The Effect of In-Vehicle Warning Systems on Speed Compliance in Work Zones

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The present study investigated the effectiveness of in-vehicle information to influence drivers' compliance to speed limits in work zones.

Why work-zones?

Highway work zones are hazardous roadway environments.

•Significantly more dangerous than comparable pre-work zone roadways in the same areas (Khattak, Khattak & Council, 2002).
•Crash rates increase by ~ two-fold on highway segments under construction compared to the same highway segments measured previously without the presence of work zones.
•The majority of people killed in work zones are drivers and vehicle occupants (~85%).
•Speed has a main contributory role in work zone crashes (Stackhouse & Tan, 1998). This overt behavior is also recognized by the drivers themselves.

IVIS (in-vehicle information systems)

In-vehicle systems could be used to convey operational information for the driver especially in difficult and demanding conditions (Vashitz, Shinar, & Blum, 2008). Research efforts have provided evidence that in-vehicle information technologies can positively affect driver compliance and improve safety, particularly with regard to driving speed (Brookhuis & de Waard, 1999).

Long term effects of a first generation intelligent speed adaptation device found an initial decrease in the time spent over the speed limit. Yet, compliance rate attenuated with time (Warner and Åberg, 2008).

Most contemporary in-vehicle displays do not place excessive visual demand on the driver in normal driving circumstances. Work has been accomplished pertaining to the in-vehicle presentation of audio and/or visual stimuli. Very little has been done to examine the delivery of in-vehicle audio and visual warning systems specifically to enhance safety in work zones.

Hypothesis

1. In-vehicle information devices can influence driver speed compliance behavior in work zones
2. Modality (i.e., auditory or visual) of in-vehicle messages can affect drivers' speed compliance pattern, e.g., auditory messages may be more effective for the initial phase of entering the work zone but more intrusive later on within the work zone.

Method

Participants. Sixty volunteers (27 males and 33 females) age 20 and 63 (mean 33) years with an average of 21 years of driving experience. All reported having normal hearing and had normal or corrected to normal vision.

Apparatus. A fixed-base I-sim driving simulator with three visual channels providing ~150° field of view. A dedicated LabVIEW program was integrated with the simulator for the purpose of recording driver measures and triggering the audio and visual in-vehicle warning messages.

In-vehicle messages. Visual messages were black text on an orange background (Fig. 1, Right), "Work Zone Ahead", "Begin Work Zone", and a warning presented only if the driver exceeded the posted speed limit ("Slow Down"). It was triggered if driving speed exceeded the posted speed limit by more than 5 Km/h. Visual messages were delivered via a Pocket PC (600x800 VGA resolution) in the location of the OEM radio (Fig. 1, Left). Audio messages were presented in a male's voice with identical content to the text in the visual ones and were delivered via a speaker set mounted below the screen (at 60dBC).

Procedure. Participants were assigned to one of three conditions; control audio, or visual. Each participant drove a simulated drive that included a work zone with the total duration of ~7 minutes. The control group saw regular work zone signage on the road (e.g., cones and markings). The other two groups received additional in-vehicle audio or visual warnings, respectively. Once in the work zone, if driving speed exceeded 45 Kph, a continuous visual or audio warning message was presented until travel speed was reduced to 45 Km\h. Before the drive began and after exiting the work zone (completing the drive) participants filled the NASA-TLX.

.Fig. 1 Left: Experimental setup in the visual condition (visual warning are presented to the right of the driver) Right: Images of the visual in-vehicle warning messages.

Results

Time spent above speed limit within work zone. Participants spent an average of 44%, 7% and 18% of the time, (71 (43), 13 (11) and 32 (39) sec) for the control, audio and visual condition, respectively. The average violation duration for the control group was significantly greater than that for either the audio or visual groups (Fig. 2).
Average violation speed. 55 (9), 50 (5) and 47 (17) Km/h for the control, audio and visual groups, respectively (NS, p<.9).

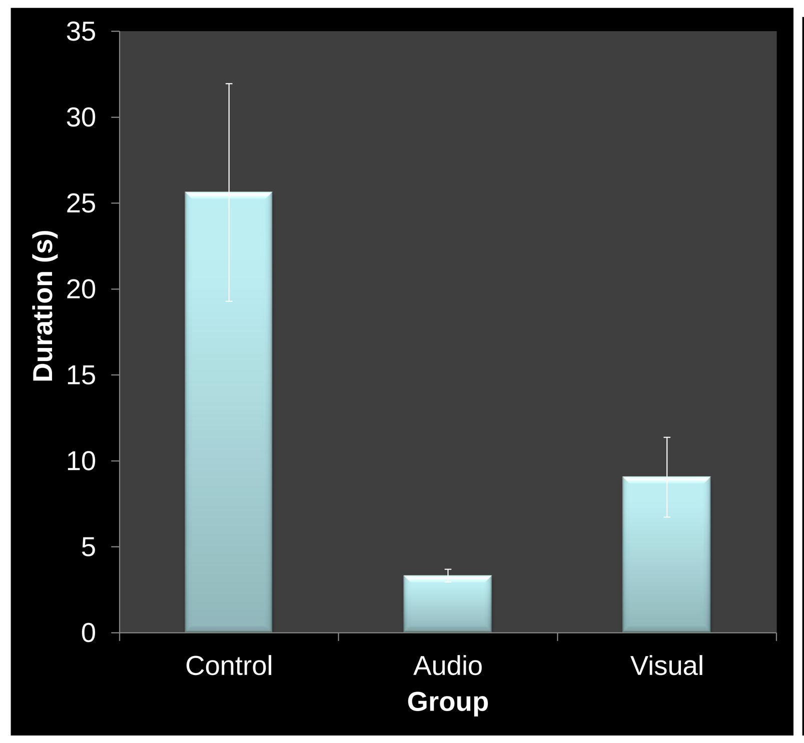

Fig. 2. Average duration of speed violations, by group. Error bars show standard error.

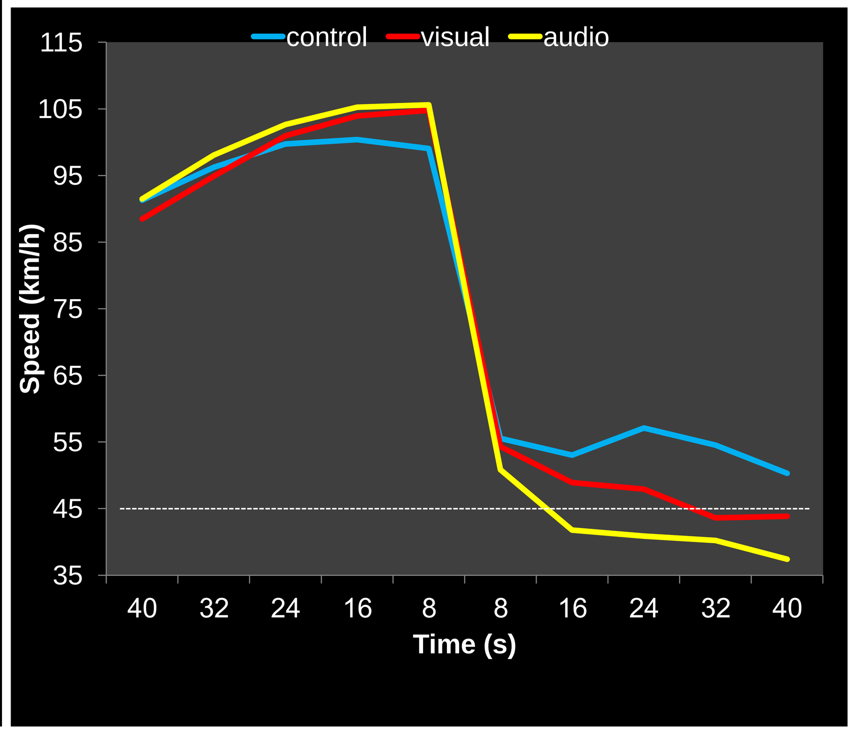

Fig. 3. Entrance to the work zone. Notice the stimulus-response differences after the entrance to the work zone.

Speed Before and Within the Work Zone . A significant effect of group on post-work zone speed was present, $F(2, 57) = 7.17$, $p = 0.0017$. The control group had a significantly greater mean speed (M = 57 (16) km/h) relative to either visual (M = 48 (16) km/h) or audio (M = 41 (5) km/h groups. There was no difference between visual and audio groups. Fig. 3 presents the difference in time until compliance when entering the work zone.

Discussion and Conclusions

Drivers with multimodal warnings most frequently violated the safe speed upon entering the work zone. However, once they were alerted to this state they typically did not have additional speed violations. Control drivers did not display such a pattern.

Differences between auditory and visual conditions were present in the time to compliance ; while drivers in the audio condition took 6 seconds to respond, their counterparts in the visual condition took 22 seconds to respond. The final outcome of both modalities was the same (speed compliance), however the longer time to compliance for the visual channel system suggests both the dominance of the auditory channel for this type of information as well as the importance of timely alerts through IVISs.

As one would predict, based on multiple resource theory (Wickens, 2002), the findings of this study suggest the necessity of redundant signal modalities in driver-messaging systems. Specifically, in order to achieve the best compliance with messages presented to the driver, those messages need to consist of a specific temporal sequence of modalities. The ideal driver message should begin with a brief auditory and visual messages (of a duration no greater than 6.0 seconds), followed by a visual warning message only which remains visible until compliance or acknowledgment.

In closing, further research is called for in the specific auditory and visual characteristics of such messages. The density of auditory and visual information, as well as the formatting of text-based messages on in-vehicle displays, remains a largely unknown contributor to the speed and accuracy of a busy driver's interpretation of the information.