the left and right keys on the keyboard and selecting their perceived safest riding position for each scenario. Participants could explore and observe each simulated road environment by moving the virtual figure horizontally across the street. An experimental program was developed to display the current view image corresponding with the position of the virtual rider (Figures 1 and 2). The simulated road environments consist of several environmental factors that could potentially affect participants' selection of safe riding positions (Figure 3). The participants' manual operations and eye movements were recorded during the experiment. In addition to the virtual scenarios task, the participants were asked to complete a self-developed questionnaire before and after the experiment to capture demographic information such as age, riding experience, law knowledge and crash involvement, and various questions concerning participants' perceptions of their riding skills and safety.

3. Results

The results will focus on the preliminary analyses of participants' manual responses without eye movements. Overall, the descriptive statistics revealed that the participants' safety preferences and attitudes do not always align with their law knowledge. Despite 85% of participants being aware that riding on the sidewalk is illegal, 54% still felt riding on the sidewalk was safer than the road, and 60% agreed with the argument that riding on the sidewalk should be allowed. Logistic regression models indicated that the participants with higher safety feelings for riding on the road preferred the road as a safer riding position regarding the sidewalk. In addition, some road environment factors adversely affected the participants' final decisions regarding the safest riding positions. For instance, 79% of participants considered the road the safest riding position in the base model without shoulder or parallel parking. However, this percentage dropped to only 3% when shoulders were presented, where 76% of the participants considered the shoulders the safest riding position. When parallel parking on both sides of the road was presented, only 36% of participants preferred staying on the road, and 64% considered the sidewalk the safest riding position. These preliminary results imply that when the road environment becomes more hazardous due to environmental factors such as parallel parking, one-lane road, large vehicles, or vehicles in the opposing travel direction, fewer participants decided to ride on the road, and it took them more time to make decisions. These findings are consistent with previous studies conducted in real road environments.

4. Conclusion

Micro-mobility riders prefer riding on the road and perceive it as the safest riding position unless environmental factors such as parallel parking or narrow roads are present. In such cases, riders consider the sidewalks safer even though pedestrians or other obstacles partially occupy them. Our findings emphasize the need to consider environmental elements when planning riding areas.

Figure 1 – Operation instruction of experiment

Figure 2 – Screen captures of four riding positions in a single lane with a parallel parking scenario.

Figure 3 – A scenario group to compare the shoulder and parallel parking effects

REFERENCES

Ensor, M., Maxwell, O., & Bruce, O. (2021, February 1). *Mode shift to micro-mobility*. https://www.nzta.govt.nz/resources/research/reports/674/

Gössling, S. (2020). *Integrating e-scooters in urban transportation: Problems, policies, and the prospect of System Change. Transportation Research Part D: Transport and Environment*, *79*, 102230. https://doi.org/10.1016/j.trd.2020.102230

Wachtel, A., & Lewiston, D. (1994). *Risk Factors for Bicycle-Motor Vehicle Collisions at Intersections. Ite Journal-institute of Transportation Engineers, 64*, 30-35.

Micro-mobility in urban environments: the case of e-scooter riders' risk perception

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Keywords: Micro-mobility, e-scooters, risk perception, GNAT, safety.

Background

In Tel-Aviv, as in many other populated metropolitans worldwide, there is a constant increase in e-scooters' prevalence, accompanied by a surge in the involvement of their users in road crashes. These riders' ages, experiences, city regulations, and infrastructure are all varied parameters that play a role in traffic safety. Although e-scooters are becoming trendy inter-city means of transport, there is little knowledge on their vulnerable users' attitudes toward the risks associated with e-scooter riding. Risk perception and safety attitudes were found to be associated with micro-mobility riders' risky riding behaviors. In accordance, the present study was aimed at exploring e-scooter riders' implicit and explicit attitudes towards the risks associated with e-scooter riding at different city locations in Israel - where implicit attitudes refer to the gut-level evaluations that exist below conscious awareness, and explicit attitudes are controlled and conscious evaluations of situations.

Method

We developed and validated a picture-based Go/No-go Association Task (GNAT) tool to explore participants' implicit attitudes toward various risky and safe e-scooter riding situations. The tool was developed in-house using C# within the Visual Studio framework. To include validated risky and safe riding situations we asked participants to briefly (1s) observe 42 pictures of different e-scooter riding situations and rate their level of hazardousness on a six-point Likert scale. At the end of this process, we selected 30 pictures that were the riskiest (20 pictures) or safest (10 pictures). Next, we included a list of 25 words with either negative or positive connotations. Sixty-four participants took part in the GNAT experiment. They were presented with various screens, each displaying a target category (safe or unsafe) and an attribute dimension (positive or negative) on the top right and left (Figure 1), and were required to press a spacebar (to reflect a 'go' response) should the picture or word currently presented on the screen for 1s belonged to the target category (picture) or the attribute dimension (word). Otherwise, they were to avoid responding (reflecting a 'no-go' response). Overall, four blocks (safe positive, safe negative, unsafe positive, unsafe negative) consisting of the same thirty pictures and a subset of the 25 words were randomly presented. The pictures and words were randomly presented in each block. Lastly, participants' explicit attitudes towards risky riding behavior were then examined by a riding behavior questionnaire.

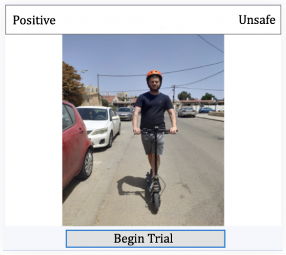

Figure 1. The Go/No-go Association Task (GNAT) tool for exploring participants' implicit attitudes toward various risky and safe e-scooter riding situations

Results

Overall, participants encountered difficulties in correctly categorising safe traffic situations as safe. Participants they were more likely to provide a correct response to safe blocks when a response should not have taken place than when a response should have taken place. In contrast, were more likely to provide a correct response to dangerous blocks when a response should have taken place than when a response should have not taken place. With regards to the positive dangerous blocks - participants with low levels of explicit risk perception had more difficulties in categorising dangerous situations as dangerous, whereas those with high levels of explicit risk perception tended to better categorise dangerous situations as such.

Conclusions

Better understanding this new, popular type of vehicle and its users, specifically their attitudes towards risky traffic situations, may contribute to producing intervention techniques that may reduce these road users' risk-taking tendencies. Implications for training, licensing, and policy recommendations will be discussed.

References

Borowsky, A., & Oron-Gilad, T. (2013). Exploring the effects of driving experience on hazard awareness and risk perception via real-time hazard identification, hazard classification, and rating tasks. Accident Analysis & Prevention, 59, 548-565.

Borowsky, A., Shinar, D., & Oron-Gilad, T. (2010). Age, skill, and hazard perception in driving. Accident Analysis & Prevention, 42(4), 1240-1249.

Crundall, D. (2016). Hazard prediction discriminates between novice and experienced drivers. Accident Analysis & Prevention, 86, 47-58.

Fishbein, M., & Ajzen, I. (2010). Predicting and changing behavior: The reasoned action approach. New York, NY: Psychology Press.

Martinussen, L. M., Sømhovd, M. J., Møller, M., & Siebler, F. (2015). A go/no-go approach to uncovering implicit attitudes towards safe and risky driving. Transportation Research Part F: Traffic Psychology and Behaviour, 30, 74-83.

Meir, A. (2022). Can Complete-Novice E-Bike Riders Be Trained to Detect Unmaterialized Traffic Hazards in the Urban Environment? An Exploratory Study. Sustainability, 14(17), 10869.

Meir, A., & Dagan, B. (2020). Can young novice e-bike riders identify hazardous traffic situations? an exploratory study. Travel Behaviour and Society, 21, 90-100.

Meir, A., & Oron-Gilad, T. (2020). Understanding complex traffic road scenes: The case of child-pedestrians' hazard perception. Journal of safety research, 72, 111-126.

Nosek, B. A., & Banaji, M. R. (2001). The go/no-go association task. Social Cognition, 19(6), 625-666.

Perceived safety of a 3D crosswalk

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Keywords: 3D crosswalks, crosswalk design, optical illusion, pedestrian safety, safety perception.

1. Background

The risk of being seriously injured or killed in a road traffic crash is higher for pedestrians compared to car drivers, and killed and injured pedestrians have been identified as a key challenge for road safety particularly in low-income countries (WHO, 2018). Infrastructure that separates pedestrians from high-speed and heavy motor vehicles and supports safe road crossings for pedestrians is therefore important to support pedestrian safety. Examples include a Danish offset in the middle of a multilane road, which forces pedestrians to face each part of the road separately before crossing, or a Media Refuge allowing pedestrians to rest in the middle of the road before crossing the second half of the road (Pulugurtha et al., 2012). Other solutions include painted crosswalks such as the traditional zebra crossing, which is easy and less costly to implement. However, studies show the safety impact to be limited.

Recently, innovative high visibility painted crosswalk solutions have been developed but the safety effect has only been evaluated to a limited extend. The “3D zebra crossing” is an example of an innovative high visibility painted crosswalk. The crosswalk markings are painted on the road using a technique, which creates an optical illusion whereby drivers approaching the crosswalk perceives a three-dimensional crosswalk. The 3D effect is not visible to the pedestrians. Different types of 3D visual illusions can be created e.g. lines perceived as floating in the air above the road, or the lines create an illusion of a cliff in the road. The purpose is to make drivers slow down when approaching the pedestrian crossing thereby increasing safety for crossing pedestrians. Very few studies have assessed their effect (for re review see Siebert et al., 2022).

However, even if relevant pedestrian infrastructure is available the pedestrians do not always use it as intended. Thus, in a Columbian observational study, approximately 35 % of the pedestrians took short cuts and crossed the street outside the designated area in intersections (Escobar et al., 2021). Thus, it is important to assess pedestrians’ perception of different infrastructure solutions concerning safety and desirability to support implementation of the best possible facilities (Saxena & Yadav, 2023). On this basis, the objective of this study was to explore car drivers and pedestrians’ perception and use of an innovative high visibility painted crosswalk namely a 3D zebra crossing.

2. Method

The study was done in Myanmar (see also Siebert et al., 2022). The painting of the 3D zebra crossing created an optical illusion of a trench in the middle of the crosswalk. The optical illusion was only visible for drivers approaching the crosswalk not for pedestrians using it. Data was collected by a questionnaire survey conducted on location. Participants were recruited and surveyed by trained interviewers in the area near by the 3D crosswalk. 201 pedestrians (49.8 % female) aged between 16 and 82 years old (M= 26.09, SD=11.59), and 102 car drivers (42.8 % female) aged between 19 and 67 years old (M=38.49, SD=10.56) participated in the survey. All participants provided demographic information. In addition, drivers were asked about their behaviour, attitude and perceived safety towards different crossing scenarios. Pedestrians were asked about their own behaviour, their perceived safety in different crossing scenarios and the behaviour of drivers. A descriptive analysis was applied focussing on the drivers and pedestrians perception of and behaviour by the 3D zebra crosswalk.

3. Results

In this section, we first present results regarding self-reported behaviour and general safety perceptions at the location. Second, we present results specifically regarding the perception of the 3D crosswalk. The majority of the pedestrians (94 %) and drivers (98 %) were familiar with the surveyed location. Most drivers (95 %) self-reported to yield for crossing pedestrians “often” or “always” and to be more likely to yield for groups of pedestrians compared to individual pedestrians. The pedestrians perceived the behaviour of the drivers very differently as 72 % replied that drivers only stopped in case of a traffic jam. However, similar to the drivers, the pedestrians also reported drivers to be more likely to yield for groups of pedestrians compared to individual pedestrians. Both drivers and pedestrians found it risky for pedestrians to cross at the surveyed location. Thus, 71 % of the drivers found crossing to be risky for pedestrians whereas 24 % of the pedestrians found it safe or very safe to cross at the surveyed location.

Specifically regarding the 3D crosswalk, both pedestrians (58 %) and drivers (65 %) rated it safer than a traditional crosswalk. The majority of the drivers (73 %) had noticed the new crosswalk and found it special, but only 54 % had consciously noticed the 3D effect. Approximately 2/3 of both pedestrians and drivers indicated it to be safer for pedestrians to cross the road with the new crosswalk compared to the previous traditional crosswalk. Almost half of pedestrians (43 %) self-reported taking a detour to use the 3D crosswalk. With regard to changes in yielding behaviour for the new crosswalk compared to the previous traditional crosswalk, drivers and pedestrians did not completely agree. The majority of drivers (73 %) self-reported to be more likely to yield for crossing pedestrians with the new 3D crosswalk compared to the traditional crosswalk, whereas only 47 % of the pedestrians indicated that the 3D crosswalk had increased the likelihood of drivers to yield for crossing pedestrians.

4. Conclusion

The results indicate that the 3D crosswalk had a significant positive effect on perceived safety among drivers as well as pedestrians. Future studies should assess if and how this relates to actual safety effects of 3D crosswalks concerning both crashes and near crashes.

REFERENCES

Escobar, D.A., Cardona, S., & Hernández-Pulgarin, G. (2021). Risky pedestrian behaviour and its relationship with road infrastructure and age group: An observational analysis. Safety Science, 143, 1054418. https://doi.org/10.1016/j.ssci.2021.105418

Pulugurtha, S.S., Vasudevan, V., Nambisan, S.S., & Dangeti, M.R. (2012). Evaluating Effectiveness of Infrastructure-Based Countermeasures for Pedestrian Safety Transportation Research Record: Journal of the Transportation Research Board, No. 2299, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 100–109. https://doi.org/10.3141/2299-11

Saxena, A., & Yadav, A.K. (2023). Clustering pedestrians' perceptions towards road infrastructure and traffic characteristics. International journal of injury control and safety promotion, 30, 68-78. https://doi.org/10.1080/17457300.2022.2112234

Siebert, F. W., Møller, M., Lwin, A.M.M., Albers, D. (2022). Illusion of safety? Safety-related perceptions of pedestrians and car drivers around 3D crosswalks. Tranportation Research Part F, 91, 213-222. https://doi.org/10.1016/j.trf.2022.10.003

World Health Organization (2018) Global Status Report on Road Safety 2018. World Health Organization. Retrieved from: Global status report on road safety 2018 (who.int)

Motorcyclists, Motorcycle Stakeholders and Driverless Vehicle Stakeholders: How do their Positions Align?

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ABSTRACT

Vulnerable Road Users (VRUs) are a major concern when introducing Connected and Autonomous Vehicles (CAVs) to the roads. An underrepresented VRU in particular are Powered Two Wheelers. To ascertain how the current views, plans and aspirations regarding CAVs and PTWs currently align, focus groups of PTW riders, PTW Stakeholders and CAV Stakeholders were carried out. Topics of discussion included: (1) what is needed from CAVs for PTW rider safety; (2) what inspires trust in CAVs; (3) views on advanced technology; (4) current and proposed plans for implementation; and (5) current capabilities regarding PTWs. Thematic analysis was used to assess the transcripts, with the addition of analysis for misalignments between groups. There were three major themes which were (1) concerns; (2) unknowns; and (3) desires. No one group completely aligned with another. PTW riders and PTW Stakeholders had the most aligned views, with the major misalignment being acceptance of technology. CAV and PTW stakeholders showed a reliance on advanced technology (especially vehicle to vehicle communication) which PTW riders were resistant to. The greatest misalignments were between CAV Stakeholders and PTW riders, and CAV Stakeholders and PTW Stakeholders. Given the nature of these misalignments, the results could potentially lead to oversights in both CAV developments and legislation regarding PTW designs.

Keywords: Powered Two Wheelers, Autonomous Vehicles, Vulnerable Road Users, Stakeholders.

1. INTRODUCTION

Autonomous technology is rapidly making an appearance on roads. Advanced driver assist systems (ADAS) are the first step in this direction, with autonomous lane keeping and adaptive cruise control already starting to perform functions previously exclusively undertaken by drivers. While these technologies in particular have been present on the roads for a number of years, the regulation and safety aspects have been lagging, especially in regards to PTWs. In fact, Euro NCAP have only introduced safety tests specifically targeted at PTWs in their safety assessments this year. On the whole research into CAVs and VRU has started to pick up momentum, especially regarding pedestrian interaction, however, other road users have been not yet been as thoroughly addressed. A recent tesla crash was resulting from a cyclist walking their bicycle remaining unclassified by the software, and subsequently failing to alert the vehicle minder. As the object in front of the vehicle remained unclassified (but detected), it hit the VRU, killing them (National Transportation Safety Board, 2018). If vehicles struggle to classify a VRU user in such a common status, with a fairly uniform presentation, classifying and identifying PTWs, a more variable, less visible and unpredictable VRU is likely to pose a real challenge, although this hasn't been raised or addressed in research or policy. Moreover, this case is just one of many incidents with various developers and manufacturers of CAVs and autonomous technologies around the world. Some work has been completed into crash analysis to create testing scenarios for CAVs, however thus far this has been exclusive to China, which has its own distinct PTW landscape (Zhou et al., 2022).

Perception of CAVs by VRUs is a particularly vital part of the introduction and transition stages for autonomous technology. Perception of safety is a particular concern especially for PTWs riders who have a low trust in drivers in the current road matrix. Pammer et al., (2021) investigated the trust of both PTWs riders and cyclists have in CAVs and found that overall, both VRUs investigated have a lower trust in CAVs than human drivers, except regarding their own personal safety, where they would trust a CAV over a human driver. While there has been a limited amount of work completed with PTW riders, research thus far has not included the stakeholders involved in PTWs and those stakeholders involved in CAV development and implementation. Since these stakeholders will be guiding both legislation and implementation, maybe even being consulted on design aspects, it is important that not only the stakeholders algin, but the users themselves algin with those advising and designing on their behalf. Vehicle to Vehicle communication (V2V) is also likely to be a major contributing introducing and operating CAVs, since PTW riders are known to have a resistance to technology (Beanland et al., 2013; FEMA, 2008; Simpkin et al., 2007), this V2V technology for PTWs could be a barrier to CAV acceptance by PTWs.

Overall, there is missing knowledge surrounding PTW and CAVs in general, but specifically in the perceived trust, safety, how to improve these perceptions, what PTWs actually want from CAVs and how this new autonomous system will be implemented. There is also little knowledge about the current consideration of PTWs in CAV development. Moreover, the alignment between the PTWs themselves and the stakeholders representing them and the CAV stakeholder guiding developing the technology needs to be addressed.

2. OBJECTIVES

The objectives for this research were: to assess the perception of CAVs by PTW riders, to determine the desires of PTWs regarding CAVs, to assess the views of PTW Stakeholders and CAV stakeholders and assess how aligned the outcome between the three groups are.

3. METHOD

Focus groups were chosen to allow open development of concepts and further investigation of unexpected themes that is impossible in surveys. Thematic analysis was used to determine common themes and trends within and between the groups. This was based in the 6 stage method outlined in Braun & Clarke, (2006), this method was slightly adapted to identify potential misalignments between the groups. Any disparities in outlook between the three sets were also identified. Five focus groups and two interviews were conducted, spilt into three sets, according to participants, outlined below.

3.1 Group 1- PTW Riders

Two groups of motorcyclists were created, those with advanced training and those without. These groups were asked questions surrounding a number of subjects: (1) Current experiences with advanced driver assist systems (ADAS) on the road in cars (lane assist, blind spot indicators, adaptive cruise control) - Both using them as a driver in cars and interacting with them as motorcyclists; (2) Current trust levels for ADAS on cars (3) Advanced rider assist systems: how likely they are to use those systems, how much they would trust them, which systems they would use; (4) Trust in human vs computer: CAV capacity to sense a PTW and capacity to react to a PTW; (5) What is important during implementation and development of CAVs? (6) What riders want from CAVs (7) V2V communication: general perception, implementation methods, classic bike considerations; (8) General thoughts on CAVs: integration with driven vehicles, how to increase trust in CAVs.

3.2 Group 2 – PTW Stakeholders

This group contained PTW stakeholders- those representing PTWs' interests across various geographical locations. One stakeholder was interviewed separately. PTW Stakeholders were interviewed to give a more holistic view of the riders they represent, and less biased opinion than given by the riders themselves. It also presented the opportunity to see how their views align with the actual riders. The sample included both PTW riders and non-riders within the stakeholder group. This group gave their thoughts around the following topics: (1) Whether CAVs or drivers pose a greater risk to PTWs; (2) ADAS systems: speed of implementation, advertising of ADAS systems, potential benefits and concerns; (3) Regulation/official guidance regarding future and current technology; (4) PTW rider's requirements for CAV eHMIs; (5) Integration of CAVs with driven vehicles: transition periods, infrastructure; (6) V2V communication; (7) How to increase trust in CAVs; (8) Education for PTWs.

3.3 Group 3 – CAV Stakeholders

This group included employees of CAV manufacturers and developers. An advisory body was interviewed separately. This focus group was completed to gain a better understanding of where currently PTWs sit in CAV development considerations. Participants were asked on their views around the following topics: (1) Current guidance/regulations for CAV development, how much of this is PTW specific/inclusive; (2) When/if PTWs are considered during CAV development; (3) How PTWs are considered; (4) Direct contact with riders or stakeholders, how much consideration is given to PTWs; (5) Awareness/consideration of PTW unique behaviours and characteristics; (6) Identification of PTW by Artificial Intelligence (AI); (7) Addressing PTW's concerns; (8) V2V communication importance for future implementation, methods to increase ARAS uptake for V2V communication (9) How to increase PTW consideration by manufacturers in CAV development. The Stakeholder groups were completed after the rider groups to allow preliminary data from the riders to be used in those discussions.

4. Results

There were three main themes identified between the groups: Concerns, Unknowns and Desires. Within in these sections, several topics were identified, some exclusive to single or two groups (Figure 1) .

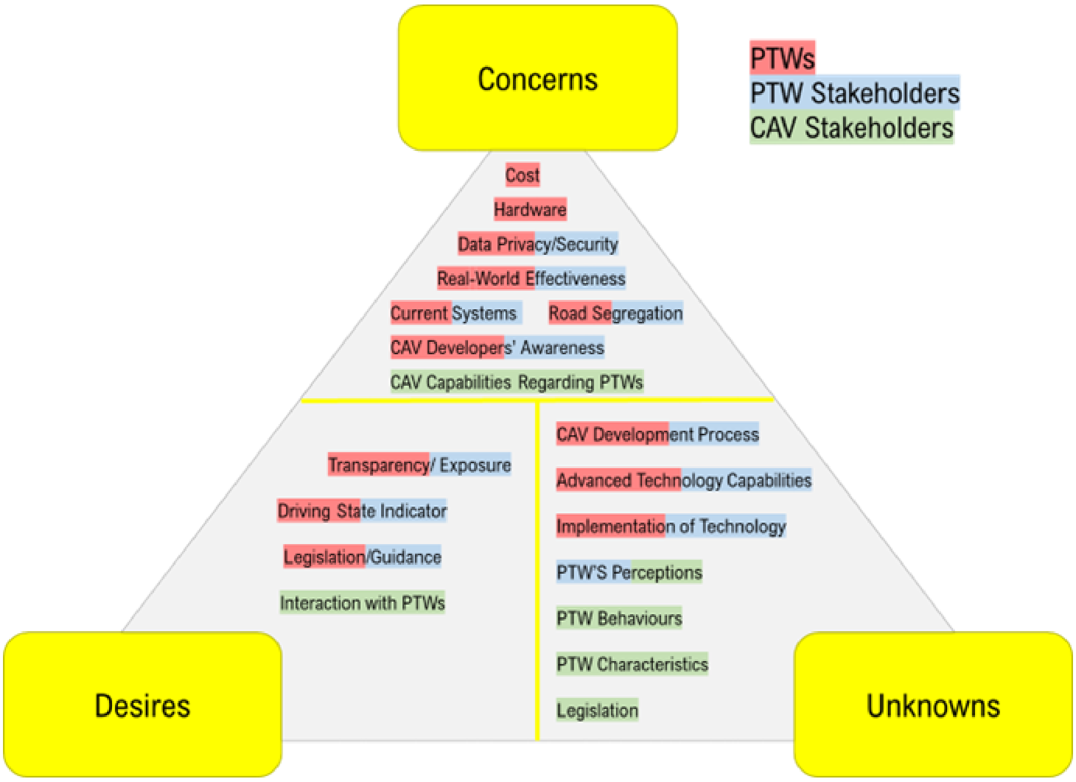

Figure 1 – An overview of the themes and topics identified, crossed referenced by group.

There were no major changes in outlook between advanced and just experienced riders. Therefore, they were treated as one group- PTWs. The second round of analysis focused on the alignment between the 3 groups, this found that none of the groups, completely aligned with one another view's/opinions/outlooks. The main subjects of these misalignments are detailed in Figure 2. The groups with the highest alignment were PTWs Riders and PTW Stakeholders. The only major misalignment was in the acceptance/stance on advanced technology, specifically V2V communication.

The misalignments between CAV Stakeholders and PTWs and CAV and PTW Stakeholders were very similar. CAV Stakeholders misaligned with both the PTW and PTW Stakeholders on PTW behaviours and characteristics. Both PTW Riders and PTW stakeholders were aware of the range of PTW behaviour and characteristics, while CAV Stakeholders were not.

CAV and PTW stakeholders also misaligned on desired legislation, CAV Stakeholders only expressed a need for the highway code, while PTW stakeholders expressed a desire for rigid legislation/guidance for CAV developers. PTW riders and CAV Stakeholders misaligned with the reliance of technology- especially V2V communication.

In general, V2V communication was consistently a misalignment between all groups.

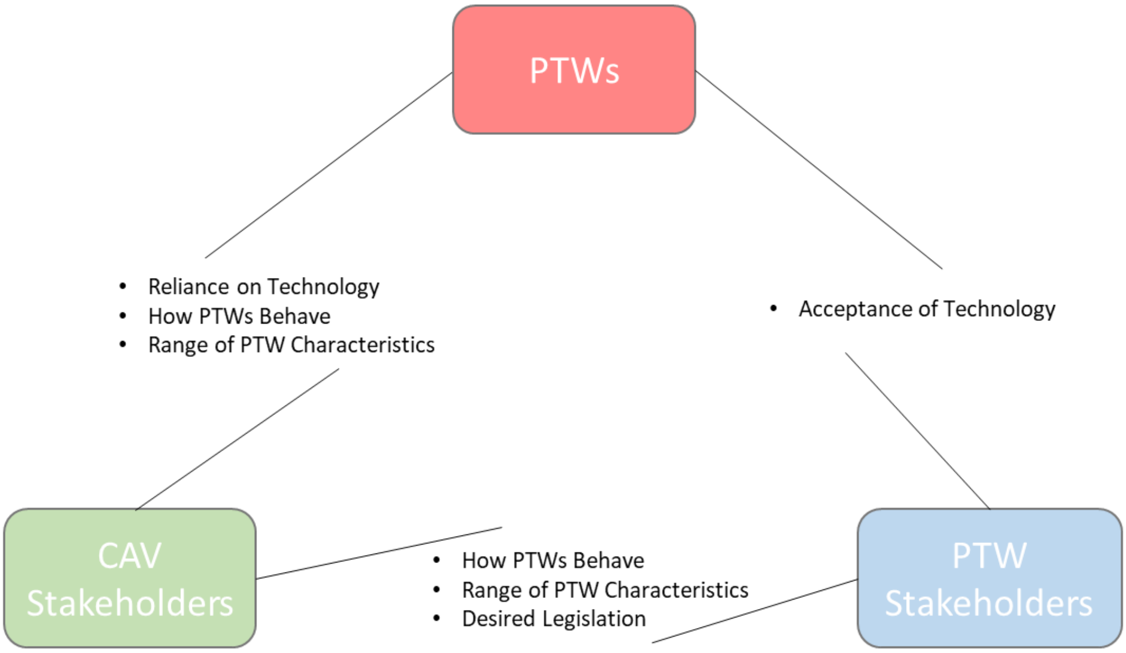

Figure 2: A summary of the misalignments between the three user types in the focus groups.

5. Discussion

Overall, riders expressed that they would trust a driver over a driverless vehicle, however, this distrust steams from a lack of trust of the humans designing and programming the systems, not from the hardware involved; in fact, they did express that they believed eventually the driverless systems could be better, but not without significant difficulties and dangers during initial introduction. A strong theme throughout PTWs and PTW Stakeholder was the unknowns of CAV development and the lack of transparency and knowledge around CAV development and even current technology. This lack of communication is likely somewhat due to the commercial interests of manufacturers and developers, but additionally in the case of PTWs, a reported lack of consideration by CAV Stakeholders. This is not surprising given the current technology on the road has no specific PTW targeting, an oversight not unnoticed by PTW riders- a lot of the participants have experience using ADAS in their own vehicles, reporting that the current systems, such blind spot detectors, on their vehicles do not pick up PTWs an/or do not react appropriately to them. PTW rider concerns around PTW oversights in CAVs are not unfounded according to CAV Stakeholder reports. CAV stakeholders themselves reported that they would like to communicate to the PTWs that they are being considered to help encourage trust in these systems. At this time no specific PTW works are reportedly being carried out. They did indicate that any future PTW specific work would involve PTW riders directly, either through interviews or focus groups. There was also some suggestion that PTWs would be specifically considered at a later date, although the CAV Stakeholders do state that PTWs should be considered earlier in development. It is appropriate that CAV stakeholders desire direct involvement with PTW riders, rather than just through PTW stakeholders, given the misalignments discussed below.

The largest section of misalignment was surrounding V2V communication. In concept PTW riders are somewhat accepting of V2V, however, in practice they found the implementation methods presented too intrusive, especially when this technology tries to communicate information to the rider. They also could not describe an implementation method they would accept. Acceptance and uptake could also be hampered by cost- PTW riders were worried about the cost of implementation, especially when this provides information that would not directly benefit them, and information provided to a driverless vehicle would be information that a “good driver” would notice without assistance or additional cost. PTW stakeholders were more accepting of V2V technology, with one stakeholder expressing that the industry felt V2V communication was the only way forward. This was not, however, a universal agreement. The more rider-based groups disagreed, stating PTW’s resistance to advanced technology (which was repeatedly reported within these focus groups), with other more intermediary groups coming to agree. This disengagement from rider’s perspective could be very detrimental moving forward, since these stakeholders are not only advising governing bodies, they also serve as a large point of contact for CAV stakeholders. It’s worth noting these PTW stakeholders represent a larger geographical area than the UK, where opinions may differ from the exclusively UK based PTW riders investigated in this research. CAV Stakeholders initially reported a high dependency on V2V communication due to the nature of PTWs; this predicted dependency was increased when a discussion of the breadth of PTW characteristics. The CAV Stakeholders reported that the AI would be identifying indicators and helmets. PTWs legally do not need to have indicators and while in the UK helmet compliance is relatively high, there are a wide style ranges of helmets had also not been considered by CAV Stakeholders, which again were reported to likely cause problems for the CAV systems. To be able to properly train these systems, more awareness of PTW riders, characteristics and the variety within these factors needs to be understood and implemented.

In conclusion, PTW riders are hopeful for the future of CAVs, however, their current experiences with ADAS do not encourage trust and they are distrustful of the CAV developers awareness of PTW characteristics. There is a general oversight of PTWs in CAV development, but reported interest in addressing this as the technology develops. CAV developers do need to raise their awareness of PTW characteristics in order to properly design and account for PTWs in their systems. There is universal misalignment between the PTW riders, PTW Stakeholders and CAV Stakeholers on the vital subject of V2V communication, which could lead to major issues when developing CAVs and the implementation phase. These misalignments need to be addressed in order for an efficient and safe introduction and development for CAVs.

REFERENCES

Beanland, V., Lenné, M. G., Fuessl, E., Oberlader, M., Joshi, S., Bellet, T., Banet, A., Rößger, L., Leden, L., Spyropoulou, I., Yannis, G., Roebroeck, H., Carvalhais, J., & Underwood, G. (2013). Acceptability of rider assistive systems for powered two-wheelers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *19*(April), 63–76. https://doi.org/10.1016/j.trf.2013.03.003

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

FEMA. (2008). *SAFERIDER Focus Groups*. FEMA.

Huth, V., Füssl, E., & Risser, R. (2014). Motorcycle riders' perceptions, attitudes and strategies: Findings from a focus group study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *25*(PART A), 74–85. https://doi.org/10.1016/j.trf.2014.05.004

National Transportation Safety Board. (2018). *Preliminary Report HWY18MH010*. https://www.ntsb.gov/investigations/AccidentReports/Reports/HWY18MH010-prelim.pdf

Pammer, K., Gauld, C., Mckerral, A., & Reeves, C. (2021). '' They have to be better than human drivers !" Motorcyclists ' and cyclists ' perceptions of autonomous vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour*, *78*, 246–258. https://doi.org/10.1016/j.trf.2021.02.009

Simpkin, B., Lai, F., Chorlton, K., & Fowkes, M. (2007). *Intelligent Speed Adaptation Motorcycle Trials* (Issue February).

Zhou, R., Lin, Z., Huang, X., Peng, J., & Huang, H. (2022). Testing Scenarios Construction for Connected and Automated Vehicles Based on Dynamic Trajectory Clustering Method. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *2022-October*, 3304–3308. https://doi.org/10.1109/ITSC55140.2022.9922145

A cross-national comparison of opinions about, current use of, and acceptability towards Advanced Driver Assistance Systems (ADAS): The case of Belgian and Vietnamese car drivers

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Keywords: Advanced Driver Assistance Systems, Acceptability, Cross-national comparison, Hierarchical regression analysis, Cross-sectional survey.

1. Background

Advanced Driver Assistance Systems (ADAS) are provided in (new) vehicles with the promise to carry out the driving task as safely and comfortably as possible. These technological systems intervene in the driving task in ways that drivers do not always appreciate (Reagan et al., 2018). It is essential to investigate what determines vehicle operators' acceptability towards ADAS. Moreover, it is not well-known whether acceptability towards ADAS is determined by different factors in countries with different socio-cultural and macroeconomic settings. This study addressed these gaps by conducting an empirical study comparing the opinions about, current use of, and acceptability towards ADAS in Belgium and Vietnam.

2. Method

A cross-sectional survey with an online self-administered structured questionnaire was used for data collection. In total, 1.069 people responded to the survey. Six hundred and twenty five valid responses (that is, surveys with complete responses for all questions) were kept for analysis (322 from Belgium and 303 from Vietnam). The questionnaire consisted of four sections: (1) socio-demographic background factors, (2) opinions about the perceived usefulness of ADAS, (3) current use of ADAS, and (4) acceptability towards ADAS and its underlying socio-cognitive determinants. Section four was based on the Unified Model of Driver Acceptance (UMDA) (**Figure 1)**, proposed and empirically tested by Rahman et al. (2018). Besides descriptive and reliability analyses (Cronbach's alpha), data were subjected to bivariate correlation and hierarchical regression analysis.

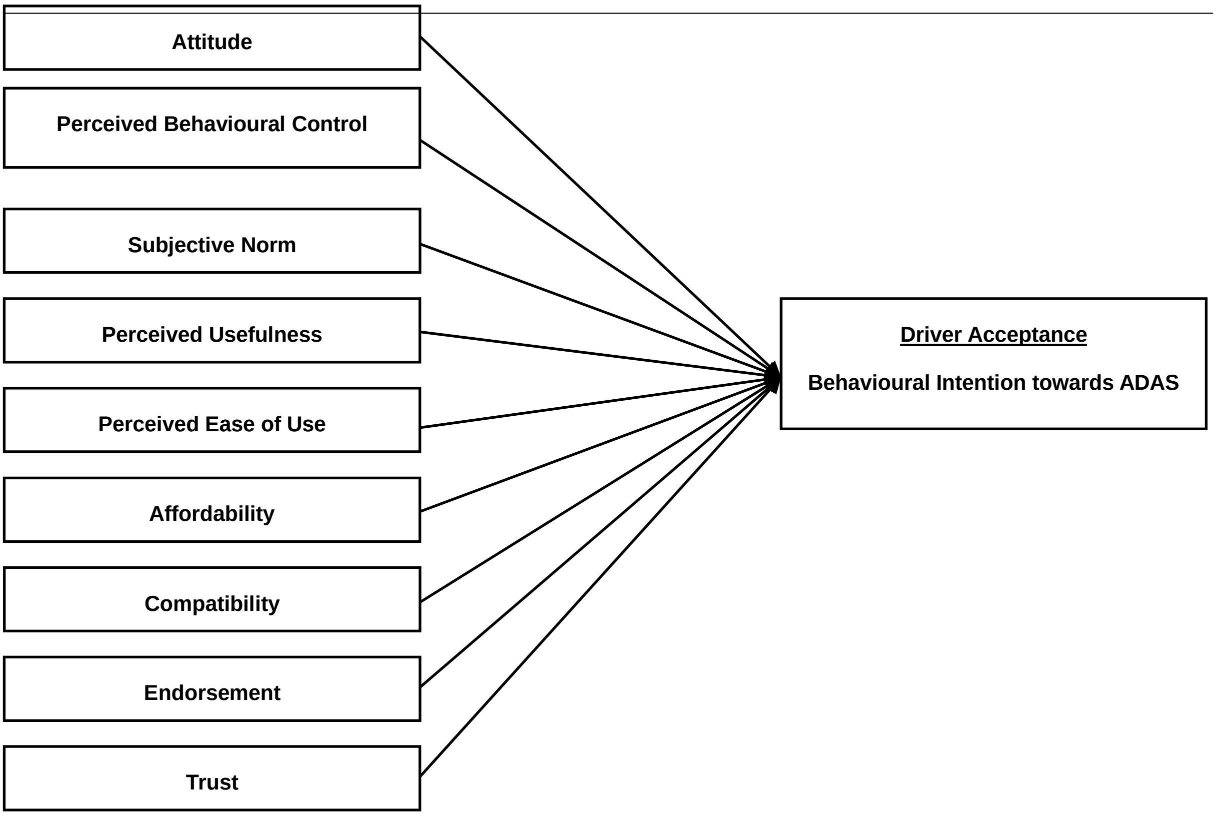

Figure 1 Conceptual Model for drivers' acceptability towards ADAS (Rahman et al., 2018).

3. Results

Participants perceived ADAS as very helpful in supporting personal driving in both countries. Similarly, personal experience and willingness to use these technologies were rated positively, suggesting strong support for ADAS in both Belgium and Vietnam. Interestingly, while personal user experience with ADAS was higher in Belgium (compared to Vietnam), the willingness to use ADAS was more pronounced among Vietnamese respondents than Belgian respondents. Regression analysis established that five socio-cognitive factors, including endorsement, compatibility, perceived usefulness, affordability, and attitude (in decreasing order of importance) determine acceptability towards ADAS among Belgian respondents. In contrast, acceptability towards ADAS in the Vietnamese sample was determined by four factors (subjective norm, perceived usefulness, compatibility, and affordability, in decreasing order of importance). These variables explained 68.2% and 56.3% of the variance in acceptability towards ADAS in the Belgian and Vietnamese samples, respectively.

4. Conclusion

Our results provide deeper insight into opinions about, the current use of, and acceptability towards ADAS in Belgium and Vietnam. Comparable between both countries is the perceived usefulness of ADAS for personal driving, meaning that both Belgian and Vietnamese car drivers consider such technology helpful for improving their driving style. While Belgians reported higher use rates, Vietnamese respondents demonstrated a higher willingness to use ADAS in the future. This probably reflects that ADAS have penetrated the European car market more extensively than is currently the case in Vietnam. Vietnamese car drivers, however, seem to express great interest in using these systems once made available. Interestingly, the underlying determinants of acceptability towards ADAS seem subject to national (or cultural) differences. Acceptability among Belgians mainly depends upon the endorsement and compatibility of ADAS with personal driving style. At the same time, subjective norm (opinions of important social referents) plays a crucial role in the model for the Vietnamese sample. This might reflect a difference in cultural identity in the sense that Vietnamese are overall more collectivistically oriented, while Belgians are rather individualistically oriented (Hofstede, 2001). In conclusion, both Belgian and Vietnamese respondents were open to using an ADAS system. While individual beliefs were prominent in predicting acceptance in Belgium, group norms and values were crucial in Vietnam. It is important to note that this study used a cross-sectional survey design, which, strictly taken, limits the ability to establish causal relationships. Still our findings offer valuable insights that can help policymakers and practitioners in both countries to devise strategies for the successful implementation of ADAS technology. For future research, we recommend the use of more robust methodologies, such as longitudinal observations in naturalistic settings or validation studies through simulation experiments, to further explore this topic in cross-national context.

REFERENCES

Hofstede, G. (2001). *Culture’s Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations*. SAGE Publications.

Rahman, M. M., Strawderman, L., Lesch, M. F., Horrey, W. J., Babski-Reeves, K., & Garrison, T. (2018). Modelling driver acceptance of driver support systems. *Accident Analysis & Prevention*, *121*, 134–147. https://doi.org/10.1016/j.aap.2018.08.028

Reagan, I. J., Cicchino, J. B., Kerfoot, L. B., & Weast, R. A. (2018). Crash avoidance and driver assistance technologies – Are they used? *Transportation Research Part F: Traffic Psychology and Behaviour*, *52*, 176–190. https://doi.org/10.1016/j.trf.2017.11.015

Children's and parents' first interactions with the autonomous family vehicle autoELF – A usability study

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Keywords: autonomous vehicle, usability, user experience, children, parents, vehicle prototype.

1. Background

Autonomous vehicles can provide children and adolescents with an independent mobility in their everyday life (e.g., Lee & Mirman, 2018; Tremoulet et al., 2020). In the UNICAR*agil* project (funded by the Federal Ministry of Education and Research, see Woopen et al., 2018), a high-fidelity prototype of the autonomous family vehicle ("autoELF") is being developed for use in a multi-generational family (Schräder et al., 2019). Apart from transporting older and mobility-impaired family members, autoELF is designed to transport children unaccompanied (Schräder et al., 2019; see Figure 1). The operational design domain of autoELF is limited to driving in urban areas (Schräder et al., 2019). So, children can use autoELF to ride to school or leisure activities without needing an adult driver to accompany them. Therefore, autoELF must be designed so that children can use it on their own.

The autoELF vehicle is equipped with four individual seats located in two rows facing each other. Two tablets are installed on the center consoles between the seats for children's infotainment during automated driving. Luggage can be stored behind the rows of seats and under the seats. Parents can control the system, e.g., for trip planning and route selection, remotely using an app on their smartphone. During the autonomous ride, parents and children can communicate via the built-in speakers, cameras and microphones.

Currently, there is a growing number of studies on the unaccompanied transportation of underage children in autonomous vehicles. At this time, available studies have used driving simulators, use scenarios, questionnaires and AV demonstrations to examine parental concerns, acceptability, and minimum age to use an AV alone (e.g., Jing et al., 2021; Koppel et al., 2021, Lee & Mirman, 2018; Lee et al., 2020; Tremoulet et al., 2020). Based on the existing literature, a key open question is how children and their parents interact with an autonomous family vehicle.

Since the autoELF family vehicle is designed for unaccompanied use by children, it is of particular interest to what extent children are able to use the vehicle functions without the help of their parents. Usability studies can also help promote the user-centered design process of automated family vehicles. In this sense, usability studies with high-fidelity prototypes are needed to understand how children and their parents interact with the autonomous family vehicle (Tremoulet et al., 2020). We conducted a usability study with a high-fidelity prototype of autoELF. The objective was to investigate the usability of the user interfaces in the autoELF vehicle in the initial use by children and their parents. In this paper, we will explain the results of the usability study by means of a task.

Figure 1: The autonomous family vehicle autoELF.

2. Method

A total of *N* = 15 parents (*M* = 42.1 years, 9 mothers / 6 fathers) with *N* = 17 of their children aged 7 to 14 years (*M* = 10.5 years, 9 girls / 8 boys) took part in the study. The children and their parents completed the study in teams of two. The study took place in the vehicle laboratory of the Institute of Control Engineering in Braunschweig, Germany. Data were collected from January to February 2023.

The teams were first briefed about the study objectives and the procedure. After informed consent, teams completed a pre-session interview about their family's mobility and smartphone/tablet use. The teams then completed ten usability tasks in the high-fidelity prototype of autoELF. These tasks included all of the vehicle functions that children and their parents would need to operate the vehicle. The usability tasks were built around a story about a visit to a swimming pool. Children were asked to try to complete each task on their own, but they could ask their parents for help at any time. Therefore, the parent was present during the whole testing. To prepare for the imaginary trip to the swimming pool, the child and parent first opened the vehicle (1), stowed the backpack with bathing suits in autoELF (2), closed the door (3), and buckled up (4). Then, the parent planned the ride to the pool using the tablet app (5), and the child started the ride by pressing the start button (6). During the imaginary trip, the child and parent played a game against each other on the tablet (7), and turned on music (8). The imaginary trip then continued after “swimming”. The child planned the trip home on the tablet (9) and got out of the vehicle (10).

After each usability task, we asked the children to rate the perceived difficulty of the previous task ("How easy was the task for you?") and satisfaction ("How much fun was the task for you?") on 5-point scales ranging from 1 ("very easy" / "very little") to 5 ("very difficult" / "very much"). In addition to satisfaction, we also measured the other two dimensions of usability, i.e., effectiveness and efficiency (International Organization for Standardization, 2018; ISO 9241-11), using video recordings and a timer. For effectiveness, we measured the number of correctly solved tasks, the number of children asking their parents for help, and the number of task cancellations. For efficiency, the time interval between the start signal of the experimenter and the fulfilment of the success criterion was measured.

After completing the usability tasks, the teams were interviewed on their user experience during the tasks, including their requests and suggestions for improvement of the vehicle features.

3. Results

The focus of the results presented is on the "stowing the backpack" task. The two spaces designated to stowing luggage inside autoELF were (1) the space behind the seat rows, where a net was installed during the course of the study, and (2) the spaces under the seats. Of $N = 17$ children, 15 children successfully solved the task and stowed the backpack, while two children cancelled the task. Eleven children stowed the backpack in the luggage compartment behind the seat rows and two children stowed the backpack underneath a seat. Two children stowed the backpack on the seat, which was considered a solution to the task, even though it was an unsafe choice in the event of hard braking. The majority of 9 children asked their parent for help with the task, with 7 children asking their parent to suggest a solution. Only 2 children asked their parent to confirm a solution that the child has come up with by itself. On average, teams took $M = 48$ s ($SD = 23$ s; Min. = 7 s, Max. = 90 s) to solve the task. Children indicated that the task was a lot of fun ($M = 3.9$, $SD = 0.7$), but partly difficult to solve ($M = 2.8$, $SD = 1.2$).

When asked about how they arrived at the solution to the task, seven children stated that they expected that they would have to actively open a compartment, four children identified the space behind the luggage net as a luggage compartment, and three children were searching for a trunk inside or outside of the vehicle. As the luggage net was installed during the study, only 6 children could interact with the net. Of these 6 children, 4 children, used the space behind the net to stow the backpack.

4. Conclusion

Although the majority of children were successful in the "stowing luggage" task, the amount of assistance children needed from their parents and the efficiency of solving the task varied significantly across children. These results may be due to the fact that stowing luggage in a vehicle is a traditional parent task. Of the children who asked their parents for help, the majority of children wanted their parents to suggest a suitable place to stow the backpack, thus solving the entire task. Only two children wanted their parents to help them solve the task. Some children looked for a compartment that could be opened, a net, or a trunk, as in a conventional vehicle. These children transferred their knowledge from everyday life to the context of autonomous driving. From a design perspective, it might therefore make sense to create interfaces that children are already familiar with.

An open question is what children would do if they were alone in the vehicle - without receiving instructions from an adult. Would they make the effort to find a safe space to stow luggage? Or would they simply choose the most convenient space that is easily accessible.

Apart from this question, future research also needs to examine how children would interact with the autonomous vehicle during the automated ride, i.e. if they were actually moving around inside the vehicle unaccompanied. Moreover, it is unclear how safe it is for children to use the vehicle in the real world. For example, the children are exposed to traffic hazards when getting in and out of the car, as there will be a parent present who could intervene.

5. Acknowledgment

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6. References

International Organization for Standardization. (2018). Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts (ISO Standard No. 9241-11). ISO. https://www.iso.org/standard/63500.html

International Organization for Standardization. (2019). Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems (ISO Standard No. 9241-210). ISO. https://www.iso.org/standard/77520.html

Jing, P., Du, L., Chen, Y., Shi, Y., Zhan, F., & Xie, J. (2021). Factors that influence parents' intentions of using autonomous vehicles to transport children to and from school. *Accident Analysis and Prevention, 152,* 105991. https://doi.org/10.1016/j.aap.2021.105991

Koppel, S., Lee, Y.-C., Mirman, J.H., Peiris, S., & Tremoulet, P. (2021). Key factors associated with Australian parents' willingness to use an automated vehicle to transport their unaccompanied children. *Transportation Research Part F: Traffic Psychology and Behaviour, 78,* 137-152. https://doi.org/10.1016/j.trf.2021.02.010

Lee, Y.-C., Hand, S.H., & Lilly, H. (2020). Are parents ready to use autonomous vehicles to transport children? Concerns and safety features*. Journal of Safety Research, 72,* 287-297. https://doi.org/10.1016/j.jsr.2019.12.025

Lee, Y.-C., & Mirman, J.H. (2018). Parents' perspectives on using autonomous vehicles to enhance children's mobility. *Transportation Research Part C: Emerging Technologies, 96*, 415-431. https://doi.org/10.1016/j.trc.2018.10.001

Schräder, T., Stolte, T., Jatzkowski, I., Graubohm, R., & Maurer, M. (2019). An Approach for a Requirement Analysis for an Autonomous Family Vehicle. Proceedings of the 2019 IEEE Intelligent Vehicles Symposium (IV), Paris, France, 09-12 June 2019. https://doi.org/10.1109/IVS.2019.8813882

Tremoulet, P.D., Seacrist, T., Ward McIntosh, C., Loeb, H., DiPietro, A., & Tushak, S. (2020). Transporting Children in Autonomous Vehicles: An Exploratory Study. *Human Factors, 62*(2), 278-287. https://doi.org/10.1177/0018720819853993

Woopen, T., Lampe, B.; Böddeker, T.; Eckstein, L.; Kampmann, A.; Alrifaee, B.; Kowalewski, S.; Moormann, D.; Stolte, T.; Jatzkowski, I.; Maurer, M.; Möstl, M; Ernst, R.; Ackermann, S.; Amersbach, C.; Leinen, S.; Winner, H.; Püllen, D.; Katzenbeisser, S.; Becker, M.; Stiller, C.; Furmans, K.; Bengler, K.; Diermeyer, F.; Lienkamp, M.; Keilhoff, D.; Reuss, H.-C.; Buchholz, M.; Dietmayer, K.; Lategahn, H.; Siepenkötter, N.; Elbs, M.; v. Hinüber, E.; Dupuis, M.; Hecker, C. (2018). UNICARagil - disruptive modular architectures for agile, automated vehicle concepts. Proceedings of the 27th Aachen Colloquium, Aachen, Germany, 10-12 October 2018.

Public Support for Mandatory Installation of ISA in Vehicles

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Keywords: ISA, public support, policy measures, international, national culture

1. Background

Controlling the speed of vehicles and making sure that they do not exceed the posted speed limit can prevent many road crash injuries and deaths. Since July 2022 all new models and types of cars introduced to the European market must include an ISA (Intelligent Speed Assistance) system and by July 2024, every new car sold in the EU must have a built-in anti-speeding system. However, drivers will be allowed to turn off the system. As part of a PhD project on public support for the road safety policy measures, factors affecting support and opposition for such ISA systems have been identified.

2. Method

Three methodologies have been used: (1) analysis of the support for ISA as measured in the ESRA2 survey (Meesmann et al., 2021) in 48 countries (45 000 respondents, representative for the adult population) and link this support to other socioeconomic and cultural variables; (2) asking 40 experts from 5 countries (France, UK, Austria, Sweden and Greece) about their views and arguments on the desirability of ISA systems being compulsory in cars; and (3) a dedicated survey organised in 10 countries (China, USA, UK, Belgium, Austria, Sweden, Greece, France, Nigeria and Argentina) with over 5500 respondents overall (representative for the adult population). In method (1), new values for national culture were used as described by Minkov (2018). For methods (2) and (3) the condition was added that ISA could not be turned off. Details on the methodology can be found in Van den Berghe (2022).

3. Results

A range of factors appears to influence public support for ISA in studies (1) and (3). Females are more supportive to ISA than men; older females are more supportive than younger ones. Figure 1, based on study (1) shows that the support for ISA is (very) strongly associated with a key dimension of national culture, called "Independent" (r = -0.801**), referring to the level of independent thinking in a country. It is noteworthy that 64% of the variation between countries can be statistically explained by the variable Independent. Public support is lower in independent countries such as the Anglo world, Germanic and Nordic Europe and highest in more collectivistic ones, i.e., Sub-Saharan Africa and the Middle East.

Most experts interviewed in study (2) considered ISA to be a fair measure. A minority of those who considered ISA to be fair, nevertheless opposed it because of other arguments. The most frequently used prime arguments for supporting ISA were 'a good solution to the problem', 'effective', and 'addresses an important problem'. The largest number of counterarguments were 'negative side effects' and 'other measures are better'.

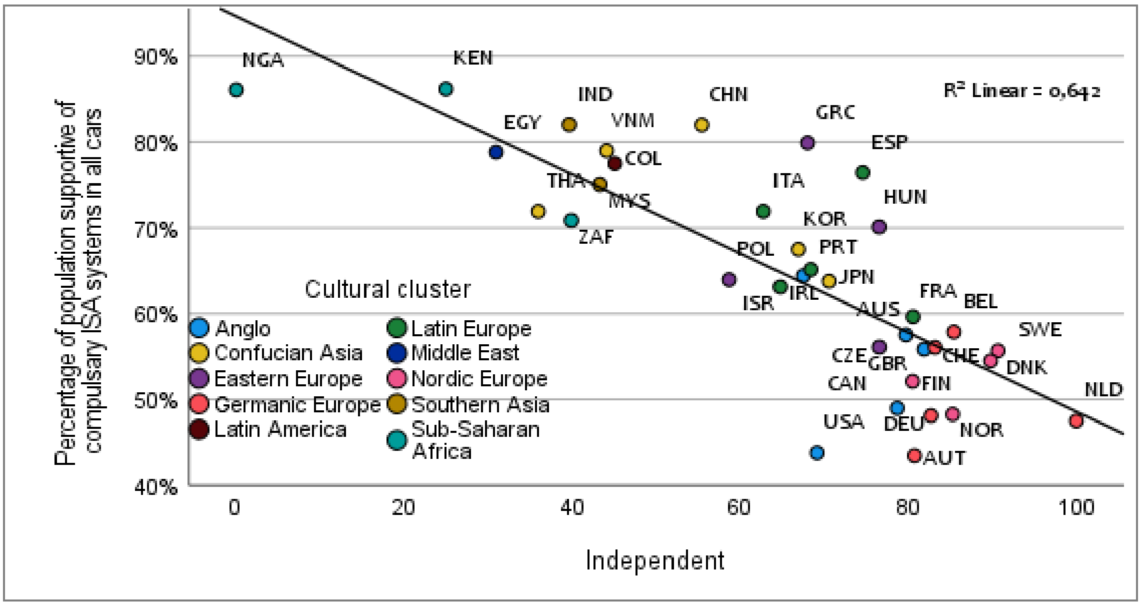

Figure 1. Support for ISA by the cultural dimension “Independent”

Study (3) illustrated that counterarguments for ISA differ considerably between those opposing and those supporting ISA. Many respondents which opposed ISA thought that this would limit their freedom or privacy and would be an ‘unjustifiable state intervention’. Also, the expected consequences of making ISA compulsory differ between supporters and opponents of ISA. Those supportive of ISA strongly believe in its effectiveness; in other words, that ISA will make roads safer, reduce the crash risk, and make driving more comfortable. The opponents, on the other hand, fear ISA as a means of controlling and restricting their behaviour. They also think it would make driving less pleasant and even unsafe when overtaking a car. The study also showed that those who self-reported to have been speeding in the last month were also more likely to oppose ISA.

4. Conclusion

The analysis show that a wide range of factors are associated with support for, or opposition to, mandatory installation of ISA systems, that national culture is a very good predictor of support for ISA, and that the expected consequences for an individual affect the attitude of that individual towards ISA.

5. References

Meesmann, U., Torfs, K., Wardenier, N., & Van den Berghe, W. (2021). ESRA2 methodology. ESRA2 report Nr. 1 (updated version). ESRA project (E-Survey of Road users’ Attitudes) (Vol. 1). Vias institute.

Minkov, M. (2018). A revision of Hofstede’s model of national culture: old evidence and new data from 56 countries. Cross Cultural & Strategic Management, 25(2), 231–256.

Van den Berghe, W. (2022). The influence of fairness and ethical trade-offs on public support for road safety measures. An international and intercultural exploration. PhD Thesis, University College London.

Monitoring Distracted Driving in Europe: from Baseline to Trendline.

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Keywords: driver distraction, Key Performance Indicator (KPI), road safety, mobile device, Baseline, Trendline

*Speaker

Integrating mixed data for a human-centred mobility

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ABSTRACT

This study is situated in the context of smart cities, characterised by abundant available digital data resources. The main problem addressed is the difficulty in effectively integrating and analysing diverse data sources to derive meaningful insights about urban mobility. The goal is to present a mixed data process to understand the relationship between weather and modes of transportation from Rio de Janeiro, exemplifying successful and unsuccessful aspects. We employed three methods: open data analysis, a diary study, and sentiment analysis on Twitter. Open data analysis revealed the need for integration due to unstructured datasets, but the government's transparency channel proved effective in providing requested tables. The diary study faced limitations with available tools and algorithm inconsistencies, yet engagement strategies enhanced participation. Twitter sentiment analysis encountered challenges with structural adjustments and limitations in accessing the full archive, but we gained valuable insights regarding public sentiment about transportation modes. The main results indicate that buses are popular but have security concerns. Bicycles receive fewer complaints on social media, but their usage is affected by the weather. The ferries are part of a multi-modal journey, and thermal comfort requires improvement. The metro is praised for climate control and punctuality. Integrating mixed data contributes to a comprehensive understanding of urban mobility and climate change. Artificial Intelligence facilitated task automation and code development. Future steps involve data analysis and a co-design process for collaborative solution development. This research has implications for transportation planning, policy-making, and understanding the intricate relationship between climate, mobility, and human behaviour.

Keywords: smart cities, urban mobility, mixed data, climate change, data integration, gamification.

1. INTRODUCTION

In the era of smart cities, the abundance of available data offers immense potential for understanding and optimising urban environments. However, integrating diverse data sources to create a comprehensive context remains a significant challenge (Kitchin, 2015). This study is part of a broader doctoral research focused on examining the impact of weather on urban mobility. Specifically, this paper explores the complexities and obstacles associated with leveraging diverse data sources within a human-centred process.

In light of the urgent need to address the effects of climate change, integrating data from various sources has become increasingly crucial (IPCC, 2022). Understanding the intricate relationship between weather conditions and urban mobility patterns is essential for developing adequate, sustainable transportation and urban planning strategies. By employing a range of data collection techniques and considering the unique characteristics of human behaviour, this research aims to provide valuable insights into the interplay between mixed data approaches.

This study employed multiple methods to accomplish the research objectives. Initially, we analysed mobility and weather data from Rio de Janeiro. This investigation provided a foundation for understanding the existing urban mobility patterns within the context of weather variations. We also conducted a user diary study involving citizens who traversed the city and reported their experiences. This approach captured real-time observations and subjective perspectives on how weather impacts daily mobility choices. Furthermore, sentiment analysis of tweets about different transportation modes was undertaken, providing valuable insights into public perceptions and sentiments about urban mobility under varying weather conditions.

The primary focus of this research is to explore the collection of mixed data through various research techniques to identify and analyse urban mobility behaviour. This paper presents a comprehensive overview of the research, highlighting the challenges and methodologies employed. The subsequent sections will delve into the specific methodologies, findings, and implications derived from the data collected, providing a deeper understanding of the complex relationship between weather and urban mobility patterns.

2. METHODS FOR COLLECTING MIXED DATA

The methodology employed in this study involved using open data from Rio de Janeiro to investigate the impact of weather on urban mobility. The initial data collection process relied on gathering information from the DataRio[1] website. DataRio is a portal for disseminating information by the municipal government, fostering integration and enhancing data production about Rio de Janeiro. Although it provided a valuable foundation for the analysis, we requested additional data from the respective companies responsible for the transportation services to ensure a comprehensive examination. The Brazilian information access law (nº 12.527/2011) obligated government-operated companies to provide transparent data, while the exact requirement did not bind private companies.

The research focused on obtaining data on the daily number of bus, taxi, bicycle, tram, train, metro, and ferry trips in Rio de Janeiro, spanning as far back as the earliest available records up to the present day. We obtained monthly data from the municipal portal and more detailed daily information through requests directed at operators. In contrast, weather data was relatively more accessible, as detailed information was readily available on the AlertaRio[2] website, the municipal alert system for heavy rains and landslides on slopes. This data collection and integration method is a crucial foundation for this study's subsequent analysis and findings.

1 https://www.data.rio/

2 http://alertario.rio.rj.gov.br/download/dados-meteorologicos/

The second method employed in this research was a diary study conducted in March 2023, where participants recorded their observations and data at specific moments, documenting particular aspects related to their experiences (Marsh, 2018). A pilot test was initially conducted with eight participants to refine the methodology. Subsequently, 30 participants were recruited, 20 actively engaging in the diary study. We asked participants about their travel frequency using different transportation modes during recruitment. The goal was to recruit a minimum of six participants who travelled at least once a week using each mode of transportation.

To achieve a diverse sample of participants, we initially targeted residents of neighbourhoods with access to various transportation modes, such as ferry terminals, bike lanes, and metro stations. Once we recruited them, we requested to share the study with friends in similar regions. This snowball sampling technique allowed us to gather a representative number of participants for each mode. The initial set of users identified indicated others willing to participate in the study (Lazar et al., 2017).

We selected Instagram as the platform for data collection and participant communication due to its widespread usage and user familiarity. We shared posts informing the participants about data, weather conditions, and traffic. The diary component of the study was shared through stories, allowing participants to comment on their daily experiences and provide details such as the day, hour, departure, and arrival neighbourhood. This information enabled the researchers to determine travel times, whether short or long, and factors influencing transportation choices. Participants also provided insights into the purpose of their travel, the mode of transportation used, weather conditions, thermal sensation, and satisfaction levels, with close questions and any other relevant factors that might have influenced their transportation decisions. We asked open questions if participants had anything to add.

A weekly ranking of the most engaged participants was shared to encourage active participation. After one month, we gifted a personalised art piece featuring the winner's data as a token of appreciation. This diary study allowed for qualitative and detailed insights into the participants' daily travel experiences and their interactions with various transportation modes concerning weather conditions and other contextual factors. The findings derived from this methodological approach contribute to a deeper understanding of the impact of weather on urban mobility in Rio de Janeiro.

The third method employed in this research involved the analysis of Twitter data. We requested an academic account through the API (Application Programming Interface) to access the complete archive. The Twitter API is a set of tools and protocols allowing developers to interact with the platform, access its data, and perform various operations programmatically. Initially, we used the Twitter Downloader tool for data collection. However, this tool became unavailable due to changes within the company, prompting a switch to the Postman platform, which the Twitter developer platform recommends.

A search was conducted for tweets containing specific transportation-related hashtags such as #rioonibus, #metrôrio, #BikeRio, #CCRBarcas, #UberRJ, #TaxiRio, #SuperVia, #vltcarioca, and #BRTRio within the last ten years, resulting in 36,016 tweets. Subsequently, the tweets were filtered using weather-related keywords extracted from the most common subjects commented in the diary study, such as Ensolarado (sunny), Nublado (cloudy), Chuvisco (drizzle), Calor (heat), among others.

The query was limited to tweets in Portuguese and excluded retweets, resulting in a reduced dataset. So we collected from the entire Twitter archive from 2016 until 31 March 2023 and had 3,514 results. A sentiment analysis code was applied to further analyse the sentiment of the tweets. Sentiment analysis is a technique used to analyse sentiments and opinions expressed in written language, specifically, in this case, comments on the social media platform. Also known as opinion mining, this technique utilises natural language processing to systematically identify, extract, quantify, and study the affective states and subjective information conveyed in the text. By analysing the language used, sentiment analysis aims to determine individuals' opinions, sentiments, evaluations, attitudes, and emotions (Liu, 2012).

Numerous data processing codes and tools are available on public platforms like GitHub, making it easier to leverage these programming resources. For sentiment analysis, specific code is required for each language, necessitating training on texts in the desired language. In this study, we choose a repository with pre-trained models for sentiment analysis in Portuguese. This model detects polarity, classifying comments as positive, neutral, or negative. The analysis of this Twitter data provides valuable insights into public sentiment and perceptions of weather-related conditions about urban mobility in Rio de Janeiro.

3. RESULTS

This section presents the key findings obtained from each of the three methods employed in this research: open data analysis, diary study, and Twitter sentiment analysis. The general findings encompass observations applicable to Twitter and Instagram, highlighting the challenges associated with using these social networks due to their unstable systems.

The analysis of available data sets revealed several significant findings. Firstly, many open data sets were unstructured, requiring integration efforts for meaningful analysis. We also encountered difficulties locating contact information on the data owner's website, hindering data acquisition and communication. Moreover, the data sets exhibited different structures, with some tables divided time by hour, day, or month, as well as location per station, neighbourhood or city, making the cleaning and standardisation process challenging. Furthermore, the datasets lacked informative descriptions and valuable metadata, making it necessary to download each table to understand its subject matter. One notable finding was the effective functioning of the government's channel for transparency within the information access law. This channel successfully provided the requested tables in the exact format as specified, demonstrating compliance with regulations.

The diary study conducted on Instagram revealed specific limitations and noteworthy findings. Firstly, certain tools for personal use were unavailable for business purposes, creating challenges in automating messages, such as the inability to schedule stories with pools. Additionally, the reliability of Instagram analytics was questioned, as there were instances of inaccurate data. The algorithm of Instagram was an issue by not displaying stories to all followers, resulting in some participants not seeing the shared content and subsequently forgetting to respond the diary. To address this, we shared posts about weather and traffic, which helped engage participants, as the algorithm favoured showing more content to those users. Gamification techniques, such as sharing participant rankings, effectively motivated citizens to register their trips and enhance participation.

The Twitter sentiment analysis yielded specific insights and notable findings. The process faced challenges due to structural adjustments within the companies involved, affecting the research. Additionally, signing up for the Twitter API proved complex, involving technical terms and requirements. Despite having an academic account with access to the full Twitter archive, the website was limited to 500 tweets per request, necessitating pagination to download all the required posts. The sentiment analysis revealed that Twitter, a platform commonly used for criticism, had a prevalence of negative text. We also observed that the sentiment analysis struggled with identifying sarcasm, leading to instances where seemingly positive comments were negative. Nevertheless, some patterns related to transportation modes were discernible, and several subjects of criticism were identified, providing valuable insights that authorities could utilise for improvement.

The data provided by the municipality shows that buses are the most widely used mode of transportation, primarily due to their affordability and extensive coverage. However, diary responses and Twitter comments revealed that the travel experience is generally poor. The main complaints are related to security concerns, the unpredictability of bus schedules, and the lack of air conditioning.

Bicycles received more positive comments than other modes of transportation, including on Twitter. The diary study also confirmed this positive sentiment, with participants expressing satisfaction with their trips. Weather conditions influence the usage of bicycles, with a decrease in trips on rainy days.

The ferries are typically part of a multi-modal journey, requiring passengers to access and leave the terminal using other transportation. In addition, thermal comfort needs improvement, as there are often complaints of heat and non-functioning air conditioning, despite the refreshing sea breeze.

The metro generally receives positive feedback for its climate-controlled environment, predictability, and punctuality. However, like the ferry, passengers may require additional transportation to reach the metro station from their residence or their final destination after disembarking. Therefore, knowing which train carriages have more space could benefit passengers.

Overall, the results obtained from each method shed light on the challenges, limitations, and significant findings related to the use of open data, diary studies on Instagram, and sentiment analysis on Twitter. These findings contribute to a deeper understanding of the relationship between weather, urban mobility, and citizen experience in Rio de Janeiro.

4. CONCLUSION

In conclusion, our research demonstrates the significance of integrating mixed data to understand urban mobility, particularly in climate change. Artificial Intelligence (AI) has played a crucial role in automating various tasks, such as sending messages to participants and implementing sentiment analysis. AI assistance has proven valuable in guiding individuals with limited programming experience in developing code to address specific tasks.

In the following steps, we plan to develop a co-design process, where stakeholders will work together to analyse the data collected and create solutions for the issues found. We will use data visualisation techniques to achieve a participatory process, mixing digital and analogue representations.

The implications of this research are significant for transportation planning and policy-making. By leveraging mixed data, our findings shed light on the intricate interactions between climate, mobility, and human behaviour (Consoli et al., 2017). Overall, this research contributes to the broader field of urban studies and provides valuable insights for policymakers, urban planners, and researchers seeking to enhance sustainable urban mobility.

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REFERENCES

Consoli, S., Presutti, V., Reforgiato Recupero, D., Nuzzolese, A. G., Peroni, S., Mongiovi', M., & Gangemi, A. (2017). Producing Linked Data for Smart Cities: The Case of Catania. *Big Data Research*, *7*, 1–15. https://doi.org/10.1016/j.bdr.2016.10.001

IPCC. (2022). Summary for Policymakers. In H. O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, & B. Rama (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (p. In Press). Cambridge University Press.

Kitchin, R. (2015). Making sense of smart cities: Addressing present shortcomings. *Cambridge Journal of Regions, Economy and Society*, *8*(1), 131–136. https://doi.org/10.1093/cjres/rsu027

Lazar, J., Feng, J. H., & Hochheiser, H. (2017). *Research Methods in Human-Computer Interaction* (2nd ed.). Morgan Kaufmann. https://doi.org/10.1016/b978-0-444-70536-5.50047-6

Liu, B. (2012). Sentiment Analysis and Opinion Mining. *Synthesis Lectures on Human Language Technologies*, *5*(1), 1–167. https://doi.org/10.2200/S00416ED1V01Y201204HLT016

Marsh, S. (2018). *User research: a practical guide to designing better products and services* (1st ed.). Kogan Page Limited.

Collaboration Across Three Continents During and After a Global Pandemic: Reflections of Early and Established Career Academics

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ABSTRACT

The International Research Centre to study the Effects of Autonomous Vehicles (AV) on Vulnerable Road-users (VRU) (ICAROS) was established in September 2019. This ambitious international research centre brings together academics from Loughborough University UK, Queensland University of Technology, Australia and Tongji University, China. We had big plans for collaborative working to tackle the problems of AV and VRU interaction, we were set to go. Then 2020. Like others we switched to online working and we made the best of what we had - online seminars, online workshops, emails. This paper presents our perspectives on research and collaboration during a global pandemic, and the positive/negative legacy of the pandemic on our current working. Reflection is made on how personal experience differs by careers stage comparing options of authors who are current Ph.D students (early-career n = 8) and those who had worked in research for at least 5 years prior to the pandemic (established-career n = 8). A major impact on early-career academics has been a restriction in establishing academic networks due to lack of face-to-face experiences. Early-career academics have enhanced their skills in online data collection but have had fewer experiences at in-person data collection. Postdoctoral funding will have a huge role to play in expanding the horizons of this new generation of academics. Many elements of pandemic working are a compromise not an ideal.

Keywords: academic working, research collaboration, pandemic, autonomous vehicles, vulnerable road users, COVID-19.

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1. INTRODUCTION

1.1 Background

ICAROS is an international initiative developed to study the impacts of Connected and Autonomous Vehicles (CAVs) on Vulnerable Road User (VRU) safety, established in September 2019 (https://icaros.lboro.ac.uk/). VRUs encompass pedestrians, cyclists, motorcyclists, child road-users and senior road-users; as well as the newly emerging micro mobility such as e-riders, who travel on scooters or skateboards. Mobility is important for VRUs but they comprise 59% of road users killed. CAVs have potential for improving road safety, however, not all road users have the capability or willingness to be connected and/or autonomous. It is vital that those vehicles with CAV capability are able to successfully share the road with all users. For example, pedestrians and cyclists will not be automated, and must be able to safely coexist alongside CAVs (Vissers et al 2016, Botello et al 2019).

ICAROS is a collaboration between Research Centres on three continents, Loughborough University (UK), Queensland University of Technology through CARRS-Q (Australia) and Tongji University (China). A unique research programme on the safety of VRUs with respect to CAVs is being co-ordinated and disseminated through collaborative activities including PhD programmes, research seminars, publications and a future International Conference (planned in 2024). Its principles are embedded in cross-centre collaborative working and exchange. The plan for ICAROS during 2020 and 2021 included two in-person sand pit events to develop a research proposal, two sets of academic exchanges between the three Universities, two physical meetings with the Project Advisory Board (PAB), and in-person research seminars, none of which happened during this time. From March 2020 (like all other research collaborations) our plans changed in response to the global coronavirus pandemic. Like others we adapted (Metcalf and Blanco, 2021) but as our collaboration started before the pandemic, we were adapting an existing relationship rather than forging a new one under pandemic circumstances (Envuladu et al., 2022). The ICAROS online approach during 2020 and 2021 included 6 steering committee meetings, 9 research student seminars where students take it in turns to present work in progress to the group on MS Teams, 10 independent research student online meetings (without established-career academics present), 1 online meeting with the project advisory board, 2 established-career academic seminars and 1 online sandpit event for developing research proposal ideas.

1.2 Objectives

This paper sets out to: 1) document the impact of the pandemic on career development, training and international collaboration, 2) outline the longer term positive and negative lasting impacts of pandemic working practice on academia, 3) compare the impacts of the pandemic on early and established career academics.

2. METHOD

The authors of this paper are all research active academics working at Centres associated with the ICAROS project. In order to provide structure to writing and a method to collate the lived experience each author independently answered six questions:

1. What was the impact of the COVID-19 pandemic on research methods?
2. What was the impact of the COVID-19 pandemic on career development?
3. What was the impact of the COVID-19 pandemic on research training?
4. What was the impact of the COVID-19 pandemic on research collaboration?
5. What lasting positive benefits to research and academic work remain from the COVID-19 pandemic?
6. What lasting negative limitations to research and academic work remain from the COVID-19 pandemic?

The lead author collated responses by synthesising common opinions. The lead author wrote a first draft of the paper, the other authors edited the text ensuring their opinions were accurately reflected.

Each author self-identified as early (n=8) or established career (n=8). All early-career authors are currently completing a Ph.D. Established career authors had at least 5 years of research experience in a University prior to March 2020. Differences in opinions between career stage are considered.

3. RESULTS

3.1 Research during a global pandemic

Our collective experience of impact of the pandemic on our research methods is similar. Regardless of career stage or geographical location, we all adapted to online data collection during the height of the pandemic. There was an increased focus on theoretical approaches and new analysis of existing data. Online focus groups and interviews were frequently used. These were beneficial because they increased the range of people that could participate as there was no geographical constraints. However, those of us with established careers noted that it was necessary to have fewer participants per group than we had been used to in-person pre-pandemic. When COVID-19 related restrictions reduced, the dominant impact on methods was to design studies with minimal interaction between participants e.g. data collection from single participants in isolation, and allow increased time for cleaning labs and equipment between participants. Many of us faced difficulties in participant recruitment when COVID-19 restrictions were lifted. The reluctance of participants and the increased time required for cleaning labs and equipment between participants likely reduced sample sizes for data collected during this time.

There were two notable experiences voiced by established-career academics about research methods but not by early-career academics, both related to research opportunity. Firstly, an increased appetite for active travel research providing new opportunities to study VRUs. Secondly, a perceived decrease in funding opportunities for transport research as funding for COVID-19 -related research was prioritised.

Our differing experiences of career and training impact are presented in Table 1. Regardless of career stage, the pandemic brought feelings of isolation, stress and worry which we felt impacted career progression. The isolation experienced by early-career academics included a feeling of separation from the University itself. In situations of not long having started a PhD there was lack of familiarity with systems and procedure which increased feelings of isolation. Regardless of career stage, there was opportunity for formal online training. A notable difference in our experience is that those with established careers raised concerns about the quality of research during this time. Specifically, that transport data collected during pandemic lacks generalizability as travel patterns were disturbed and participant travel behavior was likely influenced by life circumstance change e.g., reduced commuting.

Table 1 – Authors' experience of impact of pandemic on career and training by career stage

	Early-career	Established-career
Career impact	-Isolation from University -No learning from experienced PhD students. -Additional workload. -Stress and mental health struggles.	-Isolation from colleagues. -Reduced motivation -Felt "on pause" -Worry about family and childcare. -Research quality concerns (generalizability, participant behaviour). - Managing funder expectation given emerging restrictions
Training impact	-Harder to access supervisor and peers. -Additional training need in safe participant data collection. -Online training is easier to access but it is less engaging. -Quality of learning from training is reduced without other student interaction.	-Reduced opportunity of informal training. -Increased opportunity for formal online training. - Face to face presenting skills were impacted.

3.2 Collaboration during a global pandemic

The authors' experience of the pandemic's impact on collaboration is presented in Table 2. Those of us with established careers noted an increase in available work time as a positive outcome of not having to travel. Early-career academics found it harder to coordinate collaboration online than those who already had existing working relationships.

Table 2 - Author experience of impact of pandemic on collaboration by career stage

	Early-career	Established-career
Collaboration impact	-No opportunity for in-person conference. -No opportunity for exchange trips. -Harder to coordinate online. -Time consuming.	- Online collaboration was smooth due to existing (past) relationships. -No travel increased work time. -Reduced funding opportunity as money diverted to COVID-19 research. - Fewer academic visitors to share ideas

	Early-career	Established-career
		-Grant proposal generation is difficult online

3.3 After a global pandemic

Fortunately for ICAROS, the project continues until March 2025 so we have been able to resume our face-to-face activities. International visits have taken place, in-person seminars have resumed and the PAB has met in person. We have experienced collaboration together during and after a global pandemic. Table 3 presents our reflections on the lasting positive and negative legacies of global pandemic. Those of us who are early in their careers were more likely to identify their improved kills in using online data collection methods as a positive legacy. Whereas those of us who have established careers are more likely to see positives in changes to their work arrangements e.g., increased acceptance of working from home. When considering the negative legacy, early-career academics noted more impact related to themselves and how they now work, whereas established-career academics noted negative impacts to the broader academic system e.g., reduced funding for research administration support.

Table 3 – Authors' experience of the positive and negative legacy impact of the pandemic

	Early-career	Established-career
Positive legacy	-Improved computer literacy for online research methods. -Improved literacy of online collaboration tools e.g. Miro -Personal resilience and adaptability. -Remote data collection experience.	-Normalizing online rather than in person meetings has reduced travel. -There are now more networking and training events available online. -Flexible working and working from home more accepted.
Negative legacy	-Uncertainty in how/when to reach out for informal help/support/training as used to working in isolation. -Now doing in person activities e.g., interviews is harder. -Struggle to change to office working. -Work schedules are demanding as we are in a routine of back-to-back meetings. -Missed opportunity to build networks during Ph.D.	- COVID-19 illness has greater impact as we plan work as if it has gone away. -Flexible working means seeing colleagues infrequently reducing informal discussion. -More email traffic. -Reduced sense of belonging. -Reduced University budget (e.g., reduced international students) has impacted research admin support. -Reduced ambition in research design in early career grant applications.

4. DISCUSSION

This paper documents the authors' experience of the impact the COVID-19 pandemic had on our career development, training opportunity and international collaboration as part of the ICAROS project focused on CAV and VRU. In structuring our experiences by our career stage, we are able to note some key differences in our experiences between early (current Ph.D student) and established (at least 5 years of research career prior to pandemic) academics. It is beneficial for the academic research community to have awareness of the specific impacts of the pandemic on junior academics, with this information we can help shape our academic landscape within a supportive and understanding culture.

The process of collaboration changed during the pandemic, but our situation was a continuation of our existing collaboration. Our existing relationship as a group, particularly between those with established careers, likely aided our continued work. The senior members of the team already knew each other and got along well. The project is also lead by an experienced principal investigator. For research collaborations starting during the pandemic, team formation is reportedly difficult (Envuladu et al 2022).

Between us we shared many common experiences during the pandemic, for example, a lack of informal training/peer support, difficulty with idea sharing and feeling of isolation from other academics. However, this has had greater lasting impact on early-career academics than those of us with established careers. Academics thrive within our formal and informal networks, and trusted academic relationships are highly valued and are a source of support (Metcalfe and Blanco 2021). Academics start forming networks with academic "friends" of a similar career stage from early in their career. Those who started their career during the pandemic have been limited in opportunity to start developing their networks. This difference is also reflected in an early-career perspective of the negatives of loss of travel possibility compared to the established-career perspective of more flexibility due to less travel.

Those of us with established careers were able to note the changes in funding landscape and how this impacts the research being undertaken. This was particularly relevant to our research topic as active travel increased during the pandemic (Aldred and Goodman 2021). However, it should be considered that this difference in perception is likely an impact of career stage independent from COVID-19 impact. Additionally (and perhaps more importantly), those of us with established careers have stronger concern over the quality of transport data collected during the pandemic than those who are early-career. This might be an issue worthy of further investigation. The PhD is a time of grounding and training for an academic career but it is a fixed period of time, it is not possible for those entering academia from 2020 to compare with the pre-2020 context. This is something that the academic community should be conscious of in the way we support our Ph.D students in awareness of the limitations of data and data collection methods. Many academics feel most comfortable in the methods that they honed during their Ph.D. The Ph.D allows time to develop a greater depth of knowledge for the methods used and this methodological familiarity shapes our future research proposals. Those of us lucky enough to have had research careers starting pre-pandemic are in a position to learn from the pandemic years by bringing in new remote approaches to methodologies. However, the pandemic PhD students who are just starting their postdoctoral careers have had an atypical methodological grounding and may feel limited in their vision for future study plans.

There is an emerging generation of early career academics with limited experience of face-to-face academic activity (data collection and dissemination of findings) and a restricted personal academic network. Dedicated post-doctoral funding has potential to minimise long term impact on the academic landscape. For example, conferences could offer travel grants to post-doctoral as well as Ph.D students as an approach to help mitigate impact of reduced face-to-face activity. Research funders could offer knowledge exchange and training funding opportunities for early career academics, targeting broadening in depth data collection methods experience for those who were forced to conduct their PhD research using remote methodologies. Many elements of pandemic working are a compromise not an ideal, dedicated postdoctoral funding calls could be a useful tool for expanding the horizons of pandemic trained academics and supporting diversity of approach in future research endeavours.

REFERENCES

Aldred, Rachel, and Anna Goodman. 2021. "The Impact of Low Traffic Neighbourhoods on Active Travel, Car Use, and Perceptions of Local Environment during the COVID-19 Pandemic." Findings, March https://westminsterresearch.westminster.ac.uk/download/4ee2815b53f3d776b8e5aee3ac88841e81ee328401bbadbd1871e849ae74af04/523263/21390-the-impact-of-low-traffic-neighbourhoods-on-active-travel-car-use-and-perceptions-of-local-environment-during-the-covid-19-pandemic.pdf

Botello, B.; Buehler, R.; Hankey, S.; Mondschein, A.; Jiang, Z. Planning for walking and cycling in an autonomous-vehicle future. *Transp. Res. Interdiscip. Perspect.* **2019**, *1*.

Envuladu, E. A., Miner, C. A., Oloruntoba, R., Osuagwu, U. L., Mashige, K. P., Amiebenomo, O. M., ... & Agho, K. E. (2022). International research collaboration during the pandemic: Team formation, challenges, strategies and achievements of the african translational research group. *International Journal of Qualitative Methods*, *21*, 16094069221115504.

Metcalfe, A. S., & Blanco, G. L. (2021). "Love is calling": Academic friendship and international research collaboration amid a global pandemic. *Emotion, Space and Society*, *38*, 100763.

Vissers, L.; Van der Kint, S.; Van Schagen, I.; Hagenzieker, M. *Safe Interaction between Cyclists, Pedestrians, and Autonomous Vehicles. What Do We Know and What Do We Need to Know?* Report R-2016-16; SWOV Institute for Road Safety Research: The Hague, The Netherlands, 2016

An Extension to the Traditional Technology Acceptance Model (TAM) for Semi-Autonomous Vehicles

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ABSTRACT

The notion of trust in automation has significant implications for designing disruptive technologies as well as its acceptance by users. Furthermore, the level of (perceived) trust influences interactions between users and technology and subsequently plays a critical role in safe operations of those technologies. Therefore, the urgency for designing interfaces that enable effective and timely human-machine interactions are utmost in developing safety-critical systems where an error can have severe consequences. Semi-autonomous vehicles or conditional automated vehicles fall under the category of safety-critical systems that still require their users to interact with the onboard driving and navigating technologies during autonomous driving (AD). This can be considered as a source of safety risk since inappropriate levels of trust may obstruct the performance of such vehicles and cause a collision. This research proposes an extension to the Technology Acceptance Models by including trust as a predictor for acceptance and intention to use. To this end, a multidisciplinary scoping literature review was conducted to identify determinants and metrics of trust and construct a model for semi-autonomous vehicles. The main emerging themes are explainable AI, transparency, and predictability. The proposed model encompasses a broader picture of trust in autonomous systems and offers insights for further research and development in designing interfaces which can safeguard the safety of vehicles while the promised benefits of autonomous vehicles are not affected.

Keywords: autonomous vehicles, trust, functional safety, human-machine interactions (HMI).

1. INTRODUCTION

While a considerable body of research suggests that there are serious safety implications associated with semi-autonomous driving (e.g., Banks et al., 2018; Demeulenaere, 2020; Favarò et al., 2019; Merriman et al., 2021; Pearl, 2018; Toliyat, 2022), it appears that a swift transition from human-driven vehicles (HDVs) to fully autonomous vehicles (FAVs) is not feasible (Nascimento et al., 2019). The safety concerns around partially automated vehicles tend to be even deeper in complex scenarios, for example, due to faded situational awareness, drowsiness, engagement in non-driving related tasks, and overreliance on the autonomous features. Nevertheless, semi-autonomous or partially automated vehicles are viewed as a bridge to FAVs and a transition period where human drivers are still in the control loop is inevitable (Banks et al., 2019).

Acceptance and intention to use are vital for the uptake of an innovation and securing return on investment for technology developers (Golbabaei et al., 2020). The academic literature identifies trust as one the key causal factors (or predictors) for acceptance (Liu et al., 2019; Wilson et al., 2020) and intention towards using disruptive technologies such as autonomous vehicle vehicles (AVs) (Payre et al., 2016; Zhang et al., 2019). Trust also plays an active part in promoting effective and timely interactions with autonomous ground vehicles. The notion of trust in AV capabilities and its convolutions have been covered in the academic literature as well as technical reports, especially in the past decade. However, a conceptual model which integrates determinants, moderators, mediators, and metrics is still lacking. To fill this gap, a broad scoping literature review was designed and implemented to ascertain and discuss the interdisciplinary aspects of user trust in partially automated vehicles. A following conceptual model in this research would endeavour to transcend the traditional Technology Acceptance Model (TAM) which is predominantly used in marketing studies and provide further insights for designers and mitigating safety (i.e., collision) risks.

2. RESEARCH BACKGROUND

The foundation of TAM was developed by Fred Davis in 1980s based on the Theory of Reasoned Action and identified *perceived usefulness* and *perceived ease of use* as the principal motives of usage intention and adoption (Davis & Venkatesh, 1996; Mara & Meyer, 2022; Zhang et al., 2019). One limitation of TAM is that it has been predominantly applied in assessing acceptance of Information Technology and Information Systems such as office automation software packages (Legris et al., 2003). The main disparity between office automation systems and AVs is that the former is not safety-critical in essence and the concept of trust in automation (or autonomy) for that category of technology is not as paramount as it is for transportation means. As a result, the original TAM falls short of capturing a comprehensive abstraction of the trust dynamics in safety-critical systems.

From a sociological point of view, acceptance encompasses the social conditions surrounding the AVs too—seeing technology as a socio-technical means of mutual influence (Zoellick et al., 2019). Therefore, trustworthiness must be seen as an integral property for AVs that can persuade users to relinquish driving tasks and control to Artificial intelligence (AI). Lacher et al. (2014) defined trust as *expectations* and *perceptions* that individuals maintain in their minds about the performance of a system (e.g., AV). Thus, trust is rather the status of a system that humans perceive in their minds than a trait of the system itself (Lacher et al., 2014). This definition further suggests that the issue of trust in an autonomous (or automated) system goes beyond a merely engineering challenge and entails psychological, cultural, social, neurological, and cognitive factors too (Liu et al., 2020; Mara & Meyer, 2022).

A trustworthy AI system must function in a way that maximises benefits and simultaneously eliminates or minimises risks for a society (Fernández Llorca & Gómez, 2021). To achieve those objectives, an AV needs to be safe and reliable in the first place. AVs are categorised under the safety-critical systems (Nascimento et al., 2019) and technical failures can damage trust and adversely affect intention to use (De Visser et al., 2018). For socio-technical systems, interactions with human agents are unavoidable and even tend to be necessary at some points. In semi-autonomous vehicles, human-machine interaction (HMI) is an obligatory mechanism shared between users and vehicles which may differ for one automotive brand to another and demands a user-centred design approach (Carsten & Martens, 2019). A large body of literature has been already dedicated to observing and examining the interactions of human beings during AD trials. This provides grounds for in-depth analysis and synthesising available evidence to determine moderators, mediators, and metrics of trust.

3. RESULTS

The aim of scoping review in this research was to discover the key concepts pertinent to ‘trust’ and outline an overview of causal factors, mediators, moderators, and metrics influencing trust in semi-autonomous vehicles. A set of keywords (i.e., “autonomous vehicle*/car*”, “automated vehicle*/car*”, “driverless”, “self-driving”, “risk”) were used to run a search in WorldCat database (internal to the University of Southampton) together with Google Scholar. WorldCat (formerly DelphiS) provides access to over 1500 databases including Scopus and Web of Science. The aimed keywords returned 636 records which were mainly published between 2005 and 2022. Then, the collated records were transferred into NVivo for further filtering and screening. ‘Trust’ was included among the keywords at this stage. After excluding the records which did not contain ‘trust’, the remained papers were down to 217. Seven papers were chosen from the references of the remaining papers and were added, increasing the number of records to 224. Finally, the screening criterion was applied, and 59 papers (56 from DelphiS & 3 from Google Scholar) were carried forward for content analysis.

Thematic content analysis is the most basic qualitative analysis to identify and classify recurrent themes (Green & Thorogood, 2004) and is recommended for interference interpretation. The thematic content analysis (coding) for this research was carried out in NVivo and resulted in 30 codes (themes). Three codes (i.e., design, heuristics, and standardisation) were not as frequently used as others and were consequently merged or removed. The remaining 27 codes are listed in table 1.

The combination of human and technical factors among the emergent themes in table 1 denotes a socio-technical transition in mobility which involves not only technology, infrastructure, and standardisation, but also embraces consumer preferences, market rules, user practices, and social values (Milakis & Müller, 2021). The emergent themes from the reviewed literature can be categorised into two clusters: human and technical. Human factors relate to user’s perception, interactions and intentions. The implication of human factors such as reaction time and situation awareness are not limited to just trust and safety facets and have a decisive role in developing a legal framework and regulating AVs (De Winter et al., 2014). Technical themes, on the flip side, are concerned with the design, technical competence, and technological capabilities. “Technical competence refers to the degree of user perception on the performance of the autonomous vehicles” (Choi & Ji, 2015; Niu et al., 2018). This indicates that even technical matters and performance are not independent from user perception.

Table 1 - The emergent themes from the scoping review and content analysis

Theme number	Theme	Theme number	Theme
1	Acceptance	15	Perceived risks
2	Adoption	16	Predictability
3	Anthropomorphism	17	Prior Experience
4	Complexity	18	Privacy
5	Control	19	Reaction time
6	Disengagement	20	Reliability
7	Drowsiness	21	Safety
8	Excessive/under-reliance	22	Secondary task
9	Explainability	23	Security
10	HMI	24	Situation awareness
11	Human-like driving style	25	Testing
12	Interfaces	26	Training
13	Mental model	27	Transparency
14	Perceived benefits		

4. CONCLUSIONS AND FUTURE WORKS

Expansion of traditional TAM can offer a broader picture of interacting (and perhaps interdependent) factors that affect or are being affected by trust in AVs. Introducing granularities into the acceptance model for AVs and involving trust can contribute to testing, regulating, standardisation, and policymaking initiatives. A causal map can further manifest a series of causal links that can be exploited for further research, for example, statistically testing the strength of the links between the factors listed in table 1. Another research strand to follow can be evaluating the impact of socio-economic factors (e.g., income and education) and personality traits.

REFERENCES

Banks, V., Shaw, E., & Large, D. R. (2019). Keeping the driver in the loop: The 'Other'ethics of automation. Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018) Volume VI: Transport Ergonomics and Human Factors (TEHF), Aerospace Human Factors and Ergonomics 20,

Banks, V. A., Eriksson, A., O'Donoghue, J., & Stanton, N. A. (2018). Is partially automated driving a bad idea? Observations from an on-road study. *Applied ergonomics, 68*, 138-145.

Carsten, O., & Martens, M. H. (2019). How can humans understand their automated cars? HMI principles, problems and solutions. *Cognition, Technology & Work, 21*(1), 3-20.

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

Davis, F. D., & Venkatesh, V. (1996). A critical assessment of potential measurement biases in the technology acceptance model: three experiments. *International journal of human-computer studies, 45*(1), 19-45.

De Visser, E. J., Pak, R., & Shaw, T. H. (2018). From 'automation'to 'autonomy': the importance of trust repair in human–machine interaction. *Ergonomics, 61*(10), 1409-1427.

De Winter, J. C., Happee, R., Martens, M. H., & Stanton, N. A. (2014). Effects of adaptive cruise control and highly automated driving on workload and situation awareness: A review of the empirical evidence. *Transportation research part F: traffic psychology and behaviour, 27*, 196-217.

Demeulenaere, X. (2020). How challenges of human reliability will hinder the deployment of semi-autonomous vehicles. *Technological Forecasting and Social Change, 157*, 120093.

Favarò, F. M., Eurich, S. O., & Rizvi, S. S. (2019). "Human" problems in semi-autonomous vehicles:

Understanding drivers' reactions to off-nominal scenarios. *International Journal of Human–Computer Interaction, 35*(11), 956-971.

Fernández Llorca, D., & Gómez, E. (2021). Trustworthy autonomous vehicles. *Publications Office of the European Union, Luxembourg,, EUR, 30942*.

Golbabaei, F., Yigitcanlar, T., Paz, A., & Bunker, J. (2020). Individual predictors of autonomous vehicle public acceptance and intention to use: A systematic review of the literature. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 106.

Green, J., & Thorogood, N. (2004). *Qualitative Methods for Health Research*. Sage.

Lacher, A., Grabowski, R., & Cook, S. (2014). Autonomy, Trust, and Transportation. AAAI Spring Symposia,

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & management, 40*(3), 191-204.

Liu, H., Yang, R., Wang, L., & Liu, P. (2019). Evaluating initial public acceptance of highly and fully autonomous vehicles. *International Journal of Human–Computer Interaction, 35*(11), 919-931.

Liu, N., Nikitas, A., & Parkinson, S. (2020). Exploring expert perceptions about the cyber security and privacy of Connected and Autonomous Vehicles: A thematic analysis approach. *Transportation research part F: traffic psychology and behaviour, 75*, 66-86.

Mara, M., & Meyer, K. (2022). Acceptance of autonomous vehicles: An overview of user-specific, car-specific and contextual determinants. *User experience design in the era of automated driving*, 51-83.

Merriman, S. E., Plant, K. L., Revell, K. M., & Stanton, N. A. (2021). Challenges for automated vehicle driver training: A thematic analysis from manual and automated driving. *Transportation research part F: traffic psychology and behaviour, 76*, 238-268.

Milakis, D., & Müller, S. (2021). The societal dimension of the automated vehicles transition: Towards a research agenda. *Cities, 113*, 103144.

Nascimento, A. M., Vismari, L. F., Molina, C. B. S. T., Cugnasca, P. S., Camargo, J. B., de Almeida, J. R., Inam, R., Fersman, E., Marquezini, M. V., & Hata, A. Y. (2019). A systematic literature review about the impact of artificial intelligence on autonomous vehicle safety. *IEEE Transactions on Intelligent Transportation Systems, 21*(12), 4928-4946.

Niu, D., Terken, J., & Eggen, B. (2018). Anthropomorphizing information to enhance trust in autonomous vehicles. *Human Factors and Ergonomics in Manufacturing & Service Industries, 28*(6), 352-359.

Payre, W., Cestac, J., & Delhomme, P. (2016). Fully automated driving: Impact of trust and practice on manual control recovery. *Human factors, 58*(2), 229-241.

Pearl, T. H. (2018). Hands on the wheel: a call for greater regulation of semi-autonomous cars. *Ind. LJ, 93*, 713.

Toliyat, S. M. H. (2022). *Developing a Bayesian belief network to assess collision risks for connected and autonomous vehicles in urban environments: A socio-technical synthesis* University of Southampton].

Wilson, K. M., Yang, S., Roady, T., Kuo, J., & Lenné, M. G. (2020). Driver trust & mode confusion in an on-road study of level-2 automated vehicle technology. *Safety Science, 130*, 104845.

Zhang, T., Tao, D., Qu, X., Zhang, X., Lin, R., & Zhang, W. (2019). The roles of initial trust and perceived risk in public's acceptance of automated vehicles. *Transportation research part C: emerging technologies, 98*, 207-220.

Zoellick, J. C., Kuhlmey, A., Schenk, L., Schindel, D., & Blüher, S. (2019). Assessing acceptance of electric automated vehicles after exposure in a realistic traffic environment. *PloS one, 14*(5), e0215969.

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