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Perceived mental workload, trust, and acceptance resulting from exposure to advisory and incentive based intelligent speed adaptation systems

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ABSTRACT

A 2010 field operational test completed in the United States (US) used an advisory level Intelligent Speed Adaptation (ISA) system coupled with a modest cash incentive to reduce speeding. Each participant drove an instrumented vehicle for a four week period in a naturalistic setting, with the beginning week and final week being baseline periods. The ISA system and incentive were activated for some participants, depending on assignment to experimental conditions, during the middle two weeks of the trials. Driving with the systems, particularly the incentive component, led to a significant reduction in the percentage of time speeding over the posted limit (these results are reported elsewhere). At the end of each week of driving, participants provided ratings of perceived mental workload and completed a “Trust and Acceptance” rating scale after experiencing the incentive and speed warning systems. This paper documents the results of the workload and trust data. As expected, the incentive condition was associated with increased mental demand, temporal demand, frustration, and effort. Unexpectedly, the speed warning did not reduce mental workload of drivers in the incentive condition compared with the incentive only condition. Also counter to our predictions, drivers who experienced the warning without the incentive did not indicate increased mental demand or temporal demand. Trust and acceptance ratings were generally positive for both systems, although the auditory component of the warning was rated unfavorably. Participants who experienced the incentive system rated the speed warning system as less trustworthy than participants who did not experience the incentive, and this finding may partially explain the lack of a reduction in mental workload for participants in the incentive + warning compared with the incentive only condition.

1. Introduction

The US National Highway Traffic Safety Administration reported that speeding related crashes were associated with more than 10,000 (32%) traffic fatalities in 2010 (NHTSA, 2012a, 2012b), and considerable evidence suggests that increased speeds lead to increased numbers of crashes, injuries, and fatalities (see Elvik, Christensen, & Amundsen, 2004). However, changing speeding behavior has been difficult as it seems culturally accepted by many drivers in the United States. As summarized by Harsha and Hedlund (2007), cars drive faster yet more quietly than ever, and manufacturers' marketing campaigns

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frequently emphasize the speed capabilities and the smooth rides of their vehicles. Such ad campaigns may foster a sense in the driver that speeding is not only acceptable but desirable. The findings from studies of observed travel speed on our roads provide further evidence to support the notion that speeding is a normal, accepted behavior (Huey, De Leonardis, & Freedman, 2012). In their survey, which used a nationally weighted sample of speeds on US roads, Huey et al. reported that the percentages of vehicles exceeding the speed limit by 5 or more mph during free-flow conditions on restricted access highways, major arterials, and minor arterials were 46%, 31%, and 33%, respectively. Given the ubiquity of speeding above the posted limit, it is not surprising that most jurisdictions throughout the country encourage traffic enforcement to provide a considerable "cushion" of 5–10 mph over the posted limit (Governor's State Highway Safety Administration, 2005). This tolerance may further contribute to the prevalence of speeding, as the absence of enforcement within these cushions suggests that there is little deterrent effect of the speed limit itself. Thus, despite strong evidence that indicates speeding reduces road safety, the conflicting goal of expedited travel from A to B frequently compels US drivers to drive above posted limits (Wickens, Lee, Liu, & Gordon Becker, 2004). Faster travel does not impact only drivers' decisions – the Texas state legislature recently set an 85 mph limit on a toll road that will encourage drivers to drive at very high speeds (Lund, 2012).

Intelligent Speed Adaptation (ISA) shows promise as a technology-based countermeasure for speeding. ISA systems link vehicle speed with established speed limits in real time. With this coupling the systems can constrain vehicles from accelerating faster than the limit, provide feedback to drivers when they speed, or incentivize drivers to avoid speeding. Several field operational tests (FOTs) indicate that each level of automation increases adherence to posted speed limits (see Biding & Lind, 2002; Jamson, Carsten, Chorlton, & Fowkes, 2006; Reagan, Bliss, Van Houten, & Hilton, 2012). The current paper is an outgrowth of the work of Reagan et al. In their 2012 article, the authors presented their methodology and behavioral results for a FOT that tested separate and combined effects of incentive- and advisory-based ISA systems. The current article supplements the findings associated with speeding behavior presented in Reagan et al. (2012) (and summarized below) with trust, acceptance, and mental workload data.

Potential of ISA to reduce speeding. The largest ISA study to date was a field test of several thousand vehicles across four sites in Sweden (Biding & Lind, 2002). Two of the sites tested levels of automation that advised drivers of the current speed limit and/or warned drivers when they sped faster than the posted limit. The other locations in the study used a level of automation that intervened with speed selection by introducing resistance against the accelerator pedal when a driver exceeded the limit. For all sites, the researchers compared a one-month baseline period to two month-long activation periods, with the first being just after activation and the second occurring several months later. Biding and Lind reported that both levels of automation led to a similar decrease in average speeds compared to baseline, although the effects in the second post-activation period were smaller than the first. In a different effort, Carsten et al. (2008) tested a highly automated system that prevented speeding through braking or constraining the throttle. The authors documented a significant decrease in the mileage traveled in violation of the posted limit during the ISA activation period compared to the baseline phase, but speeding returned to baseline levels during a post-activation period when systems were deactivated. Additional research endeavors provide further evidence to support the conclusion that activated ISA systems will reduce speeding violations (see Carsten, 2012). This applies whether the level of automation is advisory (Brookhuis & de Waard, 1999; Lahrmann, Agerholm, Tradisaukas, Berthelsen, & Harms, 2012), advisory with external motivator (Hultkrantz & Lindberg, 2003; Lahrmann, Agerholm, Tradisaukas, Berthelsen, & Harms, 2012; Reagan et al., 2012) intervening (Varhelyi & Makinen, 2001), intervening with advisory (Regan et al., 2006) or preventive (Duynstee, Katteler, & Martens, 2001).

Synopsis of Reagan, Bliss, Van Houten, and Hilton. The following synopsis of Reagan et al. (2012) provides an overview of the behavioral effects associated with the FOT effort to give context to the current workload, trust and acceptance results. The basic research design was a split-plot design with one between and one within subject factor. Fifty drivers were assigned to three independent groups and were measured during four one-week periods creating the 3 (Monetary Incentive) × 4 (Speed Warning (SW) Week) mixed factorial design. Monetary Incentive (MI) was the between subjects variable, with 20 participants receiving MI during weeks 2 and three and 30 (20 who received SW plus 10 control drivers) who drove without receiving MI. The SW system activated for one week, either Week 2 or Week 3. The 20 participants assigned to receive MI and the 20 participants assigned to the no-MI conditions experienced the SW system. The 10 participants in the control group did not experience either system, but they did provide data at the same four periods as the 40 participants who received SW. Weeks 1 and 4 served as baseline and reversal periods for the 40 experimental participants, respectively. Table 1 shows how SW and MI were crossed during the SW period. The SW condition was counterbalanced within each MI group; half of the MI and half of the no-MI group received the warning during Week 2 and the other half of each group experienced it during Week 3.

Prior to analysis of the speed data, we defined four speed ranges because of the nature of the feedback and incentive systems. These ranges were (1) speeds equal to or slower than the limit, (2) speeds 1–4 mph over the limit, which was the range that drivers could speed without incurring an incentive loss or experiencing an alert, (3) speeds 5–8 mph over the limit, the range that drivers were considered to be moderately speeding and would lose a incentive at the slower rate of $.03/occurrence and experience the less urgent warning, and (4) speeds 9 mph or greater over the limit, defined as egregious speeding. Within the road network used for the study, there were the following seven speed limits: 25 mph, 30 mph, 35 mph, 40 mph, 45 mph, 55 mph, and 70 mph.

The primary inferential analyses focused on the percentage of time each week that the vehicles were traveling in each of the four speed ranges. The pattern of results indicated a robust effect for the incentive system, although there were some differences between the different speed limits. For drivers assigned to the incentive condition, there were few significant