ACOUSTIC AND SEMANTIC WARNING PARAMETERS IMPACT VEHICLE CRASH RATES

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ABSTRACT

Auditory Collision Avoidance Systems (CASs) are increasingly common in the modern automobile. Verbal warnings are increasingly being used in aviation and medical environments; but, they have received considerably less attention in the driving research community. Here, I discuss a recent series of investigations aimed at examining the impact of acoustic and semantic warning parameters on crash rates and drivers' perceptions of perceived urgency, alerting effectiveness, and annoyance. Drivers were exposed to high crash risk scenarios in a high fidelity driving simulator. Just prior to the potential crash event, drivers received a verbal warning that varied in signal word (e.g., Notice, Danger) or presentation level (e.g., 70 dB and 85 dB). Experiment 1 demonstrated that drivers' crash rates were reduced significantly by CAS warnings of intermediate urgency relative to either low or high urgency warnings. Experiment 2 demonstrated that auditory CAS warnings of intermediate urgency were particularly effective in reducing the crash rates of drivers over the age of 65 years. The implications of these investigations for improving automotive warnings and highway safety will be discussed.

[Keywords: verbal warnings, driving, older drivers, crash reduction]

1. INTRODUCTION

The modern automobile comes equipped with many advanced safety features and collision avoidance systems (CASs) providing visual and auditory warnings are commonly one of these important features. Designing CASs that alert drivers to potential hazards and result in appropriate driver response is an ongoing challenge [1-3]. CASs functionally operate as a sensory aid assisting the distracted, inattentive or fatigued driver in detection of roadway hazards. CASs may be particularly useful for certain older drivers who require more time to react in hazardous situations. Perceptual –cognitive errors (e.g., looked but did not see) are frequently cited as a causal factor in the crashes of drivers over the age of 65 [4, 5]. CASs may also be effective as crash prevention and training devices for young inexperienced drivers who are not yet aware of many potential roadway hazards.

The auditory modality has several advantages over the visual for presenting warning information that are particularly relevant for the driving situation. Auditory warnings do not require that the driver take his or her eyes off the road and they typically result in faster response times. Verbal warnings offer the additional advantages of being able to inform as well as alert drivers and they may aid appropriate hazard matching.

Hazard matching requires presenting a warning that is perceptually suited to the situation it represents. Presenting an extremely urgent warning in a low collision risk situation is annoying and could even increase crash potential.

Signal words such as, "Danger" are perceived as more urgent than "Warning" or "Note" [6-8] and frequency and speaking style also impact urgency ratings [9]. Baldwin and colleagues have examined the impact of acoustic and semantic warning variables on ratings of perceived urgency, alerting effectiveness and annoyance while participants were engaged in simulated driving [10-13]. Two investigations will be briefly reviewed here. The first demonstrated the relative effectiveness of verbal collision avoidance messages varying in signal word and presentation amplitude on reducing crash probability in high risk situations. The second experiment extended the results of Experiment 1, demonstrating that auditory warnings of intermediate urgency significantly reduce crash risk in older drivers.

1.1. Experiment 1: Impact of Acoustic and Semantic -Level Warning Parameters on Crash Rates

Baldwin's [11] previous research indicated that both presentation amplitude and signal word impact response time and ratings of perceived urgency, alerting effectiveness, and annoyance in a medium fidelity driving simulation paradigm. The current investigation was carried out to see if these results transferred to a high fidelity simulation and to see if warnings of different perceived urgency improved collision avoidance behavior [12].

Sixteen licensed drivers 18-26 years of age drove a simulated vehicle through various urban scenarios containing potential collision situations. Five high risk collision scenarios included events such as a vehicle running a red light and crossing the path of 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.

In Experiment 1, participants drove through each of the scenarios in partially counterbalanced order and CAS warnings differing in signal word (Notice and Danger) and presentation level (PL: approximately 70 dB and 85 dB) were presented just prior to the hazardous event, except in the control condition in which no warning was provided. In addition to crash rate, hazard response reactions (accelerator input, brake input, steering input, steering directionality and velocity) were examined. 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 warning.

1.1.1 Results of Experiment 1

Results indicated that the warnings of intermediate perceived urgency (Danger at 70 dB and Notice at 85 dB) resulted in significantly lower crash rates relative to the no warning control condition and the lowest and highest urgency warnings. The highest urgency warning (Danger at 85 dB) resulted in a nonsignificant trend towards higher average crash rates than providing no warning at all. The lowest urgency warnings (Notice at 70 dB) did not differ in crash rate from the control condition.

Ratings of perceived urgency, alerting effectiveness, and annoyance obtained after each collision event were as expected. The warning "Danger" presented at 85 dB was rated as the most alerting but also the most annoying while "Notice" played at 70 dB was rated as the least alerting but also the least annoying. Ratings of the other two warnings were intermediate in terms of urgency, alerting effectiveness and annoyance.

1.1.2 Discussion of Experiment 1

Results of Experiment 1 provide empirical evidence that verbal CAS warnings of different urgency influence crash probability in simulated high collision situations. Further, the acoustic and semantic parameters of the warning interacted. Warnings of intermediate urgency – consisting 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 resulted in the greatest reduction in crash probability. Warnings at either extreme (Low urgency and High urgency) did not reduce crash risk.

Finally, even in high risk collision situations, the high urgency warning was rated as extremely annoying. The high annoyance rating of this warning in combination with its failure to reduce crash probability indicates that caution must be exercised when designing warnings to be used in real collision avoidance systems. If users find the systems annoying they are likely to ignore or disable them.

1.2 Experiment 2: CAS Warnings for Older Drivers.

Experiment 2 aimed to extend the results of the previous investigation by examining the crash rate reduction probability of CAS warnings of intermediate urgency presented to young and older drivers [13]. Further, in order to simulate a more realistic driving situation, participants in Experiment 2 were engaged in a general driving task for a period of approximately 1 ½ hours prior to being exposed to a collision event. Each driver experienced only one potential high risk collision scenario, thus making for a more naturalistic situation.

Forty-eight participants, including 19 between the age of 18-35, and 23 between the ages of 60 and 82 years volunteered for this experiment. Drivers performed an unrelated secondary speech processing task while engaged in a car following task prior to their exposure to the experimental drive scenario. The lead car was traveling along a two-lane freeway at a consist speed approximating 55 mph. Drivers were asked to maintain a consistent headway behind the lead vehicle, thus partially controlling for differences in speed of travel. Each driver's individual lane variability was measured and tracked in real time. After approximately 1 ½ hours of driving, and when participants lane variability exceeded their personal variance by one standard deviation, a potential collision event was triggered.

The collision event consisted of the lead car suddenly breaking and coming to a full stop. The brake lights on the lead car did not come on, further maximizing crash potential. At the beginning of the lead cars' deceleration, an intermediate urgency auditory warning was presented (accept in the no warning control condition). The warnings consisted of either a 1000 Hz warning tone or the signal word "Danger". Both auditory warnings were presented at approximately 73 dB, thus representing an intermediate urgency level as assessed in Experiment 1.

1.2.1 Results of Experiment 2

A binary backward stepwise logistic regression was used to analyze the data. Results revealed that providing a CAS warning significantly reduced crash probability, and follow up analyses indicated that this was particularly true for older adults. Approximately 17% of drivers who received no warning crashed, while roughly only 10% of drivers who received a warning crashed; crashes in the warning condition were primarily exhibited by young males. Relative to young drivers, older driver typically left almost twice the distance between their car and the lead car. Despite this, older drivers were much more likely to crash if not provided an auditory warning.

1.2.2 Discussion of Experiment 2

Older drivers are a fast growing segment of the driving population, since more drivers over the age of 65 are obtaining and maintaining their licenses and these drivers are driving more miles than their counterparts of previous generations [14, 15]. Results of the current experiment provide encouraging support for the hypothesis that CASs that act as sensory aids may mitigate crash risk in older drivers.

2. CONCLUSIONS

Despite considerable advances in automotive safety, crashes are an all too common occurrence. Increasingly collision avoidance systems providing visual or auditory warnings in advance of potential crash situations are a part of the advanced safety suite of the modern automobile. However, designing effective warnings for these systems remains a considerable challenge. A warning that is perceived as too urgent for the situation or that is presented to frequently is extremely annoying to drivers.

Drivers will find ways to ignore or disable annoying warnings. Yet, a warning of too low urgency may do little to reduce crash risk.

Results of the two investigations reviewed here indicate that auditory warnings have great potential for reducing crash risk, particularly if presented at intermediate hazard levels in order to alert without startling or annoying drivers. Particularly encouraging are the results of Experiment 2 that indicated that warnings of intermediate urgency can significantly reduce crash probability of older at risk drivers. Further work examining methods of improving existing auditory warnings to facilitate the safety of our roadways is clearly warranted.

3. REFERENCES

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