23rd ITS World Congress, Melbourne, Australia, 10–14 October 2016

Paper number ITS-XXXX

Performance Measures of Smartphone Warning Messages in Work Zones and Intersections

Qing Li [1*], Fengxiang Qiao [2*] , Lei Yu [1]

1. Innovative Transportation Research Institute, Texas Southern University, USA.

2*. Innovative Transportation Research Institute, Texas Southern University, 3100 Cleburne St. Houston, Texas 77004, USA. Phone: +1(713)313-1915. Qiao_fg@tsu.edu

Abstract

Work zones and intersections are hot spots of conflict areas, leading to crashes. Though many efforts have been made to enhance the safety, there is little indication that the crashes in the two types of conflict areas are declining nationwide. Thousands of crashes are recorded every year in the United States, which are mainly attributed by the insufficiency in the traffic controls and drivers' misjudgement. To supplement the conventional traffic controls, a smartphone based audio warning message (AWM) was proposed and tested in driving simulators regarding safety of workers in work zones as well as vehicles at intersections for left-turn. Results show that the AWM is able to effectively increase drivers' awareness of traffic signs and dynamic traffic situations, in particular, in a hazardous situation.

Keywords: SMARTPHONE WARNING MESSAGE, WORK ZONES, INTERSECTIONS

The Proposed Smartphone based Warning Messages

Crashes are often observed in a conflict area, such as work zones and intersection. Thousands of crashes are recorded in work zones and intersections every year in the United States [1]. The failure of controlling speed limit and drivers' inattention [2] and drivers' misjudgement [3] are the major causes of crashes in work zones and intersections for left-turn, respectively. With regard to this, a smartphone based audio warning message (AWM) was proposed as a supplement to improve drivers' awareness of dynamic traffic situation and perception of traffic controls in work zones, and instruct drivers to turn left safety at intersections. A smartphone is a portable device and the most prevalent communication tool. Audio messages are able to draw drivers' attention more effective than static traffic control signs do [4]. In particular, the warning messages come from drivers' personal device. Besides, some studies have demonstrated that audio warning messages could change drivers' driving behaviors, including driving speed and manoeuvre [4-6]. Therefore, this research intends to test the effectiveness of the AWM on the drivers' driving behaviros in work zones and intersection clearance for left-turn.

A smartphone-based application (app) was designed and developed using the Massachusetts Institute of Technology (MIT) App inventor 2, to provide drivers with AWMs on traffic control and incident occurrence. When a driver approaches a traffic sign or an incident scene within a certain distance, a suitable AWM from the app will be triggered. The geo-location and the mobility of the vehicles ahead and workers are continuously detected by a Dedicated Short Range Communication (DSRC) technology and sent to a cloud-based Intelligent Transportation System (ITS) management server. Within the certain range, the upcoming vehicles will receive this message by their smartphone app. Local Wi-Fi, cellular data networks, or DSRC system are alternative to build up the communication between the app and the cloud server.

Test Procedure

A hazardous situation (pedestrian/worker crossing) and a potential conflict between left-turn vehicle and opposite through vehicles during clearance were designed in the test scenarios, with and without the AWMs. For a safety issue, a driving simulator was chosen for the tests, with 101 subjects (50 males and 51 females) participated. Seventy-one of them used the app to drive through a typical work zone in a rural area. Meanwhile, thirty of them used the app to cross a signalized intersection with Flashing Yellow Arrow on turn left during clearance in the daytime and at night, respectively. Subjects' driving behaviors were collected and analysed at sampling of 60 Hz.

Various AWMs were designed for specific traffic control signs and hazardous situations, such as "Work Zone Ahead", "Pedestrian Crossing", or "Yield, wait for further instructions". Except the yield message that lasts 2 sec, other messages were shorter than 1 second. In the scenarios with the app, subjects received an AWM at 47 and 107 m away to the traffic sign or occasion site for 1 sec and 2 sec message, respectively, which consider the travel distance for drivers to percept and react for 2.5 sec [7] and breaking distance of 36 m [8].

Test Results

With the AWMs, subjects drove slowly to approach the work zone (Mean_noAWM: 62.3 km/h, Standard deviation SD 11.7; Mean_AWM: 52.8 km/h, SD 8.1), and further slower to pass the traffic sign of "Right Lane Closed" (in the middle of the advance warning area) (Mean_noAWM: 55.5 km/h, SD 9.4; Mean_AWM: 49.7 km/h, SD 5.6). In other words, the AWM can help subjects to better control their speeds to around the speed limit 48 km/h. Without the AWM, 63.83% of subjects changed their lane and merge at the last minute, in the transition area (55 m long next to the buffer area in workers' activity area). It is worth noting that the buffer area is a hot spot of incidence in work zones. This implies that the last minute action may lead to a higher risk of crashes. When the AWM was applied, most of subjects (95.74%) completed their lane change actions in the advanced warning area. Thus, the AWMs could help subjects to effectively prevent crash from occurring. In the activity area of the work zone, 29% percent of subjects were not aware of the worker's crossing and hit the worker unconsciously. The rest subjects stopped for the worker at the distance of about 14.1 m (SD 8.2), whereas all subjects stopped for the worker at a twice-longer distance (28 m, SD 11.2).

During the intersection clearance with the aid of AWM, subjects drove significantly slower to enter the intersection by about 16km/h (p-value_daytime:1.08E-04; p-value_night:1.00E-03), accelerated/decelerated significantly smoother (p-value: 5.00E-03), braked significantly earlier for the conflicting vehicle by 19.49 m for daytime and 20.5 m at night (*p*-value_daytime: 3.43E-05; *p*-value_night:4.97E-04), and completed the left-turn significantly quicker by 2.7 sec for daytime and 2.1 sec at night (*p*-value_daytime: 8.96E-04; *p*-value_night: 2.51E-04). Without the AWM, twenty-three percent and 27% of subjects had crashes with the conflicting vehicles in the daytime and at night, respectively. No crashes were observed in the scenario with the AWM.

Conclusions

It is concluded that, the smartphone AWM is able to improve drivers' driving behaviors by effectively enhance drivers' awareness of traffic signs and dynamic traffic situations, especially in a hazardous situation. Simulator test results show that, such AWMs work very well in work zone areas and signalized intersections.

References

1. FHWA. (2015). Facts and Statistics-Work Zone Injuries and Fatalities. 2015. http://www.ops.fhwa.dot.gov/wz/resources/facts_stats/injuries_fatalities.htm. (Accessed on December 28, 2015).
2. Texas department of Transportation (TxDOT). (2015). Work Zone. Website: http://www.txdot.gov/inside-txdot/division/traffic/safety/share-road/work-zones.html , Accessed December 2, 2015.
3. Wang, X., M. Abdel-Aty. (2013). Analysis of left-turn crash injury severity by conflicting pattern using partial proportional odds models. *Journal of Accident; analysis and prevention* 40(5):1674-82, 2008. Accessed July 18, 2015.
4. Li, Q., Qiao, F. (2014). How Drivers' Smart Advisory System Improves Driving Performance? A Simulator Imitation of Wireless Warning on Traffic Signal under Sun Glare. LAMBERT Academic Publishing. ISBN-13: 978-3-659-57193-0.
5. 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),* Volume 2, number 5, October 2015. Elsevier Publishing.. http://dx.doi.org/10.1016/j.jtte.2015.08.003.
6. Rahman, R., Qiao, F., Li, Q, Yu, L., Kuo, P.-H. (2015). Smart Phone Based Forward Collision Warning Message in Work Zones to Enhance Safety and Reduce Emissions. *Presentation and Proceedings in the 94th Transportation Research Board Annual Meeting, National Academy of Sciences*, Washington, DC, January 11-15, 2015.
7. Chang, M S, Messer, C J., Santiago, A J. (1985). Timing Traffic Signal Change Intervals Based on Driver Behavior. In Transportation Research Record*: Journal of The Transportation Research Board,* No. 1027, Transportation Research Board of the National Academies, Washington, D. C., pp 20-30.
8. Garcia, R. (2015). Roadway Design Manual, Texas Department of Transportation (TxDOT), Revised October 2014. (Accessed on July 11, 2015)