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Understanding trust and acceptance of automated vehicles: An exploratory simulator study of transfer of control between automated and manual driving

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ABSTRACT

Vehicle automation offers promise for improving safe transportation, access to mobility, and quality of life. However, at least in the early stages of automation, human drivers remain an integral component of the system and their acceptance and use of the automated technology needs to be much better understood. One factor that has emerged as a strong influence on the acceptance and use of automated technology is trust. We used regression analyses to address two research questions. The first was: What factors are associated with the extent to which individuals report trust in automated technology after a simulated automated drive experience? The second research question was: How are trust in automated technology, control preferences (both preference for control specifically related to driving and more general preference for control), and experience with technology associated with objective measures intended to capture acceptance of automated technology? With regard to the first research question, we found that driving-specific control preferences were significantly related to reported trust. Specifically, after experiencing a simulated drive that required switching between manual and automated modes, the extent to which individuals reported that they trusted the automated technology was significantly higher among those who also reported being comfortable with other drivers behind the wheel. While specific results were mixed with regard to the second research question, we did find evidence that trust in automated driving, at least as reported after a simulated experience with the technology, was an important component of acceptance of the technology.

1. Introduction

There is widespread agreement that motor vehicle automation offers promise for improving safe transportation, access to mobility, and quality of life (Eby et al., 2016). However, at least in the early stages of automation, driver decision making and behavior will continue to play a critical role. For example, based on SAE International definitions recently adopted by the National Highway Traffic Safety Administration (National Highway Traffic Safety Administration, 2016): at Level 2, an

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automated system on the vehicle can conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task; and at Level 3, an automated system can both conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests. Thus, human drivers remain an integral component of the system and their acceptance and use of the automated technology need to be much better understood to optimize system development, testing, and operation, and ultimately adoption.

One factor that has emerged as a strong influence on the acceptance and use of automated technology is trust (Lee & Moray, 1992; Parasuraman & Riley, 1997; Verberne, Ham & Midden, 2012). Understanding what contributes to trust in automation and how it relates to acceptance is especially critical given the role that trust plays in use and misuse of automated systems – that is, systems may be over-relied upon, used in other unintended ways, or not used at all. It is clear that trust is, in part, based on characteristics of the automation itself such as performance and reliability (Beller, Heesen & Vollrath, 2013; Muir, 1994; Muir & Moray, 1996), as well as how capabilities of the automation are conveyed to users and the context in which the automation is used (Lee & See, 2004). However, there is growing recognition that trust in automation may also be influenced by individual factors or characteristics (Rödel, Stadler, Meschtscherjakov & Tscheligi, 2014; Schaefer & Scribner, 2015).

Of particular interest in this study was the effect of driver age on trust in and acceptance of vehicle automation. It is reasonable to expect age effects given what we know about age differences in other areas of traffic safety. For example, we know that older drivers may experience declines in visual, cognitive, and psychomotor abilities that can compromise safe driving due to medical conditions that become more prevalent with aging, and the medications used to treat them (Eby, Molnar & Kartje, 2009). These declines, along with increased fragility and frailty associated with aging, have been identified as contributors to increased fatal crash risk among older drivers (Boot, Stothart & Charness, 2014; Dickerson et al., 2007; Meuleners, Harding, Lee & Legge, 2006). At the other end of the age spectrum, we know that inexperience and immaturity play a role in the safe driving of young novice drivers (Romer, Lee, Yi-Ching, McDonald & Winston, 2014); this age group also demonstrates elevated fatal crash rates (Insurance Institute for Highway Safety, 2016).

The literature on automated vehicles does, in fact, suggest that there are age effects with regard to trust (e.g., Gold, Körber, Hohenberger, Lechner & Bengler, 2015; Hoff & Bashir, 2015). For example, Hoff and Bashir (2015) conducted a systematic review of empirical evidence on factors that influence trust. They identified several studies in which age was a significant factor in trust in automation (Ezer, Fisk & Rogers, 2008; McBride, Rogers & Fisk, 2011), but concluded that specific age effects likely vary across different contexts.

Other individual factors of interest in this study included gender, use of technology, and preference for control in one's environment. While the relationship between gender and trust in automation appears to be less conclusive than age (Hoff & Bashir, 2015), continuing research attention is warranted, given the demonstrated relationship between gender and other aspects of driving behavior, patterns, and attitudes (Eby et al., 2009).

General technology use and preferences for control represent new opportunities for understanding trust in and acceptance of automated vehicles. Studies to date on control and automation (Choi & Ji, 2015; Cramer, Evers, Kemper & Wielinga, 2008) have focused on locus of control (i.e., generalized expectancies for internal versus external control of perceived reward or reinforcement [Rotter, 1966]) rather than the preference to be in control in one's environment. There are important distinctions between locus of control and preference for control. Thus it makes sense to explore empirically how an individual's preference for exerting control over his or her environment might affect trust in automation.

Similarly, given the evidence that trust in part depends on the degree of experience with automation (Ghazizadeh, Lee & Boyle, 2012), it is reasonable to think that peoples' past experience with other technologies might influence how they perceive automated technology, particularly in terms of its usefulness and ease of use. Several research areas outside of vehicle automation have looked at the ways in which previous experience with technology may affect later use. For example, Gefen, Karahanna, and Straub (2003) found that more experienced Internet shoppers had higher levels of trust in Online Stores, which was an important factor associated with online shopping behavior. Similarly, experience with technology may affect later behavior by building self-efficacy, as was found by Cassidy and Eachus (2002). As noted by Mitzner et al. (2010), even older adults are using a wide array of technologies around the home and in their daily lives, making the assessment of individuals' overall experience with technology a potentially important construct given the focus of the current study on trust and acceptance of automated vehicle technology.

There are important gaps in understanding with regard to human behavior and the interaction with automation (Merat & Lee, 2012), especially in the context of age, experience, and other individual factors. An important example of this gap is the fundamental human factors question on the issue of transitioning, or transfer-of-control, between automated control and manual control in an automated vehicle, and how trust and acceptance influence this process. Given the limited opportunities to test individual reactions to the real-world *experience* of automated vehicle technology, the use of an advanced high fidelity driving simulator to examine transfer of control represents an innovative approach to better understanding behavior that will become increasingly important in the real world. Driving simulation has been found to be of value in past aging and driving studies, particularly in new areas of research or for behaviors that would benefit from testing under safe and controlled conditions (see e.g., Shechtman, Classen, Awadzi & Mann, 2009).

This exploratory study was part of a project intended to examine specific human factors issues associated with transfer-of-control to characterize age-related differences in behaviors and reactions to this transition. The project had several specific aims including to: (1) characterize driving behavior and responses to transfer-of-control in an automated vehicle