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VERBAL COLLISION AVOIDANCE MESSAGES OF VARYING PERCEIVED URGENCY REDUCE CRASHES IN HIGH RISK SCENARIOS

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Summary: Collision Avoidance Systems (CASs) are increasingly being installed in motor vehicles. Concurrently, verbal warnings are increasingly utilized in aviation, surface transportation, and medical environments. The current driving simulation investigation examined crash avoidance behaviors in high risk driving situations and crash rate reduction as a function of exposure to different types of verbal CAS messages. CAS messages varied in presentation level (PL) and signal word. Post-drive ratings of perceived urgency, alerting effectiveness, and annoyance were also examined. The type of CAS warning presented resulted in significant differences in appropriate crash avoidance behaviors and crash rates. In the current paradigm, the most effective CAS warnings were those of moderate PU, specifically the low PU signal word "notice" presented at high PL and the high PU signal word "danger" presented at low PL. Results are discussed in terms of their implications for CAS warning design and hazard matching applicability.

INTRODUCTION

Designing in-vehicle collision avoidance systems (CASs) that alert drivers to potential hazards and result in appropriate driver response is an ongoing challenge (Brown, Lee, & Hoffman, 2001; Brown, Lee, & McGehee, 2001; Hoffman, Lee, & Hayes, 2003; Pierowicz, Jocoy, Lloyd, Bittner, & Pirson, 2000). Driver advisory CASs that allow drivers to maintain vehicle control while providing timely information that may prevent or reduce the severity of a vehicle incursion are the focus of this investigation. This type of CAS functionally operates as a sensory aid assisting the driver in detection of roadway hazards. CASs may be of particular benefit to drivers during periods of high cognitive workload, such as while negotiating through heavy traffic, intersections or while driving in adverse visual weather conditions. Driver inattention and distraction are frequently cited as major contributors to motor vehicle crashes, particularly for drivers over the age of 65 (Stutts, Reinfurt, Staplin, & Rodgman, 2001). CASs may also be of particular benefit to young inexperienced drivers who have not yet developed a knowledge base sufficient to allow recognition and anticipation of many roadway hazards.

In light of the potential economic and safety benefits to be gained by CASs, continued attention towards developing effective methods of presenting CAS warnings is warranted. Researchers and developers need to consider both the frequency and reliability with which to present alerts and the optimum alert modality and format. Auditory CAS warnings, relative to visual warnings have the advantage of being omnidirectional and result in faster processing times. Verbal warnings offer the additional advantage of being able to inform as well as alert drivers. However, a verbal warning that is presented too frequently or when the actual risk of collision is

low may be viewed as annoying and intrusive (Pierowicz et al., 2000). When considered in terms of the number of vehicle miles traveled, collisions are rare events. If a CAS alert is provided only in situations where a severe collision is imminent, then the alert event may be so rare as to possibly be unrecognizable to the driver (Brown, Lee, & McGehee, 2001). Conversely, a CAS that provides alerts too frequently, when the probability of a collision is low or nonexistent, is likely to be perceived as unreliable (Bliss & Acton, 2003) and drivers may ignore or disable the system.

Hazard matching, which involves matching the perceived urgency of the presented alert or warning to the probability and severity of the potential risk situation is one method of addressing the frequency/reliability paradox. Extensive research has been conducted on the influence of various presentation factors on the compliance levels and perceived urgency associated with written/visual messages (Wogalter & Silver, 1990, 1995) and for non-verbal auditory warnings (Edworthy & Adams, 1996; Edworthy, Loxley, & Dennis, 1991). However, few investigations have examined the presentation parameters affecting perceived urgency of verbal auditory warnings. In one notable exception, Barzegar and Wogalter (1998) asked listeners to judge the connoted hazard level of various signal words presented under one of three voice styles (monotone, emotional, and whisper) at one of two presentation levels (60 dBA and 90 dBA) and spoken by a male or female. In their investigation, the connoted hazard level associated with signal words were as follows. Danger received a higher hazard rating than warning and caution, which did not differ. Notice received the lowest hazard rating. The hazard level (also termed the perceived urgency) of spoken signal words has been confirmed by subsequent research (Hellier, Wright, Edworthy, & Newstead, 2000; Hollander & Wogalter, 2000; Weedon, Hellier, Edworthy, & Walters, 2000). Baldwin and colleagues have extended this research by examining ratings of perceived urgency and annoyance of verbal warnings presented while participants were engaged in a contextually appropriate task of simulated driving (Baldwin, 2003; Baldwin & Moore, 2002). Results of these investigations confirm that the signal word and presentation level (PL) chosen for verbal CAS messages significantly impact driver's ratings of perceived urgency and annoyance. The current driving simulation investigation was designed to extend this research by examining collision avoidance behaviors as a function of key presentation parameters of verbal CAS messages presented in actual hazardous roadway events.

We examined the effectiveness of verbal CAS warnings varying in signal word and PL in facilitating appropriate crash avoidance strategies and successful crash avoidance during simulated driving. Post-drive ratings of the perceived urgency, alerting effectiveness, and annoyance levels for the verbal CAS messages were also examined.

METHODS

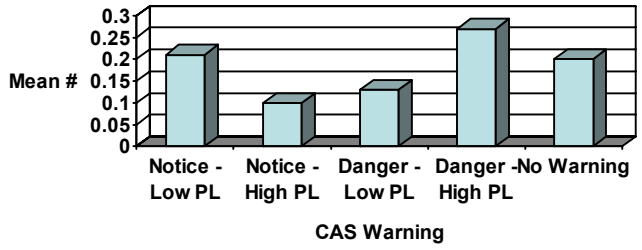
Participants drove a simulated vehicle through various urban scenarios containing potential collision situations. The collision situations included events such as a vehicle running a red light and crossing the path of the driver's vehicle, a pedestrian beginning to cross the street in the driver's path, a rear-end crash situation in which a car approached too quickly from behind while the driver was turning at an intersection, and situations involving obstructed forward views. CAS warnings differing in signal word (Notice and Danger) and presentation level (PL: approximately 70 dBC and 85 dBC) were presented just prior to the hazardous event, except in the control condition in which no warning was provided. Driving performance measures and

reactions to the hazardous event (accelerator input, brake input, steering input, steering directionality and velocity) were used to determine crash avoidance strategy. The number of collisions was also recorded as a function of the CAS warning and no warning condition. Following the hazardous event, drivers were asked to pull the vehicle over and provide ratings of the alerting effectiveness, perceived urgency and degree of annoyance of the CAS message.

RESULTS

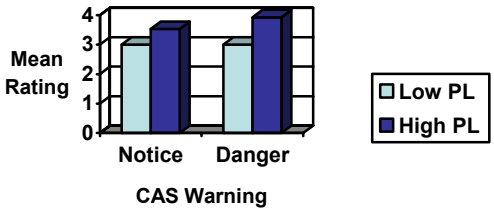
Given the hazard present in each of the driving scenarios, the overall crash rate across all scenarios was low (18% or 27 crashes out of 150 drives). There was a significant difference in crash rate between the scenarios, χ^2 (4, N = 150) = 14.27, p = .006. The most hazardous scenario was the rear-end crash situation. This scenario had a crash rate of 40% or 6 crashes out of 30 drives. The remaining scenarios had crash rates of 20% or below. For the most hazardous scenario, the type of CAS warning presented significantly impacted both the appropriateness of the crash avoidance strategy, χ^2 (4, N = 15) = 9.64, p = .047 and the number of observed crashes χ^2 (4, N = 30) = 10.32, p = .035. Not surprisingly, there was a high negative correlation between appropriate crash avoidance strategy and crashes, r (75) = -.71, p <.001. Crashes were most likely when either no CAS message was presented (control condition) or when the CAS message had been the low urgency signal word "Notice" played at the low PL and the high urgency signal word "Danger" played at the high PL. Figure 1 illustrates the mean number of crashes as a function of CAS warning type across all driving scenarios.

Figure 1: Crash Rate as Function of CAS Warning



Ratings of CAS messages revealed a main effect of PL for the dependent measure of perceived urgency, F(1,14) = 7.32, p = .02. CAS messages of higher amplitude were rated as more urgent (M = 3.73 on a 5 point scale) than those presented at lower amplitude (M = 3). The mean perceived urgency ratings for CAS warnings as a function of both PL and signal word are presented in Figure 2. Significant differences in ratings for alerting effectiveness and annoyance were not observed in the present sample.

Figure 2: Ratings of Perceived Urgency



CONCLUSION

Previous research has shown that both acoustic (i.e., PL) and semantic (i.e., signal word) parameters affect perceptions of the perceived urgency of verbal alarms in situations involving simply listening to and rating the verbal stimuli (Hellier et al., 2002) and listening to the stimuli while engaged in a contextually appropriate task (Baldwin, 2003). Results of the current experiment partially replicate the previous work by demonstrating that the presentation level of verbal CAS messages affects ratings of perceived urgency. Additionally, the current results provide additional support for the potential interacting effects of acoustic and semantic parameters in verbal warning response.

More importantly, however, the current results indicate that verbal CAS warnings of different urgency influence collision avoidance strategies and crash rates in highly hazardous driving situations. Interestingly, the acoustic and semantic parameters used in the current investigation interacted. This is demonstrated by the observation that the most appropriate collision avoidance strategy resulted from use of either the less urgent signal word in combination with the high urgency presentation amplitude or the high urgency signal word presented at the least urgent presentation amplitude, relative to the other CAS warning combinations and the control condition in which no CAS warning was given. These results support Baldwin's (2003) previous observation that acoustic and semantic parameters interact in CAS response. In her previous investigation, Baldwin observed that when CAS warnings were presented at high PLs, drivers reacted quickly in a simple response time paradigm, regardless of the semantic urgency of the message presented. However, when CAS messages were presented at lower PLs, drivers' response time depended primarily on the semantic urgency of the message. In the current paradigm, driver crash rate in the high PL, high semantic urgency (Danger) CAS warning condition was higher than in the control condition in which no warning was given, thus providing additional support for the acoustic-semantic interaction.

The current results were conducted in a driving simulator and therefore their application to actual driving situations may be challenged. Additionally, the current results may be considered preliminary as further research is currently underway including the examination of these and other related factors (i.e., existing CAS alerts, driver age and hearing acuity) with a larger sample size. However, the current results suggest that caution must be exerted in developing effective CAS warnings. The potential trade-off between acoustic and semantic warning parameters

warrants further investigation.

In conclusion, the results to date suggest that verbal CAS warnings have the potential to reduce crash risk in hazardous situations and that urgency mapping is a potential tool for improving existing CAS warnings.

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