18 Importance of Training for Automated, Connected, and Intelligent Vehicle Systems

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CONTENTS

KEY POINTS

- Training is a critical component as the vehicle fleet begins its transition through the levels of automation and the driving task fundamentally changes with each technological advancement.
- When designing driver training for ACIV systems, the learner and the system must both be taken into consideration. ~~Users must be sufficiently ready to learn before the learning can begin.~~
- Effective training must be supported by all stakeholders, including car companies, state and federal governments, academics, and traffic safety organizations.
- Intelligent HMI design and comprehensive and informative training should work as part of a coordinated effort to fully realize the safety benefits of ACIV systems.

18.1 INTRODUCTION

The mere idea of automated, connected, and intelligent vehicles (ACIVs) conjures up visions in which our vehicles cater to our every transportation need. A person walks out of their house and immediately steps into a waiting vehicle, which indicates their destination, and the vehicle quietly and effortlessly moves along freeways, suburban roadways, and local streets to deliver the person to work, a grocery store, or any desired destination. In the process, the vehicle exchanges information with other vehicles, the infrastructure, and the cloud, allowing for safe and efficient transportation. In this situation, the vehicle is, in fact, the driver. The person is only a passenger. A more realistic vision of ACIVs is one in which the vehicle and person form a partnership. In this approach, either the person or vehicle can be the "driver" that is essentially in control, but more commonly, both entities work together to sense the environment, control the vehicle, and avoid crashes. Given that humans are still an essential element of this current vision of ACIVs, it is easy to predict that safety will continue to be a significant concern. It was estimated that in 2016, approximately 94% of serious crashes were attributable to human error, including errors related to distraction, impairment, or drowsiness (National Highway Traffic Safety Administration, 2018). These statistics suggest that human-related factors will continue to require attention as the partnership between human and vehicle further develops. Indeed, the development and deployment of ACIV systems, such as advanced driver assistance systems (ADAS; sometimes referred to as driver support features—SAE Levels 0–2, automated driving features—Levels 3–5, and active safety features, e.g., automatic emergency braking [AEB]) that help to control vehicle acceleration, vehicle deceleration, and lane position, offer the potential to improve safety by relieving the human driver of tasks, particularly those which they are prone to performing with errors. It is in this situation of shared vehicle control that safety needs to be addressed.

For the last several decades, there has been an increasing focus on the technological development of ACIVs (Barfield & Dingus, 1997; Fancher et al., 1998; Tellis et al., 2016) in a shared control context to achieve the visions outlined earlier. Efforts in this area include the Automated Highway System projects in the 1990s (Congress, 1994); connected vehicle communications—vehicle to vehicle and vehicle to infrastructure—in the 2000s (Ahmed-Zaid et al., 2014; Bettisworth et al., 2015); and partially and fully automated vehicle technologies more recently (Blanco et al., 2015; Rau & Blanco, 2014; Tellis et al., 2016; Trimble, Bishop, Morgan, & Blanco, 2014). A basic premise within the human factors profession is that human–machine interface (HMI) systems should be intuitive and easy to use, both of which are a byproduct of good HMI design and standardization. In the absence of these factors, there is a critical need to provide training to drivers. However, there has been relatively little work examining the efficacy of training and learner-centered HMI design to positively impact the safety of ACIV systems, which is likely a critical key factor in promoting a *safe* person/vehicle partnership (see Chapter 15 for a more complete discussion of HMI design considerations for ACIV systems which are largely independent of learner-centered concerns).

A generally accepted definition of training, particularly relevant within the context of this work, is that it is a continuous and systematic process that teaches individuals a new skill or behavior to accomplish a specific task (Salas, Wilson, Priest, & Guthrie, 2006). This definition is particularly relevant to the domain of ACIVs because drivers must become proficient in a wide variety of tasks required to operate these technologies. However, the scope of the definition focuses solely on tasks and fails to acknowledge that the use of ACIV systems requires proficiency in tasks that rely on and interact with driving environments (e.g., lane markings that support lane-keeping assist [LKA] systems). Therefore, a more recent training definition may be more applicable to ACIVs. This definition describes training as the "systematic acquisition of knowledge, skills, and attitudes that together lead to improved performance in a specific environment" (Grossman & Salas, 2011). A successful training method will impart the necessary knowledge, skills, and attitudes related to the partnership between ACIVs and humans to promote improvements in safe driving.

This chapter will address the learner-centered design of training for ACIVs. We recognize the potential need for ACIV driver training across a wide range of topics, including sensor operation/capabilities and the limitations of the operational design domain (ODD); however, the state of driver training relative to ACIVs has not been examined extensively, so we have instead focused on training approaches which have received some research attention. This chapter summarizes the general topic of learner-centered training for ACIVs and provides information on specific training-related factors. The first section, Training Overview, will briefly discuss the importance of training, including how a person–vehicle partnership can be enhanced through training, while the second section addresses the critical question of what content should be included in training protocols for ACIV systems. The third section, titled Andragogical Considerations for ACIV Systems Training, will identify both driver and non-driver related key factors that should be considered in the development of training protocols. The fourth section provides a review of both current and future protocols that could be employed to train people on the use of ACIV systems. The chapter concludes with series of recommendations for ACIV systems training and training practices. This chapter will serve as a foundation for driver training stakeholders, technology developers, consumers, and legislatures to address the growing need to include relevant and effective training for ACIV systems as these technologies are developed and deployed.

18.2 TRAINING OVERVIEW

The prevalence of new vehicles equipped with ADAS has steadily increased over the last decade. Readers are directed to SAE J3016 (2018) for descriptions of ADAS technologies relationship to SAE automation Levels 0–5 (also, this Handbook, Chapters 1, 2). Some ADASs assist drivers in the lateral and longitudinal control of the vehicle within certain ODDs, while others provide warnings and information about the surrounding road environment. ADAS assistance in these fundamental tasks can help a driver by performing control functions and providing alerts about the presence of another vehicle or object. Despite the potential benefits associated with their use, many ADAS system capabilities and limitations are misunderstood by drivers (Larsson, 2012; McDonald, Carney, & McGehee, 2018; McDonald et al., 2015, 2016; McDonald, Reyes, Roe, & McGehee, 2017; Rudin-Brown & Parker, 2004).

As we extend the consideration of the state of the art with ADAS to the future with ACIV systems, we can see that many of these technologies share functional similarities among manufacturers; however, there are subtle differences in capabilities that are crucial for the users to understand. For example, a vehicle that has an LKA system will control the vehicle by oscillating between the lane lines on the right and left, through intermittent steering input, while a lane-centering system will attempt to center the vehicle in the lane through continuous steering input. Regardless of the fidelity of the lane-keeping system, or any Level 1 or 2 driver support feature, the driver is responsible for knowing and understanding the system's ODD. However, user's perceptions of the subtasks of the dynamic driving task that they are required to perform versus those that the driving automation system will perform are dependent on their perception and understanding of the system

(SAE, 2016). Moreover, there is little to no uniformity when it comes to naming for these technologies. Survey findings revealed the importance of vehicle technology naming and how the naming of an in-vehicle technology can influence the driver's mental model of system purpose, function, and operator responsibility (Abraham, Seppelt, Mehler, & Reimer, 2017; Casner & Hutchins, 2019).

18.2.1 Mental Models

If we think of product design as a game of Pictionary (Figure 18.1), designers are the ones drawing and users are the ones trying to interpret their creations. Designers want users to understand the conceptual models of their applications. The system image, according to Norman (2013), is the product, and this product is typically the only way that designers are able to communicate with their users. If the system image is not presented to the user in such a way that its purpose and function are adequately transparent and intuitive, then the image becomes abstract and is subsequently open to user interpretation, which leads, inevitably, to misinterpretations (see also, this Handbook, Chapter 3).

System users will look to the visible components, observe system behavior, and then make guesses about how the system works. Thus, users will create their own mental model, which may differ, often significantly, from the designer's intentions due to varying prior knowledge, individual variability, and different beliefs about the purpose and function of the system (Jonassen, 1995). Having an accurate mental model will appropriately guide user behavior and predictions about system behavior. Having an inaccurate mental model may lead to user errors and inaccurate predictions about system activity.

When drivers lack an appropriate understanding of ACIV systems, the consequences can be misused or underused, which undercut the potential benefits of these technologies (Parasuraman & Riley, 1997). This can also lead to gaps in knowledge

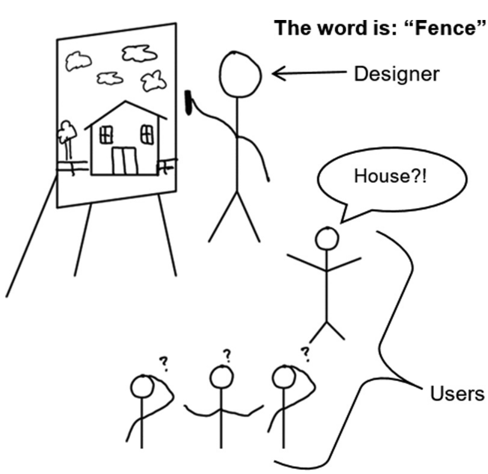

FIGURE 18.1 Example of a mental model misinterpretation.

that consumers will fill on their own, potentially with inaccurate information or beliefs derived from limited exposure or observation.

Mental models can be carefully formed and structured through training (Wickens, Hollands, Banbury, & Parasuraman, 2013). Using training combined with intuitive design practices can decrease variability in mental models among users. Furthermore, with increasing levels of automation and variability of system capabilities, increased levels of training are required (Sarter, Woods, & Billings, 1997). Additional training will improve the user's mental models to help ensure that vehicle operators are fully aware of their role and breadth of responsibilities while operating their vehicle on public roads.

18.2.2 Consumer Protection

New challenges in litigation are reinforcing the importance of effectively training and educating drivers regarding vehicle operation. To minimize liability, a cornucopia of information regarding the operation of any vehicle that can be found in the manufacturer-provided operator's manual. However, there are a multitude of problems with this approach: many drivers don't read their owner's manual (Leonard, 2001), manuals are quite extensive (Brockman, 1992; Mehlenbacher, Wogalter, & Laughery, 2002), and studies suggest that when people believe that they are familiar with a product, they are less likely to read the documentation and warnings (Godfrey, Allender, Laughery, & Smith, 1983; Wogalter, Brelsford, Desaulniers, & Laughery, 1991; Wright, Creighton, & Threlfall, 1982). Furthermore, driver's knowledge of vehicle systems after reading the owner's manual has rarely translated to a demonstrated improvement in driving performance (Manser et al., 2019).

As the capabilities of driver support features progress to the higher levels of automation (SAE Levels 3–5), manufacturers may avoid potential legal claims by requiring consumers to undergo extensive training to ensure that they understand the various hazards and limitations of such systems (Glancy, Peterson, & Graham, 2015). At present, in the purview of SAE Levels 0–2, it is the driver's responsibility to use the system appropriately and understand system limitations. Some vehicle manufacturers are implementing systems to monitor driver behavior when automated features are activated, so the technology can be deactivated if the driver is not being attentive to system warnings or requests for intervention (Anderson et al., 2014; this Handbook, Chapter 14).

However, a recent National Transportation Safety Board report suggested that not all methods of driver monitoring are an effective means to ensure engagement in the driving task (National Transportation Safety Board, 2017a). Regardless of their effectiveness, recent research indicates that liability and control are among the top factors that drivers are most concerned about with regard to the use of vehicle automation (Howard & Dai, 2014; Kyriakidis, Happee, & de Winter, 2015; Schoettle & Sivak, 2014).

18.2.3 Goals of Training for ACIV Systems

There are at least three overarching goals which training programs for ACIV Systems should aim to address. First, they should lead to improvements in safety.

Second, they should create appropriate levels of trust, and third, they should increase user acceptance of the benefits of the technology. These three goals are discussed in more detail below.

18.2.3.1 Increased Improvement in Safety

Training is one of the standard procedures used to aid people in acquiring safe behavior practices and remains the fundamental method for effecting self-protective behaviors (Cohen, Smith, & Anger, 1979). Current and future driver support features have the potential to reduce the number of crashes, injuries, and fatalities on public roadways, but only if they are accepted, used appropriately, and deployed responsibly. Benson, Tefft, Svancara, and Horrey (2018) estimated that technologies that include AEB, blind spot monitoring (BSM), forward collision warning (FCW), lane departure warning (LDW), and LKA, if installed on all vehicles, would have potentially mitigated roughly 40% of all crashes involving passenger vehicles, 37% of all injuries, and 29% of fatalities that occurred in those crashes in 2016.

The success of training depends on the use of positive approaches that stress learning safe behaviors rather than avoiding unsafe behaviors. Ensuring suitable conditions for practice that guarantee transferability of learned behaviors to real situations is critical (Cohen et al., 1979). Effective evaluation coupled with frequent feedback is also critical for reaching specified goals to mark progress.

18.2.3.2 Appropriate Levels of Trust

Mediating trust requires that ACIV system users have an accurate and realistic understanding of system capabilities, limitations, and responsibilities (see also, this Handbook, Chapter 4). Trust is defined by Lee and See (2004) as “the attitude that an agent will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability.” The formation of trust involves thinking and feeling, but emotions are the primary determinant of trusting behavior (Lee & See, 2004). The construct of trust is complicated and multi-faceted. However, the outcome of inappropriate trust in automated systems is fairly simple—when drivers do not possess appropriate trust in vehicle automation and understand the limitations and ODD of the ACIV systems, maximum safety benefits will not be realized due to users not using the systems (disuse) or using them inappropriately (misuse).

Research supporting this contention has shown that trust is a significant factor in the success of ADAS, as demonstrated by live road-, simulator-, and questionnaire-based studies (Banks, Eriksson, O’Donoghue, & Stanton, 2017; Eichelberger & McCartt, 2016; Rudin-Brown & Parker, 2004). Automation bias (or over trust) refers to the omission and commission of errors as a result of using automated cues as a heuristic replacement for vigilant information seeking and processing (Mosier, Skitka, Burdick, & Heers, 1996; Skitka, Mosier, & Burdick, 1999; 2000). In a study by Mosier, Skitka, Heers and Burdick (1998), automation bias played a significant factor in aircraft pilot interaction with automation aids. Pilots were not utilizing all available information when performing tasks and were making decisions with automated systems due to inappropriate trust in those systems. An example of misuse of systems was also found within the automotive domain by Victor et al. (2018), who found that, while system-based reminders influenced driver’s eyes on-road and hands-on wheel behavior, prompts or explicit instructions regarding system limitations and supervision responsibilities were not able to prevent 28% of participants from colliding with an obstacle in the roadway despite seeing the hazard. This finding may suggest that participants were overly reliant on the vehicle system due to incorrect expectations of system capabilities.

18.2.3.3 User Acceptance

A critical concept relative to user acceptance is that user's attitudes and behavior have a bidirectional, multi-level relationship. Stated plainly, attitudes influence use and use influences attitudes (see also, this Handbook, Chapter 5). As drivers use ACIV systems, driving performance will likely improve as long as the systems are well-designed and the driver has a reasonable understanding of the system's ODD (see also, this Handbook, Chapter 12 for a discussion of behavioral adaptation to technologies).

Davis (1989, 1993) identified the lack of user acceptance as an impediment to the success of new information systems. The Technology Acceptance Model developed by Davis specifies the causal relationship between system design features, perceived usefulness, perceived ease of use, attitude toward usage, and actual usage behavior. Ghazizadeh, Lee, and Boyle (2012) extended that model to create the Automation Acceptance Model, which includes the explicit additions of trust and compatibility as well as a feedback loop that continues to inform user trust, perceived ease of use, compatibility, perceived usefulness, and behavioral intention to use. The Automation Acceptance Model captures the importance of experience and trial-and-error learning. Understanding the benefits of ACIV systems shapes the social norms regarding the use of these systems on the road. These norms may influence individual driver's perceptions of ACIVs and, ultimately, their use decisions (Ghazizadeh et al., 2012).

18.3 TRAINING CONTENT FOR ACIV SYSTEMS

Given that training is necessary, it is important to determine what is to be learned from that training. In the context of driver training for ACIVs, the question is: *what are the different skills, rules, and knowledge that a driver should be trained on to be able to safely operate a vehicle with automated features?* In light of the above, safely operating a motor vehicle is broadly to be interpreted as having appropriate trust in and acceptance of the technology as well as knowing the different skills, rules, and knowledge that are needed to successfully complete the driving task.

While drivers' familiarity with system activation, system deactivation, and the ability to perform both are essential components to system use, they are not the only criteria required for safe, efficient, and appropriate operation of ACIVs. Beyond these meager requirements, there exist higher-level knowledge-based skills that need to be learned, understood, and applied by operators of ADAS-equipped vehicles. The Federal Automated Vehicle Policy (U.S. DOT, 2016) recommends that training documents not only address the following topics for highly automated vehicles (e.g., SAE Levels 3–5) but also contain relevant elements across all levels of vehicle automation that could be applied to the ACIV framework. The recommended areas are as follows: highly automated vehicle system's intent, ODD, system capabilities and limitations, engagement/disengagement methods, HMI, emergency fallback scenarios, operational boundary responsibilities, and potential mechanisms that could change function behavior in service. Additionally, the policy recommends a hands-on experience program for consumers to ensure that they are fully aware of their vehicle's functions and capabilities. A report by the Pennsylvania Department of Transportation identified familiarity with assistance features and with required interactions between drivers and vehicles as areas that should be included in both knowledge and skill testing criteria (Hendrickson, Biehler, & Mashayekh, 2014). As of August 2016, seven states and the District of Columbia have enacted autonomous vehicle legislation, and one state has an executive order pertaining to the testing of autonomous vehicles on public roads (Council of State Governments, 2016). Training should educate consumers on the limitations and capabilities of HAVs, how to engage and disengage the system functions, risks of misuse, and how to deal with emergency situations related to the ACIV (American Association of Motor Vehicle Administrators, 2018). Furthermore, driver training should make every effort to ensure consumers will use the products within the established parameters.

18.3.1 System Purpose and Associated Risks of Use

When a member of the motoring public elects to use an ACIV system, one of the required fundamental levels of knowledge includes the purpose of the system as well as any associated risks and benefits. Training drivers on this information could eliminate many negative consequences that result from the misuse of ACIV systems by appropriately modulating the user's expectations of the system's capabilities. Several factors influence drivers' decisions to use an ACIV system. As discussed above, user's attitude toward automated systems, the level of trust in the systems, mental workload, self-confidence, and the level of perceived risk are among the most important factors (Parasuraman & Riley, 1997). Drivers should be informed of the relationship between their motivations for utilizing ACIV systems and potential safety-critical outcomes if not used appropriately. For example, if the motivating factor is to mitigate fatigue, training should inform drivers that fatigue could lead to over-reliance and complacency, which could result in an inability to take action in emergency situations, such as system malfunction (Parasuraman & Riley, 1997).

18.3.2 Operational Design Domain

Drivers must understand the capabilities and limitations of the ACIV system that they are using, a skill which, to date, many users have demonstrated deficiencies in through both knowledge-based tests and their own self-reported behavior while using these systems. Evidence of this situation was provided by McDonald et al. (2018), who found that only 21% of owners of vehicles with BSM systems correctly identified their inability to detect vehicles passing at very high speeds as a system limitation; the remainder expressed additional misconceptions about the BSM system's function and/or reported that they were unsure of the system's limitations. The authors also found that 33% of respondents with AEB systems did not realize that the system relied on cameras or sensors that could be blocked by dirt, ice, or snow.

Given that these are safety-critical limitations, users of these driver support and active safety features should have an understanding of when these systems can fail to operate and conditions under which it would be prudent to temporarily suspend system use. Better understanding could be achieved through the use of proper training.

The AAA Foundation for Traffic Safety in collaboration with the Massachusetts Institute of Technology AgeLab have developed a data-driven system to review and rate the effectiveness of new in-vehicle technologies that aim to improve safety (Mehler et al., 2014). This review focuses on legacy systems, such as Electronic Stability Control, and advanced features, such as Adaptive Cruise Control (ACC), Adaptive Headlights, Back-Up Cameras, FCW, Forward Collision Mitigation, and LDW. In addition to developing a rating system that considers the potential and demonstrated benefits offered by these technologies, the research team stated that while some systems require little or no familiarity with the technology to derive benefit, others have a steep learning curve (Mehler et al., 2014).

18.3.3 Monitoring the Road and the System

When a person's central concern is an individual task or decision, they are not likely to be interested in reading a comprehensive body of work on related matter. Instead, they will likely want the knowledge and skills that will be useful in dealing with the particular task or decision at hand (Tough, 1971). For this reason, it is important to highlight the responsibilities of the human operator and any system limitations. Twenty-nine percent of respondents in a study by McDonald et al. (2018) reported that they at least occasionally felt comfortable engaging in other activities while using ACC. Many respondents also reported not visually checking their blind spot when changing lanes in vehicles equipped with BSM (30%), and 25% of vehicle owners with rear cross-traffic alert systems reported not looking over their shoulder when backing up at least some of the time. These self-reported user behaviors further motivate the need for driver training just because such systems are fallible, and the most benefit is derived when the human operator is looking for potential threats as well as automation. In short, the training must be designed in a way that considers the driver as an active participant in the automation features, not just as a passive user.

18.4 ANDRAGOGICAL CONSIDERATIONS FOR ACIV SYSTEMS TRAINING

One of the standard pedagogical models of education assigns full responsibility to the instructor for making decisions about what will be learned, how it will be learned, when it will be learned, and whether it has been learned. The learner in this pedagogical model is a passive participant in their own education. Pedagogical methods are often improperly implemented for adult learners, whose intellectual aspirations are least likely to be aroused by the uncompromising requirements of authoritative, conventional institutions of learning (Lindeman, 1926). As individuals mature, their need and ability to self-direct, leverage experience, identify readiness to learn, and organize their learning around life problems increase (Knowles, Holton III, &

Swanson, 2005). Andragogical models bring into focus additional learner characteristics that should be considered in the development of training for ACIV systems (Knowles, 1979; Knowles et al., 2005). For vehicle automation, the training structure should focus on both near- and long-term improvements in driving performance as well as improved understanding of driver responsibilities and sustained understanding of vehicle system capabilities and limitations.

18.4.1 Driver-Related Factors

The characteristics of the target population may impact the design and delivery of instruction (Rothwell, Benscoter, King, & King, 2016). The training methods and content covered may need to be adjusted over time to allow users to gain the full benefit of their current driver support features based on individual differences. For example, drivers who are technology-averse may need a different level and type of training than their peers. Conversely, users who are technologically inclined may inadvertently place too much trust in technology. Additional factors that need to be considered in training design are discussed below.

18.4.1.1 Motivation

The motivational aspects of training design cover many theoretical concepts, including attribution theory, equity theory, locus of control, expectancy theory, need of achievement, and goal setting (Patrick, 1992). Trainee motivation can be influenced by individual characteristics as well as the characteristics of the training itself (Coultas, Grossman, & Salas, 2012). The temporal divisions of motivation were described by Quiñones (2003) as having an effect on (1) whether an individual decides to attend training in the first place, (2) the amount of effort exerted during the training session, and (3) the application of skills after training. Zhang, Hajiseyedjavadi, Wang, Samuel, and Qu (2018) found training transfer for hazard anticipation, and attention maintenance was observed only in drivers who were considered to be careful (e.g., low sensation seeking and aggressiveness). Due to its multi-faceted nature and the temporal inconsistencies within and between trainees, the consideration of factors affecting motivation requires significant attention when designing training programs.

18.4.1.2 Readiness to Learn

Learning can only happen when the learner is *ready* to learn. Readiness can be induced through exposure to models of superior performance, counseling, exercises, and other techniques to help trainees see value in the educational undertaking (Knowles et al., 2005). If a learner is deficient in a prerequisite skillset, readiness to learn a more advanced skillset may be futile. Gagné (1965) emphasized the importance of prerequisites in learning complex skills, as they are essentially subskills of the newer, more complex task. Consequently, trainees lacking necessary prerequisite skills will likely have to partake in remedial training prior to the onset of more advanced training in order to first achieve mastery (or at least satisfactory performance) of the remedial skill.

18.4.1.3 Affect—Anxiety Toward Technology

Affect, in this context, refers to the evaluation of an object or system as good or bad, evoked immediately and subconsciously within the individual (Finucane, Alhakami, Slovic, & Johnson, 2000; Slovic, Finucane, Peters, & Macgregor, 2006). Affect works both to focus a person's attention on what they perceive to be relevant details and to manage priorities of information processing. It is also believed to help people form complete mental models, as the cognitive complexity of decisions exceeds a human's ability to rationally evaluate a situation (Lee, 2006; Lee & See, 2004).

People's feelings toward a technology can predict their judgment of risk and benefit, regardless of the actual risk and benefit associated with the technology (Alhakami & Slovic, 1994). The affect heuristic indicates that there is a perceived inverse relationship between risk and benefit. Therefore, if a person has negative feelings about a technology, they are likely to view the technology as risky (Hughes, Rice, Trafimow, & Clayton, 2009). There are some decision-based studies suggesting that affect has an impact on subsequent information processing and judgments regarding that system or object (Cialdini, 2007). Merritt (2011; Merritt, Heimbaugh, LaChapell, & Lee, 2013) has studied the affective processes in human–automation interactions and found that user's implicit attitudes have important implications for trust in automation. Merritt found that user's decision-making processes may be less rational and more emotional than previously acknowledged, noting that implicit attitudes and positive affect may be used as a lever to effectively calibrate trust. This relationship between learner affective processes and technology may have an impact both on the prospective user's readiness to learn and on the transferability of training effects.

Biases induced by the affect heuristic may serve as a barrier to positive training transfer. A study by Smith-Jentsch, Jentsch, Payne, and Salas (1996) found that conceptually relevant negative events accounted for individual differences in learning and retention. Furthermore, the effect of [computer] anxiety in a meta-analysis by Colquitt, Lepine, and Noe (2000) demonstrated significant relationships with every training outcome examined (motivation to learn, post-training self-efficacy, declarative knowledge, skill acquisition, and reactions).

18.4.2 Design of the Training

18.4.2.1 Salient Relevance and Utility of Training Content

When training sessions are voluntary, adult learners may leave when the teaching or content fails to meet their interest or they no longer perceive value (Lindeman, 1926). The value or perceived utility in the knowledge or skill being taught needs to be salient to the learner, or their motivation to continue investing their time will plummet. To this end, simply stating learning objectives for adult learners will not be enough; rather, providing the learning objective with justification may provide enough transparency to sufficiently motivate further engagement. The link between the expected usefulness of training material and trainee motivation has been demonstrated in training and adult education literature time and time again (Burke & Hutchins, 2007; Noe, 1986; Tannenbaum, Mathieu, Salas, & Cannon-Bowers, 1991). Trainees who perceive that the new knowledge and skills are relevant and will improve performance will demonstrate positive training transfer (Alliger, Tannenbaum, Bennett Jr., Traver, & Shotland, 1997; Baumgartel, Reynolds, & Pathan, 1984; Rogers, 1951).

Another element of training content that has been shown to influence performance was found by Ivancic and Hesketh (2000), who investigated the effect of guided error training on driving skill and confidence on a driving simulator. In error training, learners are shown examples of errors that they themselves make in a test of their knowledge and skills and solutions for overcoming these errors. One group of participants was given feedback and training on their errors while driving (error training); another group was shown examples of errors in general, not their own errors, while driving (guided error training). The error training led to better performance in near and far transfer of training evaluations of performance. Moreover, error training reduced driver's self-confidence in their driving skill at the end of the training when compared with the group that received errorless training. This suggests, importantly, that training can improve performance without increasing confidence. However, error training may not be appropriate for all prospective users, especially those who demonstrate low confidence with using vehicle automation.

18.4.2.2 Framing of the Opportunity

In general, adults are motivated to learn as they experience needs and discover interests that learning new material will satisfy. Consequently, their involvement in this process should be considered voluntary—again, it is not possible to make someone learn when they do not want to. The way in which training programs are framed can enhance or diminish the effectiveness of training interventions (Quiñones, 1995). Adult learners need to feel a certain degree of autonomy in their educational endeavors. When presented with an activity labeled "education," "training," or anything synonymous, adult learners have a tendency to revert back to more dependent social roles, which is at odds with their innate desire to exercise their independence (Knowles et al., 2005).

Webster and Martocchio (1993) found that younger employees (under 40 years) who received training labeled as "play" demonstrated higher motivation to learn and performed better in an objective test of software knowledge than older employees (40 years or older). Interestingly, no differences were found between younger and older employees receiving training labeled as "work."

Games can provide models of good learning practices (Sandford & Williamson, 2005). Games are different from most other forms of learning, since players rarely want or need to read a manual before commencing play but instead they "learn by playing," which could be an enticing strategy for adult learners. The use of games to train drivers on ACIV technologies has not been examined to date but remains a potential alternative.

18.4.2.3 Opportunities to Practice and Apply Skills

Adults learn new knowledge, skills, values, and attitudes most effectively in the context of application to real-life situations (Knowles et al., 2005). This lends credence to the implementation of constructivist methods of instruction. Constructivism has roots in multiple psychological and philosophical domains and has implications for learning outcomes, such as reasoning, critical thinking, understanding and use of knowledge, self-regulation, and mindful reflection (Driscoll, 2000). Early contributors include Piaget (cognitive and developmental), Bruner and Vygotsky (interactional and cultural emphasis), as well as Dewey (1933), Goodman (1984), and Gibson (1977).

The first constructivist condition for learning is to embed learning in complex, realistic, and relevant environments. The rationale behind this condition is that "students cannot be expected to learn to deal with complexity unless they have the opportunity to experience complexity." Allowing learners to experience training through authentic activities will enhance the development of problem-solving capabilities and critical thinking skills. Problem-solving requires domain knowledge as well as structural knowledge (mental models), reasoning capabilities, and metacognitive skills.

Skills in complex tasks, including those with large social components, are usually taught best by a combination of training procedures involving both whole tasks and components or part tasks (Anderson, Reder, & Simon, 1996). Using situations that are relevant to the learner provides an opportunity for learners to engage in reflective thinking (Federal Aviation Administration, 2009; Shor, 1996). Incorporating a restrictive definition of authenticity in training design will result in learning environments that are authentic in a narrow context, thereby reducing the variability of skills and strategies acquired by the learner. Training should teach trainees to be innovative, creative, and adaptable so that they can deal with the demands of domains that are complex and ill-structured (Federation of American Scientists, 2005; Gee, 2003; Prensky, 2001).The inclusion of related cases in training can scaffold the learner's memory by providing representations of experiences that learners have not had (Jonassen, 1999), especially in ill-defined domains and for non-recurrent skills (Merrill, 2002; Schwartz, Lin, Brophy, & Bransford, 1999; van Merriënboer & Kirschner, 2017).

18.5 TRAINING PROTOCOLS

Current training methods for in-vehicle technologies show that while many of the strategies implemented by individual vehicle owners may suit some characteristics of adult learners (e.g., motivated to seek knowledge, task-oriented, need for self-direction), the current paradigm of consumer education does not provide sufficient motivation for the learner to search for a deeper understanding of the material. Several consumer-preferred methods for learning to use in-vehicle technologies were identified by Abraham, Reimer, Seppelt, Fitzgerald, and Coughlin (2017). These methods are discussed in the following sub-sections.

18.5.1 Trial and Error

Learning through trial and error is a process that involves the forming of associations (connections) between the perception of stimuli and responses that manifest themselves behaviorally to those stimuli (Thorndike, 1913). A recent study found that 53% of drivers learned to use in-vehicle technology by means of trial and error at least some of the time (Abraham, Reimer, et al., 2017).

Generally, experience can improve performance, but learning through trial and error can waste time, may lead to a less-than-ideal solution, or may never result in a solution at all. Trial and error can also result in negative effects, such as increased frustration, reduced learner motivation, discontinued use of the system, or mental model recalibration through potentially dangerous experiences. Learning by doing is not a homogenous process. A study by Pereira, Beggiato, and Petzoldt (2015) found that mastering the use of ACC took different lengths of time. Furthermore, Larsson (2012) conducted a survey of 130 ACC users. The results indicated that drivers need to be especially attentive in those situations to which, during conventional driving, they would not be attentive. The system may not be self-explanatory enough for a strictly trial-and-error based approach. Larsson's survey results indicated that as drivers gained experience using the ACC system, they became more aware of the system's limitations. However, other studies have shown that safety-critical misunderstandings of system limitations are resilient and can persist over time (Kyriakidis et al., 2015; Llaneras, 2006). Tversky & Kahneman (1971) argued that users tended to place undue confidence in the stability of observed patterns, thus resulting in misunderstandings that are not corrected when relying solely on trial-and-error learning methods.

18.5.2 Vehicle Owner's Manual

Many vehicle owners learn to use their in-vehicle technologies by reading the owner's manual. In a survey conducted by Abraham, Reimer et al. (2017), 55% of respondents reported learning to use the in-vehicle technologies in their vehicles at least some of the time by reading the owners' manual.

Given the nature of this resource, learner engagement is highly dependent on the learner's perceived need of the information and their willingness to use the manual as a resource. As a completely self-guided method, learners are typically directed by a specific line of inquiry or a particular question they want answered. This observation is substantiated by Leonard (2001), who found that individuals are more likely to read specific portions of the operator's manual as opposed to the manual in its entirety. The majority of participants (62%) in the study by Leonard reported reading "special parts" of the operator's manual. Of the manual topics that were read, many pertained to equipment or maintenance. Approximately 2% of respondents reported not reading any safety information in the manual. Consequently, Leonard concluded that the limited use of the operator's manual is not a result of lack of availability and that while the manual is recognized as a source of information, its use is limited. If drivers are not motivated to read sections of the operator's manual, they will get no benefit from the information provided.

18.5.3 Demonstration

Demonstration, also known as behavior modeling, results in the display of a new pattern of behavior by a learner/trainee who observes a model (experienced user, professional), performing the task to be learned. The trainee is encouraged to rehearse and practice the model's behavior, and feedback is provided as the trainee refines their behavior to closer approximate that of the observed model. This training style is founded in social and developmental psychology centered on the research of Bandura (1977), who argued that by observing model behavior, people can develop a cognitive representation (mental model), which can then be used to guide future behavior. In theory, observational learning is a great strategy for situations in which early errors are viewed as problematic and visual guidance could provide a means to reduce the frequency and severity of errors. This makes behavior modeling an ideal way to learn how to perform simple tasks, such as system activation, which may result in performance deficiencies if learned using trial and error.

One limitation of the demonstration method is that it does nothing to improve knowledge of the system and it appears to result in fairly superficial learning. Findings from McDonald et al. (2017) show that ride-along demonstrations were ultimately no better than self-study of the owner's manual, as there were knowledge gains across all training types, of which none provided a statistically significant difference.

The behavioral model is also assumed to exhibit desirable behaviors and have accurate information. When demonstration takes place in automotive dealerships, sales people are assumed to have been trained on how to use ACIV systems and have accurate knowledge about their use. Unfortunately, this assumption is not always accurate. Abraham, McAnulty, Mehler, and Reimer (2017) conducted a study investigating sales employees from six vehicle dealerships in the Boston, MA area associated with six major vehicle manufacturers. They found that many sales people lacked a strong understanding of ACIV systems. It was also revealed that the training the employees received was meager, consisting mostly of web-based modules with very little (if any) hands-on experience. Furthermore, two of the sixteen employees with whom the researchers interacted gave explicitly wrong safety-critical information regarding the systems.

18.5.4 Web-Based Content

Web-based content can include user-generated content or websites and materials generated by safety advocates, vehicle manufacturers, or other stakeholders in the automotive industry. The increased ubiquity and usability of technology has made it possible for a range of individuals and organizations with an interest in ACIVs to generate their own content for a variety of topics, including system performance, software updates, and maintenance.

Learning through user-generated content involves a large amount of independence, is question driven, and can result in additional extraneous load if the learner becomes too immersed in the material (Wickens et al., 2013). Additionally, less than desirable behavioral models can be found in user-generated content, such as attempts to "fool" or "hack" the ACIV system. Furthermore, information provided on the internet may not be accurate. Content may not be kept up-to-date with software updates and system capabilities, and those seeking knowledge about these systems will need to have a certain level of familiarity with their own vehicles to make the information useful.

18.5.5 Future Training—Embedded Training for ACIV Systems

Embedded training is described as a training program built into systems so that operational equipment can be switched over to a "training mode" during periods when it is not needed for operational use (Sanders & McCormick, 1993). Strategies mentioned in the previous section can be incorporated into this type of training to facilitate skill and knowledge acquisition at an appropriate level and enhance engagement by being appropriately difficult. Several important components of successful training practices that are missing from current knowledge acquisition methods for ACIV systems will be discussed.

The training needs of participants will change from their first exposure to the vehicle systems to their one hundredth exposure (Gagné, 1965). In their initial exposure, participants will need to be familiarized with the system interface, purpose, methods of activation and deactivation, and basic system signals. This could be done using the vehicle interface and multimedia methods so that auditory alerts are consistent, as are the placement, size, shape, and color of icons pertinent to the system. With increased exposure to the system, driver's perceived familiarity with the system will increase.

Godfrey, Allender, Laughery, and Smith (1983) conducted an evaluation of eight generic products and found that the more hazardous consumers perceived a product to be, the more likely they were to look for a warning. They also found that perceived hazardousness varied inversely with product familiarity, meaning the more familiar people thought they were with a product, the less hazardous they perceived it to be. This finding is particularly concerning, since studies have found that with limited exposure to vehicle automation, novice user's self-reported familiarity increased significantly (Manser et al., 2019). Over longer durations, drivers may become more aware of system limitations (Larsson, 2012), but safety-critical misunderstandings of system limitations have also been shown to persist over time (Kyriakidis et al., 2017; Llaneras, 2006).

18.5.5.1 Feedback (Knowledge of Results)

"Practice makes perfect" is a common saying; however, practice is of very little value when the results of an action are unknown or incorrect. Knowledge of results, or extrinsic feedback, is an important tool in the growth and development of learners because it provides an indication of discrepancy between actual and desired behavior (Patrick, 1992). Learning is promoted when learners are guided in their problem-solving by appropriate feedback mechanisms, which include error detection and correction (Gagné, 1965; Merrill, 2002). Feedback comes not only in the form of coaching, but also from the visual, auditory, and proprioceptive information associated with normal (correct) task execution. Consequently, Annett (1961) specified the difference between intrinsic feedback, which pertains to information concerning normal (non-training) task performance, and extrinsic feedback, which refers to additional knowledge supplied during training and not available during typical task performance.

Extrinsic feedback can be provided in real time during task performance or at some point after task completion (post hoc). Real-time and post hoc feedback for novice driver training has been shown to improve teen driving safety as well as reduce the frequency of risky driving behaviors (Klauer et al., 2017; Peek-Asa, Hamann, Reyes, & McGehee, 2016). Personalized feedback coupled with active practice was also shown to be superior to passive learning methods with no feedback when assessing older driver's scanning behaviors at intersections (Romoser, Pollatsek, Fisher, & Williams, 2013). Using real-time feedback for adults to assist them in learning/understanding ACIV systems could be a useful technique; however, additional research is needed on this topic.

If it can be determined that driver performance deficiencies are attributable to a lack of skill or knowledge, then an immediate training intervention after the first occurrence of the undesired behavior in situ may help to correct the behavior. However, if undesirable safety-related performance deficiencies cannot be attributed to a lack of skill or knowledge, then the solution does not lie in training, but in the application of salient differential consequences (Boldovici, 1992; Mager & Pipe, 1970). One example is the Tesla Autosteer system deactivation for non-compliance with hands-on wheel warnings (Telsa Inc., 2018).

18.5.5.2 When Does It End?

Giving learners complete control over when they may terminate learning invites overconfidence that a skill has been fully mastered. If the learner's metric for self-evaluation is heavily dominated by error-free performance, a highly salient measure, they may terminate their training too soon. Personal, unguided reflection on performance and understanding is a task people rarely perform well (Kruger & Dunning, 1999; Regehr & Eva, 2006). Fitts (1962) advocated that training should be continued beyond a minimum performance criterion and that skills acquired during training should be sufficiently versatile to withstand the change from a structured training situation to the less predictable application in the real world. Consequently, the criterion for trainee performance must be carefully defined and termination of training by trainee selection is not recommended.

According to Spitzer (1984), there is an unwritten law that training programs last a certain number of days, with lectures of a certain duration and breaks at specified times. This notion contributes to the erroneous idea that learning is a time-bound event that only occurs in certain defined time periods. Skills acquired during periods of training need to be sufficiently versatile to withstand the transition from the organized training context to the less predictable real-world domain. With merely "acceptable" performance, the fragile skill acquisition process will be easily disrupted unless further training is provided.

18.6 RECOMMENDATIONS

~~The importance of t~~raining drivers is critical to the successful deployment of driver support features from low to high levels of automation. As discussed in this chapter, the high variability of drivers on our roadways and the competing strengths and limitations of current ACIV systems present challenges that transportation safety researchers must address. Given these challenges, there are several recommendations listed below.

First, the areas of training should remain dynamic as ACIV systems continue to develop, new data become available, and new skills become necessary. For example, new training requirements could arise from a driver's increased exposure (and familiarity) with particular ACIV systems, software updates, or the behavioral adaptation of non-system users.

Second, considerations for the training of system users should be included as a key point in the design cycle of these new systems. Training programs should be subject to ~~the~~ proper evaluation and assessment to ensure that learning outcomes are achieved and no unintended consequences are introduced by the program.

Third, in-vehicle driver monitoring systems may be an important option to consider for ACIV system training (see also, this Handbook, Chapter 11). Campbell et al. (2018) discussed the use of driver monitoring systems to avoid out-of-the-loop problems. Salinger (2018) discussed a driver monitoring system that presented multi-modal signals to capture drivers' attention and return focus back to the control or monitoring loop. Another approach to driver monitoring is to periodically provide a message to the driver. The National Transportation Safety Board has recommended implementing driver monitoring systems (National Transportation Safety Board, 2017b).

Fourth, traffic safety professionals need to develop effective training guidelines and procedures for ACIV systems. Currently, the California Department of Motor Vehicles requires that training programs for drivers who test such systems in public include familiarization with the automated driving system technology; basic technical training regarding the system concept, capabilities, and limitations; ride-along demonstrations by an experienced test driver; and subsequent behind-the-wheel training (Nowakowski, Shladover, Chan, & Tan, 2014). Perhaps another worthwhile endeavor in the near term would be to add some measure of advanced vehicle system components to future iterations of the basic knowledge test for the standard licensing requirement, similar to what was implemented in at least twenty states and the District of Columbia for distracted driving as of 2013 (Governors Highway Safety Association, 2013).

Finally, legislative action amending statutory and regulatory definitions of applicable terms (e.g. driver, vehicle, etc.) as well as reviewing and adapting existing rules regarding vehicle operation may be a persistent challenge until policy makers are well versed in the subject matter. Educating all entities on the need for acceptance and implementation of these universal terms and definitions will be an implementation challenge (American Association of Motor Vehicle Administrators, 2018). This is one reason why communication between researchers and legislators must be clear and concise so that, in the event legislation is required, it is based on science and not on other implicit or explicit biases. Furthermore, all ~~key~~ stakeholders are encouraged to communicate with one another on the most effective ways to train novice and experienced drivers on ACIV systems. Educational materials that are developed should be proven effective and understood by the general motoring public.

18.7 CHALLENGES AND CONCLUSIONS

The true challenges that accompany the actualization of ACIV systems lie in the transition from fully manual to fully autonomous driving. As we transition through levels of automation, we are fundamentally changing the driving task primarily from the one of manual human control to automated vehicle system control. Additionally, we are changing the roles and responsibilities of driving from a process where the system supports the human driver to a process where the human driver supports the system.

Given this large change in the driving task, human factors professionals most likely will not be able to design their way to safety. The importance of intuitive and understandable HMI design is critical. However, we must also have effective and broadly available training for all users. All stakeholders will need to work together on this issue for ACIVs to deliver the safety benefits that will potentially save 1,000s of lives on our nation's roadways.

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