Transportation Research Part F 33 (2015) 7–15

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Drivers' engagement level in Adaptive Cruise Control while distracted or impaired

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ARTICLE INFO

Article history:
Received 1 October 2014
Received in revised form 27 March 2015
Accepted 22 May 2015
Available online 26 June 2015

Keywords:
Adaptive Cruise Control (ACC)
Driver behavior
Driver distraction
Driver safety

ABSTRACT

Adaptive Cruise Control (ACC) is designed for convenience to maintain a set speed and specified distance from a lead vehicle. However, use of ACC may change driving patterns and perceptions over time. Many drivers perceive safety benefits associated with ACC even though the safety implications are not always clear. This study examined the factors that can influence the frequency of ACC use with surveys distributed to ACC owners in Washington State. A cluster analysis was conducted to group drivers based on how often they activated and used ACC under various driving scenarios. Four clusters emerged that showed a range of use from those who rarely used ACC in any situation (low engagement group) to those who used it for almost all situations regardless of whether it is appropriate or not (high engagement group). An ordered logit model was used to predict the likelihood of being in one of the four clusters. Drivers that were less likely to use ACC in distracting or impaired situations tend to be older, were not willing to re-purchase a similar vehicle with ACC, and were generally confused on how to use the cruise speed setting. Drivers who reported higher overall use of ACC also used the system in situations that can be considered distracting or risky, which can negate the overall benefits of ACC.

1. Introduction

Adaptive Cruise Control (ACC) is an advanced version of Conventional Cruise Control (CCC), designed to help drivers maintain a driver's pre-selected speed and distance to a vehicle directly in front. ACC achieves this by using forward radars and sensors to automatically modulate the acceleration and deceleration (Lee, McGehee, Brown, & Marshall, 2006). The original intent of ACC was for convenience rather than safety (Kesting, Treiber, Schönhof, & Helbing, 2007; Klunder, Li, & Minderhoud, 2009; Rudin-Brown & Parker, 2004). However, there are studies that suggest that ACC does enhance the stability of traffic (Klunder et al., 2009; VanderWerf, Shladover, Miller, & Kourjanskaia, 2002), which might also impact the overall safety of the transportation system. The perceived benefits of ACC with respect to personal driving goals include enhanced safety, comfort, time, and even a reduction in fuel consumption (Molin & Marchau, 2004). However, inappropriate perceptions may actually lead to greater use at inappropriate times (Parasuraman & Riley, 1997). Xiong, Boyle, Moeckli, Dow, and Brown (2012) showed that drivers who tended to over-trust the system might be more likely to have more ACC warnings and respond later to critical events.

Studies show that ACC has changed the way drivers use their vehicles (Marsden, Brackstone, & McDonald, 2001) and this is in part due to driver's willingness to use the system (Llaneras, 2006, 2007). When ACC is activated, drivers tend to stay in

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http://dx.doi.org/10.1016/j.trf.2015.05.005
1369-8478/

the same lane (Bato, 2011) and drive at lower speeds (Tricot, Rajaonah, Pacaux, & Popieul, 2004). Drivers do seem to know when best to override ACC in some situations such as when overtaking a lead vehicle or in stop and go traffic (Pauwelussen & Minderhoud, 2008; Viti, Hoogendoorn, Alkim, & Bootsma, 2008). But oftentimes, drivers disengage ACC by manually braking rather than using the ACC disengage switch (Pauwelussen & Minderhoud, 2008). This is not considered a negative outcome but suggests that drivers may prefer to press on the brake themselves rather than having ACC disengage for them.

Rottger, Bali, and Manzey (2009) has shown that advanced driver assistance systems (ADAS) can decrease driver workload and stress, but this may not generate the intended safety outcome. These systems might help drivers stay focus on the driving task, but they may also provide more opportunities to engage in other distracting activities (operating radios, cell phones or GPS) that compete with the drivers' limited mental resources (Carsten, Lai, Barnard, Jamson, & Merat, 2012; Ma & Kaber, 2005). It has been estimated that drivers engage in distracting tasks about 30% of the time while a vehicle is in motion (Ranney, 2008) and approximately a quarter of all crashes are distraction-related (Young & Regan, 2007). There are many studies that do show a negative relationship between driving performance and cell phone use (Ranney, 2008). Drivers might adopt strategies with the aid of advanced assistance systems to maintain the driving performance (Young & Regan, 2007). The supervision of a complex system can actually increase workload, as it is a vigilance task for which humans are not always well equipped. There has been minimal evidence that these systems shift driver's attention towards secondary tasks while driving with ACC (Vollrath, Schleicher, & Gelau, 2011). ACC may provide drivers with personal comfort, but this might lead to more tepid approaches and larger inter-vehicular distances (Marsden, McDonald, & Brackstone, 2001). When compared to manual control, time headways were shown to be significantly shorter (Rajaonah, Anceaux, & Vienne, 2006b) and response time to be significantly longer for cut-in events when ACC was engaged (Larsson, Kircher, & Andersson Hultgren, 2014). A survey on ACC users showed that respondents more readily adjust the gap setting between the host and lead vehicle in accordance with the traffic situation (Jenness, Lerner, Mazor, Osberg, & Tefft, 2008).

As drivers become more familiar with ACC, they also report using ACC more often (Tricot et al., 2004) and becoming more aware of the system limitations (Larsson, 2012). But it does not necessarily create greater overall understanding about the system (Fancher & Bareket, 1998; Hagan, Fancher, Bogard, Ervin, & Bareket, 1997; Marsden, McDonald, et al., 2001; Rajaonah, Anceaux, & Vienne, 2006a). Merat and Jamson (2009) noted that experienced drivers might have expectations about the system, which does not necessarily mean they can still anticipate sudden events. If drivers were more likely to engage in secondary tasks while driving with ACC, their responses to events might be limited. Thus, it is important to know if any behavior changes could occur with increased exposure to the system.

Previous studies on ACC have focused on behavioral adaptation (Hoedemaeker, 2000; Hoedemaeker & Brookhuis, 1998; Rudin-Brown & Parker, 2004), system limitations (Dickie & Boyle, 2009), and potential impact on traffic operations (Davis, 2004; Klunder et al., 2009). ACC use is shown to increase with exposure to the system (Hoedemaeker & Brookhuis, 1998), and willingness to use ACC over time can provide insights on driver's use in various context. Moreover, differences were found between age groups and the non-driving related tasks (Young & Lenné, 2010). The goal of this current study is to understand what types of drivers are more likely to use ACC for engaging in non-driving related tasks, and why some groups may be more likely to use ACC in more risky situations.

2. Method

2.1. Subjects

Data from a survey distributed in Washington State to ACC owners were used for this study. Details of the survey can be found in Bato (2011). In summary, survey respondents were recruited using a county-stratified sampling technique, based on US zip codes listed for specific Vehicle Identification Numbers (VINs); obtained from the Washington State Department of Licensing. VINs provide unique codes that identify the make, model, year, as well as information on options that were made available as standard features such as ACC. This information was compiled from data available on the automobiles manufacturers' websites. Some vehicle models do not have ACC as standard features, thus it is possible that participants who received the survey do not have ACC. Both ACC owners and non-ACC owners were invited to enroll in the survey, but the focus of the subsequent analysis is on ACC owners only. As compensation, a US $10 gift card was sent to respondents after they returned a completed survey.

2.2. Overview of the survey

The survey was post mailed to two thousand respondents selected based on a county-stratified random sampling technique from 2010 to 2011. A total of 926 models (from 16 vehicle makes) from 2001 to 2010 that could be equipped with ACC either optional or standard were included in the potential survey pool. This study was focused on the standard ACC systems, without considering stop-and-go or full-range ACC systems. The results from the survey also showed that no stop-and-go or full range ACC systems were represented in the study.

A basic description of an ACC system was provided at the beginning of the survey so that all respondents would have the same understanding/intent of the system being evaluated. There were 72 questions related to ACC, driving habits, and demographic questions (age, gender, vehicle usage, etc.). Respondents were asked questions on their perceptions towards ACC,