Transportation Research Part F 46 (2017) 524–536

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

The effects of indicating rear-end collision risk via variable message signs on traffic behaviour

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ARTICLE INFO

Article history:
Received 29 October 2015
Received in revised form 19 August 2016
Accepted 16 September 2016
Available online 24 October 2016

Keywords:
Variable message sign
Risk message
Traffic behaviour
Risk compensation

ABSTRACT

Research on the effects of safety messages on driving behaviour remains relatively scant. The present study aims to manipulate drivers' risk perception by displaying messages containing risk level information, and measure the behavioural implications. Using proximal safety indicators (i.e. rear-end collision risk index), the risk level in each 5 min time interval was determined by traffic conditions in the previous 5 min interval based on a linguistic scale of "low", "medium" and "high" risk. The risk level was displayed on Variable Message Signs (VMS) and changes in risk perception indicators (i.e. speed, time to collision and safety margin) were compared with null messages, while keeping other conditions similar in terms of driving lane and time (day/night). The experimental data set including about 43,000 vehicles was obtained by inductive loop detectors at one freeway site over two days. The control sample, where null messages were displayed, included about 40,000 vehicles and was also obtained at the same location using the same method on two different days. Results suggest that the same message may evoke opposite effects in different situations. Risky behavioural adaptations were observed under low and medium risk messages during night time. The effects of high risk messages, however, were consistently related to safe adaptations. The effects of messaging on rear-end conflicts were significant only in the fast lane at night time. The results could be used in regulating the activation algorithm for safety messages in real time VMS.

1. Introduction

Road traffic safety is a major concern in modern approaches to road transport. While low- and middle-income countries have a considerably greater share of road victims than high income countries on a global basis (WHO, 2013), theoretical and practical advances have emerged in leading countries in road safety, where system and behavioural theories have been developed.

The systems theory recognizes human fallibility, but argues that the system should be adequately tailored to human capabilities and limitations (OECD, 2008). Hence, adapting technical systems to human cognitive and physical capabilities and limitations will result in fewer errors by different types of road users and consequently safer roads. Interestingly, however, this does not necessarily translate into a safer road system, because perception of a safe environment (i.e. a safe driving

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http://dx.doi.org/10.1016/j.trf.2016.09.019
1369-8478/

condition) may encourage the road users to behave in a riskier and compensatory fashion (Vrolix, 2006). This offsetting reverse effect and its hypothetical formation mechanisms have been widely discussed and turned into "Risk Compensation" and "Risk Homeostasis" theories (Wilde, 1982, 1998; Wilde & Robertson, 2002).

It has been shown that risk perception is a predictor of risky behaviours in the traffic context (Lund & Rundmo, 2009; Machin & Sankey, 2008). As suggested by the Risk Homeostasis Theory (RHT) individual drivers continuously compare the instantaneously perceived level of risk with the level of risk they are willing to take (i.e. accepted or analogously target level of risk) (Wilde, 1982). When there is discrepancy between the two levels, the drivers are assumed to alter their behaviour. This either results in safer or riskier actions in order to compensate for the difference between the two levels. Behavioural adaptation may be momentary, for example in the form of changing the way a vehicle is followed by another vehicle in a car-following situation.

The RHT concept has been included in more recent behavioural theories about traffic safety (Elvik, 2009) and conceptualized in diverging ways, for instance by considering the effectiveness of traffic safety solutions to the society-wide road safety policing. Addressing the compensatory effect of safety measures has been subject of relatively few observational studies, particularly in engineering fields of research. Measuring the level of risk perceived by the drivers in a special driving context is a main challenge, particularly in real world experiments. The RHT is rather complicated to test empirically and there is very limited evidence from observational studies supporting the RHT. Particularly using questionnaire-based instruments to measure risk perception may not suffice, because such instruments only yield a general overview of risk perception regarding a special hazard, rather than a momentary measurement.

Behavioural adaptation is a key issue when solutions in intelligent transportation systems (ITS) are in place as a support to human cognitive limitations, especially when tailoring the environment to human capabilities. That is because the information intake by such ITS solutions intervenes with the level of risk perceived by the drivers. In informing ITS, for instance, the drivers may be assisted by directly presenting the level of risk of collision as a cue to them, in a particular driving situation, by means of a variable message sign (VMS). Such a system may provide information based on evidence from the "objective" measures of risk, for example by observing the traffic flow at a micro level and then giving inferences regarding the crash risk based on statistical risk estimations. Although it may be considered as an intervention to help the driver to better perceive the risk level, it should be noted that the risk level delivered by the system should also correspond to the "subjective risk" perceived by the driver so that he/she will mind the information. The way such a correspondence is achieved is an important problem in dealing with smart designs (Popkema & van Schagen, 2006).

The present study is an attempt to explore the effect of manipulating drivers' risk perception through displaying the level of rear-end collision risk on VMS on drivers' behavioural offsets, using an experimental real world study based on Risk Compensation Theory. Level of rear-end collision risk will be measured and displayed to drivers on a VMS using a "Low", "Medium" or "High" risk scale in each particular time interval. The risk messages will be based on the evidence captured in the previous 5 min time interval. Vehicles' speed (Assum, Bjørnskau, Fosser, & Sagberg, 1999), time to collision (TTC) (Horst, 1991) and Safety Margin (SM) (Lu, Cheng, Lin, & Wang, 2012) are used as indicators of risk perception. Change in values of safety indicators compared with a "no effect" (Null) message gives the behavioural offsets, attributable to driving environment as well as the message.

Assessing messages on VMS has traditionally been subjected to many studies. Most studies in this area investigated the dynamic effects of messages on traffic diversion, mainly with the aim to improve traffic network performance. Studies of this type have mainly been conducted with observational data (Erke, Sagberg, & Hagman, 2007; Foo, Abdulhai, & Hall, 2008), the stated preference method (Chatterjee, Hounsell, Firmin, & Bonsall, 2002; Peeta, Ramos, & Pasupathy, 2000; Ratrout & Issa, 2014; Wardman, Bonsall, & Shires, 1997), the revealed preference method (Richards & Mcdonald, 2007; Xu, Sun, & Peng, 2011) and using a driving simulator (Yan, Wu, Yan, & Wu, 2014).

Safety effects of messages have also been subjected to another group of VMS assessment studies. These studies have mainly used observational methods (Al-Ghamdi, 2007; Rämä & Kulmala, 2000; Sui & Young, 2014), a combination of observations and interviews (Luoma, Rämä, Penttinen, & Anttila, 2000; Tay & De Barros, 2010) and driving simulator (Boyle & Mannering, 2004).

However, evaluation of messages containing risk level information has not been subject of much research in safety assessment of VMS. Using the flexibilities of variable message signs alongside the capabilities of data gathering instruments in displaying real-time messages containing the level of collision risk makes it possible to study the effect of manipulating the risk perception of drivers in the present study.

1.1. Aims and hypotheses

This study aims to investigate the effects of safety messages containing risk level information on behavioural adaptations. The information comes from categories of the risk values measured, which are based on traffic data at a micro level and displayed on a (VMS) in this system. The main hypothesis in this study is that displaying messages of low, medium and high risk level to drivers cause behavioural adaptations. Furthermore, because of the differences in risk perception in different situations, adaptation in driving behaviour may vary in different driving situations.