Journal of Ergonomics

Qiao et al., J Ergonomics 2016, 6:2
DOI: 10.4172/2165-7556.1000153

Short Communication Open Access

Identifying Demographical Effects on Speed Patterns in Work Zones Using Smartphone Based Audio Warning Message System

Fengxiang Qiao*, **Ruksana Rahman, Qing Li and Lei Yu**

Innovative Transportation Research Institute, Texas Southern University, Houston, TX 77004, USA

***Corresponding author**: Fengxiang Qiao, Innovative Transportation Research Institute, Texas Southern University, Houston, TX 77004, USA, Tel: 713-313-1915; E-mail: likiekie001@gmail.com

Received date: December 12, 2015; **Accepted date**: February 10, 2016; **Published date**: February 16, 2016

Abstract

Objective: The objective of this research is to investigate the impacts of drivers' demographic factors on speed patterns in response to a smartphone based warning message, while driving through the advance warning area of a work zone.

Methodology: A smartphone application was developed using Massachusetts Institute of Technology (MIT) App Inventor 2, which was used to provide test drivers with a warming message on traffic control and incident awareness. Twenty-four subjects with different demographic features (different gender, age, education background, and driving experience) were recruited to drive through an advance warning area of a work zone twice in two scenarios (with and without the warning message). The advance warning area was divided into three segments for the convenience of analysing the significant difference in subjects' reactions to the warning messages and the static traffic control signs, in terms of speed patterns.

Findings: Under a traditional traffic control, drivers' driving speed patterns were not significantly sensitive to the four studied socio-demographic features; but their mean driving speeds and speed variance were noticeable higher than in the situation with an audio warning message. When the smartphone-based messages were provided, drivers drove noticeably slower within the work zone, and the variance became narrower in the most studies of socio-demographic features. Experienced drivers and highly educated drivers drove significantly slower after receiving a warning message from the second and third segment (AWM 2 and 3).

Conclusion: The smartphone-based warning messages were able to help drivers to control their driving speed better for cautious driving in a work zone area, especially for the experienced and highly educated drivers driving through a merging area and an activity area of workers.

Introduction

According to The U.S. Federal Highway Administration (FHWA), hundreds of fatal crashes each year in work zones were recorded nationwide [1]. Taking State of Texas as an example, approximately 15,000 crashes and more than 100 fatal crashes take place each year in Texas highway construction and maintenance zones, the main grounds of which include failure to control speed limit and driver inattention [2]. It is convinced that the conventional static traffic control devices may not be adequate to alleviate crashes in a work zone. To enhance the safety in a conflicting area like work zones, various wireless technologies have been adopted to build up a wireless communication system between vehicle and vehicle, vehicle to infrastructure, and vehicle and workers [3-5], such as Radar, Lidar and Telecommunication (LTE) from a low-cost smartphone [6-8]. A forward collision warning system (FCWS) is one of the advanced strategies, which provides drivers with smartphone-based audio warning messages on the incidents ahead, so that drivers are able to decelerate earlier to avoid a collision with the front vehicle [9,10]. Thus, the speed control is essential to avoid the collision in a work zone. On the other hand, drivers' individual speed control is highly subject to their own timely awareness of the audio warning messages. Based on previous studies, drivers' lane-changing time and distance are sensitive to their socio-demographic factors, while driving through a work zone [11]. For instance, male drives react to the merging sign in a work zone slower than female drivers by 2 sec, and elder drivers react to traffic control signs even slower than young drivers by approximately 3 sec [12]. With regard to this, well-designed warning messages that are the most effective for the majority of drivers may be beneficial for traffic management, in terms of mobility and safety. This paper is proposed to explore the impacts of socio-demographic factors on drivers' driving speeds to a smartphone-based audio warning message, while driving through the advance warning area of a work zone. Since a virtual driving simulator could record drivers' immediate response to the stimulus of static traffic control signs as well as audio warning messages at sampling up to 60 Hz, a driving simulator test was designed.

Subjects and methodology

A smartphone-based audio warning system was designed and developed using the Massachusetts Institute of Technology (MIT) App inventor 2 [8] to provide subjects with a warming message on traffic control and incident occurrence. Twenty-four subjects (12 males and 12 females) were recruited based on Houston 2010 Census data [9,10]. Subjects' socio-demographic factors, including age, gender, driving

Citation: Qiao F, Rahman R, Li Q, Yu L (2016) Identifying Demographical Effects on Speed Patterns in Work Zones Using Smartphone Based Audio Warning Message System. J Ergonomics 6: 153. doi:10.4172/2165-7556.1000153

experience, and education, were involved in the studies. More specifically, 25% of subjects were younger (> 15 and 25 yrs old), 67% was in middle age (> 25 and < 65 yrs old), and 8.34% was elders (65 yrs old). Fifty-four of subjects had less than 2 yrs driving experience, while 46% had longer than 2 yrs. Seventy percent of subjects received their highest educational degree of high school/associate degree or below, while 30% obtained bachelor degree or above.

Each subject was requested to drive through a simulated advance warning area of a work zone (one direction of two lanes with one lane closed) twice for two scenarios, with and without warning messages in a driving simulator. Audio warning messages serve as a supplement for the traditional traffic control signs (static traffic signs). The work zone was about 2,000 m long with the posted speed limit of 48 km/h (30 mph). A warning message was provided at the distance of 47 m to each upcoming static traffic sign. For instance, subjects received an audio message of "Work Zone Ahead" spoken by a woman, while approaching a work zone. Before the driving test, subjects obtained a short training to present the volume of the audio message, and be familiar with the simulated environment and the operation of the driving simulator. The 47 m distance was calculated based on the speed limit (13.41 m/sec) multiplied by the duration of the message (1 sec) and drivers' perception-reaction time (2.5 sec) [11,12], so that subjects may have sufficient time to perceive and react to the messages.

The advance warning message (AWM) area was divided into three segments in sequence (AWM1, AWM2, and AWM3), which starts from the traffic control sign of "Work Zone Ahead" to the sign of "End Work Zone". Each segment has a length of 47 m. Subjects were notified by the first warning message (AWM1), while approaching a work zone, then another warning message (AWM2) to merge and enter an activity area of workers. Within the activity area, drivers may receive the last warning message (AWM3), "Collision ahead, please stop", on the notification of an incident happened ahead. Subjects' significant difference in driving speed within the three segments was examined by a two-factorial ANOVA test. Driving mean speed is considered as a dependent variable, while independent variables include drivers' gender, age, driving experience, and educational levels. The confidence level was 95%. The null hypothesis of this test was no significant mean speed difference among different socio-demographic factors of drivers.

Results and Discussion

Table 1 shows the significance test results on the difference in mean speed among the subjects with different socio-demographic factors in the scenario of no and with audio warning messages. Overall, with the aid of the warning messages, drivers' mean driving speeds were obviously slower than the scenario without the warning messages, especially in the areas for AWM 2 and 3. Moreover, subjects performed relatively higher variance in the scenario without audio warning messages under the most socio-demographic features. In the scenario of no audio messages, male subjects drove comparatively slower than the females by 1.80 to 5.77 m/s in the three segments. The middle-age subjects decelerated from AWM 1 (49.06 ± 2.07 m/s) to AWM 3 (22.57 ± 8.21 m/s) harder than the other two age groups. However, little difference was observed in the mean speeds performed by the subjects with different driving experience and educational levels. Further, the p-values for the four socio-demographic groups are greater than 5%, which means the null hypothesis is accepted. Drivers' socio-demographic factors did not significantly affect their driving speed for a static warning message in the work zone.

Socio-Demographics Features	**Segment**	**No Audio Messages**		**With Audio Messages**	
		Mean Speed (km/h)	P value	Mean Speed (km/h)	P value
Gender Male = 50%, Female = 50%	AWM1	M = 48.64 ± 2.9, F = 50.44 ± 3.5	0.833	M = 47.32 ± 2.53 F = 48.07 ± 1.63	0.727
	AWM2	M = 46.54 ± 2.32, F = 49.04 ± 4.5	0.123	M = 36.66 ± 4.08, F = 36.022 ± 5.07	0.845
	AWM3	M = 22.72 ± 7.9, F = 28.49 ± 8.4	0.060	M = 5.63 ± 2.71, F = 8.76 ± 4.56	0.832
Age Younger (15-24 yrs old): 54%, Middle-age (25-35 yrs old): 3%, Elder (65+) : 13%	AWM1	Y = 51 ± 4.25 M = 49.064 ± 2.07 E = 46.06 ± 1.31	0.330	Y = 47.88 ± 2.32 M = 47.62 ± 1.32 E = 47.69 ± 1.96	0.694
	AWM2	Y = 48.75 ± 4.06 M = 46.75 ± 2.89 E = 46.39 ± 4.41	0.787	Y = 36.66 ± 3.21 M = 35.54 ± 4.79 E = 37.08 ± 1.23	0.865
	AWM3	Y = 27.38 ± 8.23 M = 22.57 ± 8.21 E = 26.02 ± 11.97	0.721	Y = 6.4 ± 1.8 M = 7.8 ± 5.32 E = 4 ± 1.00	0.394
Driving Experience < 2 yrs : 54%, > yrs: 46%	AWM1	2 yrs = 51.32 ± 3.76 5 yrs = 48.03 ± 2.03	0.415	2 yrs = 47.55 ± 1.49 5 yrs = 47.86 ± 2.47	0.234
	AWM2	2 yrs = 48.74 ± 4.86 5 yrs = 46 ± 2.03	0.171	2 yrs = 38.78 ± 3.38 5 yrs = 34.27 ± 2.03	0.049*
	AWM3	2 yrs = 25.88 ± 6.78 5 yrs = 25.29 ± 3.78	0.976	2 yrs = 7.75 ± 1.59 5 yrs = 5.85 ± 0.706	0.049*
Education Highschool/ associate degree or below: 70% Bachelor and plus: 30%	AWM1	HA = 49.38 ± 0.504 BA = 49.92 ± 2.09	0.165	HA = 47.85 ± 2.07 BA = 47.30 ± 1.76	0.420
	AWM2	HA = 47.92 ± 3.76 BA = 47.47 ± 3.95	0.209	HA = 37.20 ± 2.65 BA = 34.23 ± 5.48	0.036*
	AWM3	HA = 26.68 ± 2.24	0.074	HA = 7.77 ± 0.88	0.024*

		BA = 23.00 ± 2.44		BA = 4.24 ± 3.75	
Note: *Significant different					

Table 1: Comparison of speed fluctuations in the scenarios with and without audio warning messages.

When warning messages were provided in another scenario, little difference was found in the mean speed between the first two segments (AWM 1 and 2) for gender groups and age groups (all p-values > 0.05). It is worth noting that in segment AWM3, male and elder subjects drove slower than the other groups, but not significant (males: 5.63 ± 2.71 km/h; elder: 4 ± 1.00 km/h). Likewise, little differences in speed are noticed in the area for AWM 1 between different driving experience groups and educational groups (Driving experience: p-value = 0.234; Education: p-value = 0.420). When subjects entered the areas for AWM 2 and 3, experienced driving subjects and highly educated subjects drove significantly slower than non-experienced driving and lowly educated ones, respectively (Driving experience: p-value_AWM2 = 0.049, p-value_AWM3 = 0.049; Education: p-value_AWM2 = 0.036, p-value_AWM3 = 0.024).

Conclusion

Under a traditional traffic sign control, drivers' speed patterns were not significantly sensitive to their socio-demographic factors, while approaching an incident scene within a work zone; but drivers performed higher mean driving speeds and speed variance than in the situation with the warning messages. When smartphone-based warning messages were provided, drivers drove noticeably slower within the work zone, and the variance in driving speeds became narrower in the most studies of socio-demographic features. Experienced drivers and highly educated drivers drove significantly slower after receiving a warning message from the second and third segment (AWM 2 and 3). In other words, the smartphone-based warning messages were able to help drivers to control their driving speed better for cautious driving in a work zone, especially for the experienced and highly educated drivers driving through a merging area and an activity area of workers.

Acknowledgement

The authors acknowledge that this research is supported in part by the Tier 1 University Transportation Center TranLIVE #DTRT12GUTC17/KLK900-SB-003, and the National Science Foundation (NSF) under grants #1137732.

References

1. U. S. Department of Transportation Federal Highway Administration (FHA) (2015) Work Zone Mobility and Safety Program. 4.0 Work Zone Impacts Management Strategies.
2. Texas Department of Transportation (TxDOT) (2015) Work Zone.
3. Cualain DO, Glavin M, Jones E, Denny P (2007) Distance detection systems for the automotive environment: A review, In Irish Signals and Systems Conference, Derry, N. Ireland.
4. Lee JD, McGehee DV, Brown TL, Reyes ML (2002) Collision warning timing, driver distraction, and driver response to imminent rear end collisions in a high-fidelity driving simulator. Human Factors 44: 314-334.
5. Ren Z, Wang C, He J (2013) Vehicle detection using android Smartphones. Proceedings of the Seventh International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design: 47.
6. Li Q, Qiao F, Yu L (2015) Socio-demographic impacts on lane-changing response time and distance in work zone with drivers' smart advisory system. Journal of Traffic and Transportation Engineering (English Edition) 2: 313-326.
7. Li Q, Qiao F, Wang X, Yu L (2013) Impacts of P2V Wireless Communication on Safety and Environment in Work Zones through Driving Simulator Tests. 26th International Chinese Transportation Professionals Association (ICTPA) Annual Conference, Tampa, Florida.
8. http://appinventor.mit.edu/explore/ai2/tutorials.html.
9. https://www.dshs.state.tx.us/chs/popdat/Census2010.shtm.
10. Qiao F, J Jia, L Yu, Li Q, Zhai D (2014) Drivers' Smart Assistance System Based on Radio Frequency Identification. Transportation Research Record: Journal of Transportation Research Board.
11. Chang MS, Messer CJ, Santiago AJ (1985) Timing Traffic Signal Change Intervals Based on Driver Behavior. Transportation Research Board: 20-30.
12. Li Q, Qiao F, Yu L (2015) Implications of Advance Warning Messages on Eliminating Sun Glare Disturbances at Signalized Intersections. Journal of Traffic and Transportation Engineering