Proceedings of the Human Factors and Ergonomics Society Annual Meeting
2023, Vol. 67(1) 1285–1288

DOI: 10.1177/21695067231192644
journals.sagepub.com/home/pro
Sage

L3 Vehicles are becoming a Reality: Important Human Factors Consideration for the Viability of Conditional Automation

Denny Yu[1], Mansoor Nasir[2], Brandon J. Pitts[1], John Shutko[3], Shan Bao[4], and Chris Monk[5]

Abstract

As of early 2023, only a limited number of Society of Automotive Engineers (SAE) Level 3 (L3) automated driving systems are available on the market, and they are primarily offered by luxury vehicle brands. SAE L3 automated driving systems are classified as conditional automation (CA), meaning that the vehicle can undertake some well-defined driving tasks under specific conditions, but the driver must be ready to assume control of the vehicle when prompted by the system. It is anticipated that an increasing number of L3 CA systems will be introduced on public roads in the next few years. However, L3 systems pose unique Human Factors (HF) challenges that require thoughtful consideration to ensure that production systems are feasible without compromising driver or road safety. This panel discussion brings together HF researchers and practitioners with expertise in human behavior and usability design for automotive applications to discuss and delineate key issues specifically related to L3 systems, as well as potential approaches to tackle these issues.

Keywords

L3, Use Cases, Conditional Automation, Fallback Ready state

Introduction

Level 3 (L3) systems represent a conditional automation (CA) feature where the vehicle can perform most aspects of the driving task under well-defined circumstances. However, the driver is still a critical necessity, but is not required to monitor the driving environment when the system is engaged. While the vehicle is operating in L3 mode, the driver can be in a hands-off and eyes-off the road state and engage in non-driving-related secondary activities. But, at any time, drivers are still expected to be available to get into a fallback-ready state and take control of the vehicle with advance notice. This expectation of drivers raises many significant Human Factors (HF) challenges and prompts the need to gain a firm understanding of, and design for, the many factors involved in the transition-of-control process. Therefore, this panel discussion aims to bring together HF researchers and practitioners to highlight key issues that are critical if the promise of L3 vehicles is to be realized. Topics to be discussed include: 1) the effect of engagement in various types of non-driving-related tasks, 2) the need to understand how drivers of different ages interact with L3 automation, 3) details on how transitions between different levels of vehicle automation should be designed and communicated to drivers, 4) measurements of driver trust in L3 automated vehicles, and 5) in-vehicle driver monitoring systems for L3 systems. The goal of this panel is to stir up conversations within the surface transportation research community about important HF design considerations to prioritize safety and acceptance of L3 vehicles.

Panel Abstracts

Classifying Secondary Activities and Determining what May or May not be Allowed in L3

Mansoor Nasir, PhD
Human Factors Research Engineer
Ford Motor Company
Dearborn, MI

[1]Purdue University, West Lafayette, IN, USA
[2]Ford Motor Company, Dearborn, MI, USA
[3]Westat, Rockville, MD, USA
[4]University of Michigan, Dearborn, MI, USA
[5]Exponent, Washington, DC, USA

Corresponding Author:
Mansoor Nasir, Ford Motor Company, 2101 Village Drive, Dearborn, MI 48124, USA.
Email: mnasir5@ford.com

A major appeal of L3 is to enable the driver to disengage from primary driving tasks and engage in secondary or non-driving related tasks (NDRT). Several studies have surveyed people to find out about the types of activities that drivers would undertake in L3. Interestingly, many of the common activities, such as talking on the phone or reading and writing text messages, are already performed by many drivers today (Pfleging et al., 2016). We anticipate that as drivers become more familiar with L3, the NDRTs that they are willing to engage in, will also become increasingly more difficult and consuming. Regardless, certain NDRTs (such as sleeping, leaving driver seat) will be disallowed since, even with advance notice, since it is highly likely that the drivers will be unable to assume fallback-ready position within a reasonable amount of time. Notably, however, our recent user studies have shown that some other types of NDRTs may also have to be restricted for the same reason. Computational neural network models can be trained to recognize, 'disallowed' NDRTs based on criteria such as the effect on takeover times, type (physical vs. cognitive), or driver role (active vs. passive).

Until now, HF experts have primarily reported on the effects of NDRTs on takeover times in unscheduled *emergency* situations (Borojeni, et al., 2018). However, driver behavior with respect to performing and shedding of tasks and takeovers will be different if there is lesser urgency as in the case of unscheduled *non-emergency* takeovers.

The drive to be the first to bring L3 systems to market, combined with the limitations of the range of current ADAS sensors, and a lack of a clear understanding of key HF issues, has forced original equipment manufacturers (OEMs) to only allow L3 activation at low speeds and thus, prevent usage on US highways. The inability to accurately determine a driver's readiness when a takeover request is generated has also restricted the allowed NDRTs to just a few passive ones (such as watching a video). Even these tasks must be done on the in-vehicle infotainment screen (Mercedes-Benz's Drive Pilot L3 Is Super Smooth (but Limited) Hands-Free Driving, 2022).

In light of all these issues, this discussion will focus on 1) the monitoring and classification of NDRTs, 2) the effects of modifications to cabin space while in L3, and 3) designing an effective human-machine interface (HMI) strategy to relay the appropriate level of urgency to the driver at takeover requests. Finding answers to these difficult HF issues will enable the drivers to have more flexibility in how they utilize the time while the vehicle is in L3 mode. Ultimately, this will help OEMs develop more intelligent HMIs and achieve a wider acceptance of L3 vehicles.

The Need for more Data on how Older Drivers Interact with L3 Conditional Automation

Brandon J. Pitts, PhD
School of Industrial Engineering
Purdue University
West Lafayette, IN

One promised benefit of L3 (and higher-level) vehicles is to enable independent travel for people of different ages and ability levels. Particularly, adults aged 65 years and older – who are the fastest-growing age group worldwide (US Department of Health and Human Services, 2018) and who often experience age-related perceptual and physical challenges (Boot et al., 2020) that make independent travel difficult or impossible – are expected to be major beneficiaries of automated vehicles (AVs). But, unfortunately, little attention has been devoted to ensuring that L3 vehicles are designed in ways that support older populations in effectively using this technology.

To date, the majority of older individuals are still not familiar with details of various types of vehicle automation being developed beyond adaptive cruise control (ACC) and lane centering (LKA) features, such as L3 and higher. To further complicate matters, there is a significant lack of empirical research on how this population interacts with L3 vehicles, which critically inhibits our general understanding of the usefulness of these particular vehicles for older drivers. Recently, a literature review discovered that only 14 studies (out of hundreds published) have quantified the AV takeover performance of older adults, and findings are mixed (Gasne et al., 2022). Particularly, some studies report impaired takeover performance in older adults, while others suggest that younger and older age groups have similar responses to takeover requests. To this end, more available data in this area could inform the design of future vehicles to account for driver/occupant diversity as well as the educational and marketing strategies targeted towards older populations.

This discussion will highlight current efforts to collect data on how older drivers (want to) interact with L3 vehicles and will share lessons learned. Topics will include recruitment strategies, types of data, and experiment design and procedures. This discussion will also comment on ways to educate older groups about the different types of AVs. The knowledge generated during this conversation will result in the intentional collection of more data from older drivers, and ultimately contribute to broader discussions on how to more thoughtfully design L3 systems that are compatible for a wide range of users.

Transitions between the Different Levels of Automation

John Shutko
Principal Human Factors Researcher
Westat
Rockville, MD

SAE Level 1 (L1) – Level 3 (L3) vehicles, as well as dual mode Level 4 (L4) vehicles, will all transition from one level to another. How this transition occurs is essential to whether drivers will maintain safe operation of the vehicle after the transition? These transitions will occur from lower levels of automation to higher levels, and similarly transitions will occur going from higher levels to lower levels. One question is whether the transitions should always be one step in either direction or whether a leap over a particular level should be permitted. One of the biggest concerns is mode confusion (e.g., Wilson et al., 2020), i.e., whether the driver understands what level of automation is currently active and their responsibility in assisting with the driving task. Will transitions of a single step be easier for drivers to understand? Should the system, when transitioning to a lower level, automatically transition to manual driving? What will be the driver's expectation? A related topic to the issue of transitions between automation is whether the driver should always be provided with as much support as possible and whether the system must be transparent in the level of support provided. All these questions will be discussed during this panel and potentially a coherent strategy will emerge.

Trust in L3 Automation Systems: Measurements, Impacts and Solutions

Shan Bao, PhD
University of Michigan-Dearborn, Dearborn, MI
University of Michigan Transportation Research Institute
Ann Arbor, MI

The establishment of trust in L3 automated vehicle systems is crucial to their successful implementation and utilization. Research has explored trust definitions and influencing factors from various perspectives. One widely accepted definition of trust in automation, introduced by Lee and See (2004), characterizes it as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability." To ensure that drivers trust these systems, appropriate trust measures must be developed and implemented, and the impact of trust on the interaction between the driver and the L3 system must be understood. Additionally, effective solutions should be developed to ensure drivers' trust remains at appropriate levels, neither over-trusting nor under-trusting the technology.

The level of user trust in L3 automated vehicle systems has a significant impact on the system's uses. When drivers trust these systems, they are more likely to use them as intended, allowing the technology to reach its full potential in terms of safety, efficiency, and convenience. Conversely, low trust in L3 systems can result in driver disengagement or even over-reliance on the system, leading to safety issues (Lyons et al., 2018). Research has shown that a lack of trust in automated vehicle systems can result from various factors, such as system reliability, transparency, and familiarity with the technology (Lee and See, 2004; Hoff, Bashir, & Koeske, 2015). Therefore, it is crucial to develop effective trust-building measures and strategies to ensure that drivers trust these systems and use them appropriately. Trust measurement is a critical topic in the development of automated driving systems. Previous studies have primarily used questionnaires as the primary method for measuring trust in automated vehicle systems (Lee and See, 2004; Kidd et al., 2017; Hoff, Bashir, & Koeske, 2015). Several studies have also proposed objective measures to quantify trust in automation, including body language and gaze behavior (Yu et al., 2019; Walker et al., 2019).

This discussion will highlight current efforts in developing trust measures and their impact on the interaction with L3 systems and discuss potential design solutions. Specifically, various subjective and objective trust measures have been proposed and studied to assess users' trust levels in L3 automated driving systems, including questionnaire surveys, physiological measures, and behavioral measures. However, the impact of these measures on the interaction between the driver and the L3 system needs to be carefully examined, as different measures may have different effects on the users' behavior and performance. Furthermore, the development of effective design solutions for L3 systems must take into account the impact of user trust on system use and strive to promote appropriate trust levels that do not compromise safety or system performance.

Driver Monitoring Systems and the Future of L3 Systems and Regulations

Chris Monk, PhD
Senior Managing Scientist
Exponent
Washington, DC

The first SAE L3 Conditionally Automated vehicle in the U.S. market was recently introduced, and more are expected to enter the market in the next few years. One of the key HF issues with L3 systems is successfully prompting disengaged drivers to resume control of the vehicle. Takeover performance, which involves drivers re-orienting their attention to the road and updating their situation awareness to successfully resume control of the vehicle, has been the focus of considerable research over the past 10 years (see Zhang et al., 2019 and Merlhiot & Bueno, 2022 for recent meta-analyses). Driver monitoring systems (DMS) that continuously monitor driver behavior or driving performance are useful in determining if the driver is in a sufficiently attentive cognitive and physical state to safely take over control from the vehicle automation (Wörle et al., 2019).

Current L2 implementations of takeover requests, including HM) and DMS strategies, may offer guidance for

L3 designs. However, the range of design strategies across vehicle makes and models creates challenges in deciphering which are most effective. The National Highway Traffic Safety Administration (NHTSA) has published HF guidance on SAE L2 and L3 automated driving concepts (Campbell et al., 2018), but the scientific literature is still evolving for L3 systems. The future of L3 systems rely heavily on the HMI and DMS design approaches, so it is important to understand the latest in DMS research and the potential regulatory actions NHTSA may take in the future on L3 systems.

This panel discussion will provide an overview of current state of L3 systems and the DMS, along with the latest indications and actions from NHTSA regarding automated driving systems.

Disclaimer

The views expressed in this paper and associated panel presentation are those of the authors and do not necessarily represent the views of the organizations with which they are affiliated.

References

Ahlstrom, U., Ohneiser, O., & Caddigan, E. (2016). Portable weather applications for general aviation pilots. *Human Factors*, *58*, 864-885.

Boot, W., Charness, N., Czaja, S. J., & Rogers, W. A. (2020). *Designing for older adults: Case studies, methods, and tools*. CRC Press.

Borojeni, S. S., Weber, L., Heuten, W., & Boll, S. (2018). From reading to driving: priming mobile users for take-over situations in highly automated driving. In Proceedings of the 20th international conference on human-computer interaction with mobile devices and services (pp. 1-12). Barcelona, Spain. September.

Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Bacon, L. P., Morgan, J. F., Li, H., Williams, D., & Sanquist, T. (2018). Human factors design guidance for level 2 and level 3 automated driving concepts (Report No. DOT HS 812 555). Washington, DC: National Highway Traffic Safety Administration. August.

Gasne, C., Paire-Ficout, L., Bordel, S., Lafont, S., & Ranchet, M. (2022). Takeover performance of older drivers in automated driving: a review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *87*, 347-364.

Hoff, K. A., Bashir, M., & Koeske, G. F. (2015). Trust in automation: Integrating empirical evidence on factors that influence trust. *Human Factors*, *57*(3), 407-434.

Kidd, D. G., Cicchino, J. B., Reagan, I. J., & Kerfoot, L. B. (2017). Driver trust in five driver assistance technologies following real-world use in four production vehicles. *Traffic injury prevention*, *18*(sup1), S44-S50.

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

Lyons, J. B., Stokes, C. K., & Gannon, M. J. (2018). Building trust in autonomous systems: An interdisciplinary review. *IEEE Transactions on Cognitive and Developmental Systems*, *10*(4), 1005-1018.

Mercedes-Benz's Drive Pilot L3 Is Super Smooth (but Limited) Hands-Free Driving. (2022, August 23). Retrieved March 4, 2023, from https://www.thedrive.com/new-cars/mercedes-level-3-autonomous-l3-adas-drive-pilot-review-driving-autopilot

Merlhiot, G., & Bueno, M. (2022). How drowsiness and distraction can interfere with take-over performance: A systematic and meta-analysis review. *Accident Analysis & Prevention*, *170*, 106536.

Pfleging, B., Rang, M., & Broy, N. (2016). Investigating user needs for non-driving-related activities during automated driving. In Proceedings of the 15th international conference on mobile and ubiquitous multimedia (pp. 91-99). Rovaniemi, Finland. December.

US Department of Health and Human Services (2018). 2017 Profile of Older Americans. The Administration for Community Living. Retrieved from https://acl.gov/sites/default/files/AgingandDisabilityinAmerica/2019ProfileOlderAmericans508.pdf.

Walker, F., Wang, J., Martens, M. H., & Verwey, W. B. (2019). Gaze behaviour and electrodermal activity: Objective measures of drivers' trust in automated vehicles. *Transportation research part F: traffic psychology and behaviour*, *64*, 401-412.

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.

Wörle, J., Metz, B., Thiele, C., & Weller, G. (2019). Detecting sleep in drivers during highly automated driving: the potential of physiological parameters. *IET Intelligent Transport Systems*, *13*(8), 1241–1248.

Yu, B., Bao, S., Zhang, Y., Sullivan, J., & Flannagan, M. (2021). Measurement and prediction of driver trust in automated vehicle technologies: An application of hand position transition probability matrix. *Transportation Research Part C: Emerging Technologies*, *124*, 102957.

Zhang, B., de Winter, J., Varotto, S., Happee, R., & Martens, M. (2019). Determinants of take-over time from automated driving: A meta-analysis of 129 studies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *64*, 285-307.