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Toyota drivers' experiences with Dynamic Radar Cruise Control, Pre-Collision System, and Lane-Keeping Assist

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ABSTRACT

Introduction: Advanced crash avoidance and driver assistance technologies potentially can prevent or mitigate many crashes. Previous surveys with drivers have found favorable opinions for many advanced technologies; however, these surveys are not necessarily representative of all drivers or all systems. As the technologies spread throughout the vehicle fleet, it is important to continue studying driver acceptance and use of them. *Method:* This study focused on 2010–2013 Toyota Sienna and Prius models that were equipped with adaptive cruise control, forward collision avoidance, and lane departure warning and prevention (Prius models only). Telephone interviews were conducted in summer 2013 with 183 owners of vehicles with these technologies. *Results:* About 9 in 10 respondents wanted adaptive cruise control and forward collision avoidance on their next vehicle, and 71% wanted lane departure warning/prevention again. Males and females reported some differences in their experiences with the systems; for example, males were more likely to have turned on lane departure warning/prevention than females, and when using this system, males reported more frequent warnings than did females. Relative to older drivers, drivers age 40 and younger were more likely to have seen or heard a forward collision warning. *Conclusions:* Consistent with the results in previous surveys of owners of luxury vehicles, the present survey found that driver acceptance of the technologies was high, although less so for lane departure warning/prevention. Experiences with the Toyota systems differed by driver age and gender to a greater degree than in previous surveys, suggesting that the responses of drivers may begin to differ as crash avoidance technology becomes available on a wider variety of vehicles. *Practical application:* Crash avoidance technologies potentially can prevent or mitigate many crashes, but their success depends in part on driver acceptance. These systems will be effective only to the extent that drivers use them.

1. Introduction

Advanced crash avoidance and driver assistance technologies, which initially were offered only as options on certain luxury models, are being offered on increasing numbers of mainstream vehicles. Advanced crash avoidance technologies monitor driver input and the environment around the vehicle to assist drivers when the potential for a crash is detected. These technologies have great potential to avoid or reduce the severity of crashes. Jermakian (2011) estimated that as many as 1 in 3 fatal crashes and 1 in 5 nonfatal injury crashes potentially could be prevented or mitigated annually in the United States if all passenger vehicles were equipped with four crash avoidance technologies: forward collision avoidance, lane departure warning, blind spot detection, and adaptive headlights. These estimates assume that the systems prevent or mitigate all relevant crashes and that drivers use the systems.

Forward collision avoidance systems are designed to assist the driver with a visual and/or audible warning when the vehicle is too close to a vehicle ahead, and some systems autonomously brake the vehicle if the driver does not react to a potential collision. Among the four advanced technologies studied by Jermakian (2011), forward collision avoidance systems potentially were applicable to 20% of passenger vehicle crashes per year. Analyses of insurance collision claims have found that many forward collision avoidance systems are reducing insurance claim rates for vehicles with the systems compared with the same or similar vehicles without the systems (Highway Loss Data Institute, 2011a, 2011b, 2012a, 2012b, 2012c, 2014; Isaksson-Hellman & Lindman, 2012). Studies of Volvo's City Safety, a low-speed forward collision avoidance system, have found reductions in collision claims for Volvo S60 and XC60 models with the system compared with other midsize luxury cars and SUVs without the system (Highway Loss Data Institute, 2011a, 2012a, 2015). Reductions in collision claims were found for Volvo XC60 models with City Safety compared with other Volvo models without the system (Isaksson-Hellman & Lindman, 2012). Insurance claim rates also have been reduced for Acura, Mercedes-Benz, and Volvo models equipped with forward collision

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avoidance systems that operate at higher speeds (Highway Loss Data Institute, 2011b, 2012b, 2012c). Property damage liability claim rates were lower for Acura, Mercedes-Benz, and Volvo models equipped with forward collision warning with autonomous braking than for the same vehicle models without the technology. Mercedes-Benz and Volvo models with forward collision avoidance systems that provide only warnings also appeared to prevent crash claims, but to a lesser extent than systems with automatic braking.

Another technology that is relevant to many serious crashes is lane departure warning and prevention. Although this technology is relevant to a small proportion of overall crashes, it has the potential to prevent or mitigate about 1 in 5 fatal crashes (Jermakian, 2011). Lane departure warning systems track the vehicle's position within the lane, alerting the driver prior to or as the vehicle unintentionally crosses a lane marking. Lane departure warnings may include haptic (e.g., steering wheel vibration), audible, and/or visual elements. Lane departure prevention systems actively resist moving the vehicle out of the lane or help move the vehicle back into the lane with minor steering adjustments or light braking. Compared with the analyses of collision claims for forward collision avoidance systems, studies examining lane departure warning systems have found less promising results. Analyses of Buick Lucerne and various Mercedes-Benz models with lane departure warnings showed higher claim rates for vehicles with the systems compared with their counterparts without the systems, but these findings were not statistically significant (Highway Loss Data Institute, 2011c, 2012b).

Although not marketed as a safety feature, driver assistance systems, such as adaptive cruise control, have implications for driver safety. Adaptive cruise control automatically slows down or speeds up the vehicle to maintain a set gap with a vehicle ahead but is not intended to perform emergency braking. In a field operational test of various driver assistance systems conducted in Europe, drivers using adaptive cruise control had longer headways to vehicles ahead and decreased the amount of time spent at headways less than 0.5 s compared with when they drove without it (Kessler et al., 2012). Longer headways would help drivers cope with any undetected rapid changes in traffic situations that could result in a rear-end crash (Victor et al., 2015). Another potential benefit of adaptive cruise control is a reduction in driver workload. A review of simulator and on-road studies of adaptive cruise control found it related to lower self-reported workload compared with manual driving in 22 of 24 studies (De Winter, Happee, Martens, & Stanton, 2014).

As advanced technologies with the potential to reduce crashes become available on more vehicles, it is important to monitor the effects on driver acceptance and behavior. The systems will improve safety only to the extent that drivers accept and use them. Previous surveys of luxury vehicle owners' experiences with crash avoidance technologies, including forward collision avoidance and lane departure warning, found that most drivers kept the systems turned on most of the time and would want the systems on their next vehicle (Braitman, McCartt, Zuby, & Singer, 2010; Eichelberger & McCartt, 2014). Among drivers of Volvo models, about half of drivers reported that they always used adaptive cruise control on freeways, expressways, or other high-speed roads, and 93% would want the technology again. With regard to the forward collision warning systems equipped on some Volvo models, 78–89% of the survey respondents with the system reported always having it turned on, and 86–97% would want the system again. Among drivers of Volvo or Infiniti models with lane departure warning or prevention systems, 59–69% reported always having the system turned on, and about 76–83% would want the system again. However, Volvo owners who were annoyed by any of the technologies were more likely to report that they had ever turned off one or more of the systems (Eichelberger & McCartt, 2014). A recent survey of owners of Dodge Charger, Dodge Durango, and Jeep Grand Cherokee models equipped with adaptive cruise control and forward collision warning only found that most owners used the systems and would want them on their next vehicle (Cicchino & McCartt, 2015). However, experiences with crash avoidance systems varied by age. Relative to older drivers, drivers age 40 and younger were more likely to report multiple forward collision warnings, to find the warning chime annoying, and to believe system warnings were too early. Despite being more annoyed by forward collision warnings than older drivers, the vast majority of drivers age 40 and younger reported that they always drove with the system on.

This paper reports the findings from a survey of owners of Toyota vehicles equipped with adaptive cruise control (Dynamic Radar Cruise Control), forward collision avoidance (the Pre-Collision System), and lane departure warning and prevention (Lane-Keeping Assist). This survey is the first to report non-luxury vehicle owners' experiences with autonomous braking and lane departure warning and prevention. The survey sought to understand how drivers use the systems, their perceptions of how the technologies may have affected driving, how often warnings or automatic braking were experienced, and whether drivers find the systems acceptable.

2. Methods

2.1. System descriptions

The study focused on 2010–13 Toyota Sienna and Prius models that were equipped with crash avoidance technologies. The vehicles selected for the study had Toyota's optional advanced technology package, which included Dynamic Radar Cruise Control and the Pre-Collision System. Prius vehicles also had Lane-Keeping Assist.

Functioning at speeds of approximately 30 mph and higher, Dynamic Radar Cruise Control allows a driver to set a speed and a gap behind another vehicle. A radar sensor detects slower moving vehicles ahead and the system automatically brakes or speeds up in order to maintain the gap. If the system cannot decelerate sufficiently to maintain the gap, a chime alerts the driver. If there are no vehicles in front, the vehicle travels at the set speed.

The Pre-Collision System uses the radar sensor to detect the possibility of a frontal collision and warns the driver with a buzzer and warning lights that say PCS and Brake. If the system determines that a crash is unavoidable, the system brakes automatically to reduce the collision speed, and the seat belt is retracted. Seat belt retraction linked to the radar sensor is operational when the vehicle speed is above 4 mph and the relative speed difference between the vehicle and another vehicle or obstacle is greater than 19 mph. Automatic braking, which can be turned off by the driver, is operational when the vehicle speed is above 10 mph and the relative speed difference is greater than 10 mph. If the driver brakes when the system has detected that there is a high possibility of a frontal collision, the system amplifies the braking force. This brake assist function is operational when the driver brakes, the vehicle speed is above 19 mph, and the relative speed difference is greater than 19 mph.

Lane-Keeping Assist uses a camera to monitor lane markings. When turned on, the system is active at speeds above 30 mph. When the system detects that the vehicle is drifting from the lane, it alerts the driver with a rapid beeping sound, blinking lane lines on the visual display, and a slight nudge to the steering wheel. When Lane-Keeping Assist is used with Dynamic Radar Cruise Control at speeds above 45 mph (model year 2013) or 50 mph (model years 2010–12), the system continuously applies a small amount of force to the steering wheel to help maintain the vehicle inside the lane.

2.2. Survey participants

Toyota Motor Sales, U.S.A., Inc. provided the names, addresses, and phone numbers of customers who had purchased model year 2010 or newer Prius or Sienna models equipped with the optional advanced technology package. Participation was restricted to owners for whom complete contact information was known. Before contacting survey