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# Special Issue: Human Factors and Advanced Vehicle Automation


## SPECIAL SECTION: HUMAN FACTORS AND ADVANCED VEHICLE AUTOMATION

**William J. Horrey, John D. Lee. *Preface to the Special Issue on Human Factors and Advanced Vehicle Automation: Of Benefits, Barriers, and Bridges to Safe and Effective Implementation*. pp. 189–193.**

**Objective:** The aim of this special issue is to bring together the latest research related to driver interaction with various types of vehicle automation. **Background:** Vehicle technology has undergone significant progress over the past decade, bringing new support features that can assist the driver and take on more and more of the driving responsibilities. **Method:** This issue is comprised of eight articles from international research teams, focusing on different types of automation and different user populations, including driver support features through to highly automated driving systems. **Results:** The papers comprising this special issue are clustered into three categories: (a) experimental studies of driver interactions with advanced vehicle technologies; (b) analysis of existing data sources; and (c) emerging human factors issues. Studies of currently available and pending systems highlight some of the human factors challenges associated with the driver–system interaction that are likely to become more prominent in the near future. Moreover, studies of more nascent concepts (i.e., those that are still a long way from production vehicles) underscore many attitudes, perceptions, and concerns that will need to be considered as these technologies progress. **Conclusions:** Collectively, the papers comprising this special issue help fill some gaps in our knowledge. More importantly, they continue to help us identify and articulate some of the important and potential human factors barriers, design considerations, and research needs as these technologies become more ubiquitous.

**Nathan L. Tenhundfeld, Ewart J. de Visser, Anthony J. Ries, Victor S. Finomore, Chad C. Tossell. *Trust and Distrust of Automated Parking in a Tesla Model X*. pp. 194–210.**

**Objective:** The present study aims to evaluate driver intervention behaviors during a partially automated parking task. **Background:** Cars with partially automated parking features are becoming widely available. Although recent research explores the use of automation features in partially automated cars, none have focused on partially automated parking. Recent incidents and research have demonstrated that drivers sometimes use partially automated features in unexpected, inefficient, and harmful ways. **Method:** Participants completed a series of partially automated parking trials with a Tesla Model X and their behavioral interventions were recorded. Participants also completed a risk-taking behavior test and a post-experiment questionnaire that included questions about trust in the system, likelihood of using the Autopark feature, and preference for either the partially automated parking feature or self-parking. **Results:** Initial intervention rates were over 50%, but declined steeply in later trials. Responses to open-ended questions revealed that once participants understood what the system was doing, they were much more likely to trust it. Trust in the partially automated parking feature was predicted by a model including risk-taking behaviors, self-confidence, self-reported number of errors committed by the Tesla, and the proportion of trials in which the driver intervened. **Conclusion:** Using partially automated parking with little knowledge of its workings can lead to high degree of initial distrust. Repeated exposure of partially automated features to drivers can greatly increase their use. **Application:** Short tutorials and brief explanations of the workings of partially automated features may greatly improve trust in the system when drivers are first introduced to partially automated systems.

**Christopher D. D. Cabrall, Jork C. J. Stapel, Riender Happee, Joost C. F. de Winter. *Redesigning Today's Driving Automation Toward Adaptive Backup Control With Context-Based and Invisible Interfaces*. pp. 211–228.**

**Objective:** We investigated a driver monitoring system (DMS) designed to adaptively back up distracted drivers with automated driving. **Background:** Humans are likely inadequate for supervising today's on-road driving automation. Conversely, backup concepts can use eye-tracker DMS to retain the human as the primary driver and use computerized control only if needed. A distraction DMS where perceived false alarms are minimized and the status of the backup is unannounced might reduce problems of distrust and overreliance, respectively. Experimental research is needed to assess the viability of such designs. **Methods:** In a driving simulator, 91 participants either supervised driving automation (auto-hand-on-wheel vs. auto-hands-off-wheel), drove with different forms of DMS-induced backup control (eyes-only-backup vs. eyes-plus-context-backup; visible-backup vs. invisible-backup), or drove without any automation. All participants performed a visual N-back task throughout. **Results:** Supervised driving automation increased visual distraction and hazard non-responses compared to backup and conventional driving. Auto-hand-on-wheel improved response generation compared to auto-hands-off-wheel. Across entire driving trials, the backup improved lateral performance compared to conventional driving. Without negatively impacting safety, the eyes-plus-context-backup DMS reduced unnecessary automated control compared to the eyes-only-backup DMS conditions. Eyes-only-backup produced low satisfaction ratings, whereas eyes-plus-context-backup satisfaction was on par with automated driving. There were no appreciable negative consequences attributable to the invisible-backup driving automation. **Conclusions:** We have demonstrated preliminary feasibility of DMS designs that incorporate driving context information for distraction assessment and suppress their status indication. **Application:** An appropriately designed DMS can enable benefits for automated driving as a backup.

**Dustin J. Souders, Neil Charness, Nelson A. Roque, Hellen Pham. *Aging: Older Adults' Driving Behavior Using Longitudinal and Lateral Warning Systems*. pp. 229–248.**

**Objective:** This study assessed older drivers' driving behavior when using longitudinal and lateral vehicle warning systems together. **Background:** Advanced driver assistance systems (ADAS) can benefit drivers of all ages. Previous research with younger to middle-aged samples suggests that safety benefits are not necessarily additive with additional ADAS. Increases in following distance associated with the use of forward collision warning (FCW) decreased when drivers also used lane departure warning (LDW), likely due to attending to the LDW more than the FCW. **Method:** The current study used a driving simulator to provide 128 older drivers experience with FCW and/or LDW system(s) during a ~25-min drive to gauge their usage's effects on driving performance and subjective workload. **Results:** There were no significant differences found in headway distance between older drivers who used different combinations of FCW and LDW systems, but those who used an FCW system showed significantly longer time-to-collision (TTC) when approaching the critical event than those who did not. Users of LDW systems did not show reductions in standard deviation of lane position. Analyses of subjective workload measures showed no significant differences between conditions. **Conclusion:** Findings suggest that FCW could increase older drivers' TTC over the course of a drive. Contrary to previous findings in younger samples, concurrent use of FCW and LDW systems did not adversely affect older drivers' longitudinal driving performance and subjective workload. **Application:** Potential applications of this research include the assessment of older drivers' use of vehicle warning systems and their effects on subjective workload.

**Wayne Biever, Linda Angell, Sean Seaman. *Automated Driving System Collisions: Early Lessons*. pp. 249–259.**

**Objective:** This research evaluated Automated Driving Systems (ADSs) involved collisions to identify factors relevant to future ADS research and development. **Background:** Rapidly developing ADSs promise improved safety, among other benefits. Properly applied collision research can inform ADS development, to minimize future collisions. Errors and failures that result in collisions come from sources including the system, ADS operators, and external factors including other drivers. Partially automated systems incorporate new equipment and procedures creating new sources of human error. Fully autonomous systems represent a new class of drivers that interact in unique ways. **Method:** ADS collision reports from the California Department of Motor Vehicles and the National Transportation Safety Board were collected. An expert in human factors and collision investigation analyzed and categorized the crashes while extracting common factors. **Results:** ADS vehicles were never at fault but were often affected from the rear during braking, turning, and gap acceptance maneuvers. Side impacts to ADS vehicles were related to passing vehicles and lane keeping behaviors. Unique incidents also provided additional insights. ADS collision rates cannot yet be determined with confidence. **Conclusion:** Conflicts that lead to collision-involvement with ADSs may be caused by differences between ADS and human driving behavior. Conservative ADS behavior may violate the expectations of other nearby human road users. **Application:** The findings from this work help inform the future development of ADS, as well as potentially the testing of ADS and the formation of policy to guide their future deployment.

**John D. Lee, Kristin Kolodge. *Exploring Trust in Self-Driving Vehicles Through Text Analysis*. pp. 260–277.**

**Objective:** This study examined attitudes toward self-driving vehicles and the factors motivating those attitudes. **Background:** Self-driving vehicles represent potentially

transformative technology, but achieving this potential depends on consumers' attitudes. Ratings from surveys estimate these attitudes, and open-ended comments provide an opportunity to understand their basis. **Method:** A nationally representative sample of 7,947 drivers in 2016 and 8,517 drivers in 2017 completed the J.D. Power U.S. Tech Choice StudySM, which included a rating for level of trust with self-driving vehicles and associated open-ended comments. These open-ended comments are qualitative data that can be analyzed quantitatively using structural topic modeling. Structural topic modeling identifies common themes, extracts prototypical comments for each theme, and assesses how the survey year and rating affect the prevalence of these themes. **Results:** Structural topic modeling identified 13 topics, such as "Tested for a long time," which was strongly associated with positive ratings, and "Hacking & glitches," which was strongly associated with negative ratings. The topics of "Self-driving accidents" and "Trust when mature" were more prominent in 2017 compared with 2016. **Conclusion:** Structural topic modeling reveals reasons underlying consumer attitudes toward vehicle automation. These reasons align with elements typically associated with trust in automation, as well as elements that mediate perceived risk, such as the desire for control as well as societal, relational, and experiential bases of trust. **Application:** The analysis informs the debate concerning how safe is safe enough for automated vehicles and provides initial indicators of what makes such vehicles feel safe and trusted.

### Patrice D. Tremoulet, Thomas Seacrist, Chelsea Ward McIntosh, Helen Loeb, Anna DiPietro, Sophia Tushak. *Transporting Children in Autonomous Vehicles: An Exploratory Study*. pp. 278–287.

**Objective:** Identify factors that impact parents' decisions about allowing an unaccompanied child to ride in an autonomous vehicle (AV). **Background:** AVs are being tested in several U.S. cities and on highways in multiple states. Meanwhile, suburban parents are using ridesharing services to shuttle children from school to extracurricular activities. Parents may soon be able to hire AVs to transport children. **Method:** Nineteen parents of 8- to 16-year-old children, and some of their children, rode in a driving simulator in autonomous mode, then were interviewed. Parents also participated in focus groups. Topics included minimum age for solo child passengers, types of trips unaccompanied children might take, and vehicle features needed to support child passengers. **Results:** Parents would require two-way audio communication and prefer video feeds of vehicle interiors, seatbelt checks, automatic locking, secure passenger identification, and remote access to vehicle information. Parents cited convenience as the greatest benefit and fear that AVs could not protect passengers during unplanned trip interruptions as their greatest concern. **Conclusion:** Manufacturers have an opportunity to design family-friendly AVs from the outset, rather than retrofit them to be safe for child passengers. More research, especially usability studies where families interact with technology prototypes, is needed to understand how AV design impacts child passengers. **Application:** Potential applications of this research include not only designing vehicles that can be used to safely transport children, seniors who no longer drive, and individuals with disabilities but also developing regulations, policies, and societal infrastructure to support safe child transport via AVs.

### Sanaz Motamedi, Pei Wang, Tingting Zhang, Ching-Yao Chan. *Acceptance of Full Driving Automation: Personally Owned and Shared-Use Concepts*. pp. 288–309.

**Objective:**This study aims to develop user acceptance models for two concepts of full driving automation: personally owned and shared use. **Background:** Many manufacturers have been investing considerably in and actively developing full driving automation. However, factors influencing user acceptance of full driving automation are not yet fully understood. **Method:** This study consisted of two parts: focus group discussions and online surveys. A total of 30 potential users participated in focus groups to discuss their perception of full driving automation acceptance. Based on the findings

from focus group discussions, theoretical foundations, and empirical evidence, we hypothesized the acceptance models for both personally owned and shared-use concepts. We tested the models with 310 and 250 participants, respectively, online. **Results:** The results of focus groups indicated that users' concerns are centered around safety, usefulness, compatibility, trust, and ease of use. The survey results revealed the important roles of perceived usefulness and perceived safety in both models, whereas the direct impact of perceived ease of use was found to be insignificant. The indirect impact of perceived ease of use was less significant in the personally owned than in the shared-use model, whereas usefulness, trust, and compatibility played more important roles in the personally owned when compared with the shared-use model. **Conclusion:** The findings uncovered a chain of constructs that affect behavioral intention to use for both full driving automation concepts. **Application:** The framework and outcome of this study provide valuable guidelines that allow better understanding for government agencies, manufacturers, and automation designers regarding users' acceptance of full driving automation.

**P. A. Hancock, Tara Kajaks, Jeff K. Caird, Mark H. Chignell, Sachi Mizobuchi, Peter C. Burns, Jing Feng, Geoff R. Fernie, Martin Lavallière, Ian Y. Noy, Donald A. Redelmeier, Brenda H. Vrkljan. *Challenges to Human Drivers in Increasingly Automated Vehicles*. pp. 310–328**

**Objective:** We examine the relationships between contemporary progress in on-road vehicle automation and its coherence with an envisioned "autopia" (automobile utopia) whereby the vehicle operation task is removed from all direct human control. **Background:** The progressive automation of on-road vehicles toward a completely driverless state is determined by the integration of technological advances into the private automobile market; improvements in transportation infrastructure and systems efficiencies; and the vision of future driving as a crash-free enterprise. While there are many challenges to address with respect to automated vehicles concerning the remaining driver role, a considerable amount of technology is already present in vehicles and is advancing rapidly. **Methods:** A multidisciplinary team of experts met to discuss the most critical challenges in the changing role of the driver, and associated safety issues, during the transitional phase of vehicle automation where human drivers continue to have an important but truncated role in monitoring and supervising vehicle operations. **Results:** The group endorsed that vehicle automation is an important application of information technology, not only because of its impact on transportation efficiency, but also because road transport is a life critical system in which failures result in deaths and injuries. Five critical challenges were identified: driver independence and mobility, driver acceptance and trust, failure management, third-party testing, and political support. **Conclusion:** Vehicle automation is not technical innovation alone, but is a social as much as a technological revolution consisting of both attendant costs and concomitant benefits.