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Variable Message Sign strategies for Congestion Warning on Motorways

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1. Introduction Motorways are the safest roads by design and regulation. Still, motorways in the European Union accounted for nearly 27,500 fatalities from 2004 to 2013 (Adminaite, Allsop, & Jost, 2015). The likelihood of the occurrence of rear-end collisions increases with higher traffic densities. This is alarming considering the proportion of traffic on motorways has increased over the past decade (Adminaite et al., 2015). The initiation of traffic congestion is characterized by changing flow conditions which can pose a serious safety hazard to drivers (Marchesini & Weijermars, 2010). Especially, hard congestion tails force drivers to change from motorway speed to stopped conditions, which can result in severe rear-end crashes (Totzke, Naujoks, Mühlbacher, & Krüger, 2012). Fatalities and injuries due to motorway crashes represent a threat to public health and should be reduced as much as possible. 2. Congestion warning and VMS The effects of congestion on safety generally depend on the extent to which drivers are surprised by the congestion. The type of congestion, the location of the queue, and the use of variable message signs to warn drivers in advance can influence whether drivers are able to decelerate safely or not (Marchesini & Weijermars, 2010). Variable message signs (VMS) are considered one of the primary components of Intelligent Transportation Systems (ITS) and provide motorists with route-specific information or warnings. The advantage of VMS is that they can display traffic state messages dynamically and in real time. Accordingly, VMS can reduce uncertainties and prepare drivers to anticipate and safely adapt to a traffic event (Arbaiza & Lucas-Alba, 2012). The Easyway II Project is one of the important guidelines for VMS harmonization in Europe that have been developed to update and improve current VMS signing practices.

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Despite this effort towards harmonization, still a broad variety of sign designs, message types and field placements are applied to warn drivers about congestions tails. Also, empirical research testing the available guidelines provides inconsistent findings. Hence, further scientific research is needed to shed more light on the effectiveness of different VMS types, message designs, and placement to influence save driving performance. 3. Objectives Available guidelines suggest that advance warning messages should be placed at 1 km, 2 km, and 4 km prior to a traffic event if the purpose is to allow drivers to anticipate safely (i.e., tactical use of VMS), and no further than 10km prior to a traffic event when the purpose is to influence route choice, rather than driver behavior (i.e., strategic use of VMS) (Evans, 2011; Federal Highway Administration, 2000). Gantry overhead signals and cantilever side poles are the most common VMS types. The Easyway guidelines contain different formats for congestion warning messages, namely, messages containing a) pictograms of congestion with or without a redundant text unit, b) a maximum of 4 information units, and c) with or without distance information (Arbaiza & Lucas-Alba, 2012). The objective of this study was to analyze the effect of different congestion warning VMS formats on visual- and driver behavior on motorways leading to a hard congestion tail. To that purpose, we used a driving simulator to observe accidents, speed and deceleration, and an eye tracker to monitor gaze fixations. 4. Method Data of thirty-six drivers (male and female) with an average age of 43 years were collected. We implemented a within-subject design with all participants exposed to seven VMS scenarios in randomized order. The apparatus used was the driving simulator of the Transportation Research Institute (IMOB, UHasselt), which is a 'medium-fidelity' simulator (STISIM M400; Systems Technology Incorporated) with a 'fixed-base' logging a wide range of driving parameters. The mock-up consists of a Ford Mondeo with a steering wheel, direction indicators, brake pedal, accelerator, clutch, and manual transmission. The virtual environment is visualized through three projectors on a 180° screen including three rear-view mirrors. Furthermore, we used the eye tracking system FaceLAB 5.0 to record eye movements. The eye tracker was installed on the dashboard of the driving cab and accommodated head rotations of +/- 45 ° and gaze rotations of +/-22 ° around horizontal-axis. 5. Results We found that drivers with higher initial speeds stop closer to the congestion tail and are more likely to have a rear-end crash. A gantry-mounted congestion warning with a pictogram and the word "congestion" presented at a distance of 1km resulted in lowest mean speeds and smoothest deceleration for all drivers. A congestion warning at a distance of more than 3km had no effect on driver behavior in the critical zone before the congestion tail. Eye fixations for gantry mounted VMS were more frequent, but shorter in time as compared to cantilevers. Finally, the imposed visual load on drivers increased with more information units on the VMS. 6. Conclusion The distance between the congestion warning and the actual congestion tail is a crucial aspect when it comes to the effectiveness this kind of VMS. VMS congestion warnings located too far away lose their effect in the critical approaching zone, and VMS congestion warnings located too close might compromise safe deceleration. A gantry-mounted congestion warning displaying the word 'congestion' together with a pictogram located at 1km before the congestion tail was clearly noticed from all lanes without imposing too much visual load, and had the best impact on speed, resulting in smooth deceleration and safe stopping distances. In contrast, a congestion warning located more than 3km from the actual congestion tail had no safety effect as drivers started to speed up again before reaching the critical approaching zone. 7. Acknowledgment This publication was made possible by the NPRP award [NPRP 9-360-2-150] from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the author[s]. 8. References   Adminaite, D., Allsop, R., & Jost, G. (2015). ETSC - RANKING EU PROGRESS ON IMPROVING MOTORWAY SAFETY PIN Flash Report 28, (March). https://doi.org/10.1016/j.trf.2014.06.016 Arbaiza, A., & Lucas-Alba, A. (2012). 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