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Improving homogeneity by dynamic speed limit systems

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ABSTRACT

Homogeneity of driving speeds is an important variable in determining road safety; more homogeneous driving speeds increase road safety. This study investigates the effect of introducing dynamic speed limit systems on homogeneity of driving speeds. A total of 46 subjects twice drove a route along 12 road sections in a driving simulator. The speed limit system (static–dynamic), the sophistication of the dynamic speed limit system (basic roadside, advanced roadside, and advanced in-car) and the situational condition (dangerous–non-dangerous) were varied. The homogeneity of driving speed, the rated credibility of the posted speed limit and the acceptance of the different dynamic speed limit systems were assessed.

The results show that the homogeneity of individual speeds, defined as the variation in driving speed for an individual subject along a particular road section, was higher with the dynamic speed limit system than with the static speed limit system. The more sophisticated dynamic speed limit system tested within this study led to higher homogeneity than the less sophisticated systems. The acceptance of the dynamic speed limit systems used in this study was positive, they were perceived as quite useful and rather satisfactory.

1. Introduction

Safe and obeyed speed limits are the backbone of a safe traffic system (Besseling and Van Boxtel, 2000; Vlassenroot et al., 2007). However, speed limits are violated on a large scale every day. Throughout Europe, typically 40–50% of the drivers are driving above the posted speed limit (OECD, 2006). These days, for specific purposes, electronic speed limit signs are being introduced at different countries around the globe, e.g. Australia, Germany, the Netherlands and Sweden. Such electronic signs are more flexible and allow speed limits to be adapted from a distance, automatically or manually, making it possible to show different speed limits at different times of the day and different days of the week. In Melbourne for example, they are used in school zones to set lower speed limits during school hours. With respect to road safety, such dynamic speed limit systems have potential advantages over the current static speed limit system (Ha et al., 2003; Rämä, 1999). For example, Abdel-Aty et al. (2006) found, that dynamic speed limits can be used to effectively reduce the hazard at certain locations on interstates. This study also concluded, that travel time is positively affected when dynamic speed limits are used in off-peak traffic. Alianahi et al. (1999) found dynamic speed limit systems to be effective in free flow conditions, which means traffic conditions without congestion.

A dynamic speed limit system offers the opportunity to adapt (default) speed limits to local and temporal circumstances in such a way that safety and credibility of speed limits can be optimized. Highly credible speed limits are speed limits that are considered as reasonable by road users, given the road characteristics and circumstances. Credibility of the speed limit rests on drivers' perception of their appropriateness in terms of specific driving conditions (Fildes and Lee, 1993; Goldenbeld and Van Schagen, 2007). Credible speed limits contribute to road safety as increased credibility leads to better speed limit compliance (Goldenbeld and Van Schagen, 2007; Van Nes et al., 2008) and is likely to improve homogeneity of traffic flows. Reduction of speeding and increase of homogeneity are known to lower the risk and severity of traffic accidents (Aarts and Van Schagen, 2006; Carsten, 2002; Dewar and Olson, 2002; Fildes and Lee, 1993; Goodwin et al., 2006; Wegman and Aarts, 2006).

Technological systems and design of dynamic speed limit systems are still under development. For future implementation of dynamic speed limit systems, it is likely that different levels of sophistication will be installed, ranging from simple roadside information systems in the near future, to more advanced roadside information system and in-car information systems in the more distant future. A range of methodological approaches and research foci were used to study the safety potential of dynamic speed limit

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systems. Field trials, simulator studies and mathematical modelling methods were used to study the effects on important variables like the homogeneity of driving speeds (Fildes and Lee, 1993; Hauer, 1971; Lave, 1985; Lee et al., 2006; Regan et al., 2006) and other indicators of safety related speeding behaviour (e.g. Kelly et al., 2007). Previous empirical studies connected the usage of dynamic speed limit systems with less critical incidents, such as conflicts with other drivers (Carsten, 2002), an increase in preventive attitudes about speeding behaviour and the perception of the speeding behaviour (Vlassenroot and De Mol, 1999), or an increase in attention to seek cues on potential hazards (Luoma et al., 2000; Rämä and Kulmala, 2000). In a simulator, Peltolta (2002) replicated the field trial (Rämä and Kulmala, 2000) and questionnaire results of Luoma et al. (2000) using different sophistications of dynamic speed limit systems (advanced roadside versus in-car system) in different situational weather conditions (icy versus non-icy). This study found that drivers with an in-car dynamic speed limit system adapted their behaviour most according to the system message. They increased their speeds on non-icy sections and reduced speed on icy road sections. Fildes and Lee (1993) found empirical support for the credibility of dynamic speed limit systems due to environmental factors such as changing weather conditions or school zones. Furthermore, in a questionnaire study, Goldenbeld and Van Schagen (2007) also found that certain road characteristics influence the perceived credibility of speed limits. Van Nes et al. (2008) varied some of these road characteristics in a driving simulator study and assessed the credibility of the speed limits and the speed behaviour at these road sections. The results of this study showed, that the credibility of speed limits has an effect on average speed and speeding; subjects showed lower speeds and less speeding at road sections with highly credible speed limits compared to road sections with less credible speed limits.

Dynamic speed limits are technically feasible and are regarded as promising to increase road safety (Abdel-Aty et al., 2006; Alianahi et al., 1999; Erke et al., 2007). An important factor underlying the success of dynamic speed limit systems is the increase of credibility that can be achieved (Peltolta, 2002).

This study aims to investigate the effect of dynamic speed limits on homogeneity of driving speeds, explicitly taking into account the credibility of the static and dynamic speed limits. Moreover, the study investigates the effects of three different dynamic speed limit systems with distinct levels of sophistication, and a regular static speed limit system in different situational conditions (dangerous–non-dangerous). In this study, the dynamic speed limit system is defined as the total technical system to implement dynamic speed limits: the electronic sign (variable message sign) to display the speed limit information, as well as the algorithm that determines which speed limit to show, the positioning and frequency of the speed limit sign, possible additional in-vehicle information devices and the possible additional information on the sign for explanatory or informative purposes. When referring to static or dynamic speed limits, the speed limit itself is meant.

For possible future implementation, the usage and effectiveness of dynamic speed limit systems will strongly depend on the acceptance by drivers (Brookhuis and De Waard, 1999; Goodwin et al., 2006; Marell and Westin, 1999; SARTRE 3, 2004). Previous research suggests a higher acceptance for systems which continuously display the current speed limit (Brookhuis and De Waard, 1999). To increase insight in the acceptance of different dynamic speed limit systems, this study briefly investigates the acceptance of the systems tested in the present paper.

2. Method

2.1. Design of the study

A driving simulator was used to study the effect of static versus dynamic speed systems on speed homogeneity, in two traffic conditions (dangerous versus non-dangerous). A driving simulator offered the opportunity to carefully manipulate dangerous and non-dangerous situations as well as different dynamic speed limit systems. For the dynamic systems, three different dynamic speed limit systems with distinct levels of sophistication were compared. A schematic representation of the study design is given in Table 1.

The effects of static versus dynamic speed limits in dangerous and non-dangerous conditions were tested within subjects by two subsequent rides in the simulator of about 20 min each. The level of sophistication of the dynamic speed limit system was tested between subjects; to test that within subjects as well would require two more rides in the simulator resulting in higher changes of simulator sickness as well as lots of repetitions leading to possible order effects.

The speed limit system (static versus dynamic) was varied within subjects between the two rides. The first ride was carried out with the static speed limit system and the second ride with the dynamic speed limit system. These rides were in fixed order, as subjects would be possibly influenced in their driving behaviour when driving with the static speed limit system after having driven with the dynamic speed limit systems. They would then be aware of the alternative speed limits for different situational conditions.

The situational condition (dangerous versus non-dangerous) was varied within subjects between the different road sections. The subjects drove along a simulated network of 12 rural roads. The first six road sections were exactly the same as the second six road sections, the only difference was the situational condition: dangerous or non-dangerous. Those road sections labelled dangerous the first time were non-dangerous the second time and vice versa. All subjects drove the route twice; the first time speed limits were normal, static signs and the second time speed limits were dynamic. In case of the static speed limit system, the speed limit was fixed at 80 km/h for all 12 road sections. For the dynamic speed limit system, the speed limit was either 70 km/h (for the six dangerous situations), or 90 km/h (for the six non-dangerous situations). Over the entire route, the average speed limit was 80 km/h for both the static and the dynamic speed limit system. The type of dynamic speed limit systems was varied between subjects for the second ride.

2.2. Apparatus

The study was conducted in a fixed-base driving simulator. A web-based questionnaire was used to obtain insight in the acceptance of the dynamic speed limit systems, the credibility of the speed limits and some demographic variables.

Table 1
Design of the study.

Subjects	Static speed limit (12 road sections)		Dynamic speed limit (12 road sections)	
	Dangerous (6) 80 km/h	Non-dangerous (6) 80 km/h	Dangerous (6) 70 km/h	Non-dangerous (6) 90 km/h
01 . . . 16			Basic roadside system	
17 . . . 30			Advanced roadside system	
31 . . . 46			Advanced in-car system	