Adjunct Proceedings of the Second International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2010), November 11-12, 2010, Pittsburgh, Pennsylvania, USA

The Effects of Intensity in Multi-modal Warning Systems

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ABSTRACT
This study tests the effects of voice and haptic alert intensity levels in a multi-modal warning system. Users favor intensity-matching, but drive better with mismatched warnings.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces.

General Terms
Experimentation, Human Factors

Keywords
Voice interfaces, haptics, multi-modal, warning systems.

INTRODUCTION
As car technology more successfully gathers environmental information, vehicle interfaces should be better equipped to forewarn drivers. Previous research showed that voice warnings improved driving performance [2]. Other modalities, such as haptic feedback, could further aid drivers. Based on evidence that users prefer consistent systems [1], we designed a study to test the effects of interface consistency.

METHOD
Twenty-four males and twenty-four females were balanced between four conditions. In this 2 (haptic feedback: low/high) x 2 (voice style: suggesting/commanding) between-subjects design participants experienced one level of haptics and one voice style warning. Haptic feedback took the form of pre-tested steering wheel vibrations lasting several seconds.

Twelve voice prompts were pre-recorded in commanding and suggesting styles. Commanding statements were spoken with a strong tone and active sentence structure (e.g. *In a construction zone, you need to slow down for your safety and the safety of others.*). The suggesting prompts were spoken in a softer tone and passive voice (e.g. *There is a construction zone ahead. It may be a good idea to slow down.*).

Procedure
Participants drove a 60,000-foot driving simulator course with elements such as curvy roads and low-visibility; programming was based on distance and the voice and haptic alerts were placed so they would appear in advance of course features. After the drive, participants completed a questionnaire.

Measures
STISIM*Drive* software collected behavioral measures. Collisions, speeding and centerline crossings were normalized and summed for a *bad driving* score ($M = 0$, $SD = 1$). A *car quality* index combined seven statements (Cronbach's $\alpha = .92$) rated on a 10-point Likert scale (e.g., well-designed, fun to use) ($M = 29.75$, $SD = 13.11$). The fourteen-item *security* score (Cronbach's $\alpha = .86$) measured confidence and steadiness experienced during the drive ($M = 85.89$, $SD = 18.27$).

RESULTS & DISCUSSION
There were significant interaction effects for the *bad driving* ($F(3, 44) = 5.27$, $p < .05$), *car quality* ($F(3, 44) = 5.59$, $p < .05$), and *security* items ($F(3, 44) = 6.44$, $p < .05$).

Table 1: Means (and Standard Deviations)

Haptic/Voice	*Bad Driving*	*Car Quality*	*Security*
Low/Command	0 (1.21)	28.33 (13.19)	87.58(16.42)
Low/Suggest	-.32 (.96)	31.17(11.98)	91.08(18.00)
High/Command	-.32 (.60)	36.83(14.64)	93.00(16.09)
High/Suggest	0 (.86)	22.67(9.42)	71.92(16.52)

Results illustrate that matching the intensity of warning modalities significantly affects drivers. Like previous research, users favored consistent systems (high/commanding, low/suggesting) in terms of attitudinal ratings. However, this consistency did not extend to performance. Drivers with inconsistent systems drove better. Matched low intensity may have been deemed unreliably passive, and the consistently high intensity may have been distracting or interpreted as alarmist.

Future work should compare multi-modal systems to individual haptic or voice warning systems. Interactions between warning style and driver personality should also be explored. Designers and manufacturers should take caution that users' attitudes are not sufficient predictors of behavior. Careful user studies are crucial for developing safe and enjoyable automotive interfaces.

REFERENCES
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