Applied Ergonomics 61 (2017) 44–52

Contents lists available at ScienceDirect

Applied Ergonomics

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

Traffic management: Assessing various countermeasures to improve detection failure of changes in speed limit signals

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ARTICLE INFO

Article history:
Received 12 June 2016
Received in revised form
7 December 2016
Accepted 12 December 2016

Keywords:
Change blindness
Variable speed limit
Flasher

ABSTRACT

Under certain circumstances, drivers fail to notice changes in electronic speed limits. A video-based study was performed to reveal which countermeasures would improve drivers' ability to detect changes in electronic speed limits. Countermeasures included leaving electronic signs blank prior to a speed limit change and adding motion signals by means of flashing amber lights or a wave. A video representing a motorway was shown repeatedly to 255 participants. They were instructed to press the space bar when detecting a change. The video was viewed 13 times before the speed limit changed. Results showed that leaving signs blank prior to the change instead of displaying speed limits continuously did not alter change detection, whereas flashers and waves eroded detection of the changed speed limit. This suggests that using flashers and waves to attract attention to electronic signs in fact decreases people's ability to process the information contained in the signs.

1. Introduction

As part of dynamic traffic management, variable speed limits have been introduced on motorways around the world. By adjusting these speed limits to fit the situation on the road, road authorities can improve both traffic safety as well as traffic circulation (Nissan, 2010; Van Nes et al., 2010). However, Nissan's simulation studies (2010) point out that the effectiveness of the system depends highly on speed limit compliance. To achieve speed limit compliance, speed limits must be perceived, comprehended, accepted and retained (McGuire, 1968). The design of standard speed limits, contrary to other types of roads, cover most of these aspects; they have proven to be relatively well observed, to be considered meaningful, and to be relatively well recollected by drivers (Al-Gadhi et al., 1994; Harms and Brookhuis, 2016; Hoogendoorn et al., 2012; Johansson and Backlund, 1970; Johansson & Rumar, 1966; Lajunen et al., 1996; Luoma, 1991; Rämä, 2001). However, variable speed limits differ from standard speed limits considerably in the sense that variable speed limits *change*.

A large body of research has shown that under various circumstances humans fail to readily detect changes in the environment around them that are clearly visible (see Rensink, 2002; Simons and Levin, 1997; for reviews). Even changes that are expected can easily be missed (Simons and Mitroff, 2001). This phenomenon – known as change blindness – has been repeatedly proven to impact human behaviour in many daily life activities, including participating in traffic. Change blindness generally occurs when transient motion signals that normally accompany a change are lacking (Zheng and McConkie, 2010). When electronic speed limits change because the limit increases or decreases, the change itself will lack motion signals for most drivers. This is because these speed limits are displayed on subsequent overhead gantries, so for most drivers the change will occur while they are driving from one gantry to the next. This makes it difficult to detect the change. A driving simulator study by Harms and Brookhuis (2016) pointed out that drivers indeed have difficulties with noticing changes in variable speed limits. Participants, unaware of the fact that they participated in a change blindness study, drove the same route twenty times to familiarise them with the route and the road equipped with overhead electronic speed limits. During the 19th drive, the speed limit changed from 80 km/h to 100 km/h. Of all drivers, 58.3% failed to notice this change even after repeated exposure to the new speed limit. Failing to perceive that a speed limit has changed yields an incorrect outcome in the first step of

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http://dx.doi.org/10.1016/j.apergo.2016.12.005
0003-6870/

McGuire's (1968) information-processing steps to obtain compliance.

The perception of *changes* in electronic speed limits is an important prerequisite for speed limit compliance on roads equipped with variable speed limits. The current study is a follow-up to Harms and Brookhuis (2016). The objective of the current study is to improve drivers' ability to detect changes in electronic speed limits. To this end, countermeasures will be assessed in order to improve the effectiveness of variable speed limits as a traffic management measure. Additionally, this study aims to answer the question whether reintroducing motion signals – such as the commonly used flashers on electronic road signs – are in fact capable of capturing attention and redirecting it to the information contained in the signs.

2. Theoretical framework

Some studies have shown that many drivers have difficulties with detecting changes while driving, even when the changes are traffic related (e.g. Charlton and Starkey, 2013; Galpin et al., 2009; Lee et al., 2007; Velichkovsky et al., 2002). Failing to detect approaching 'hazards', such as pedestrians, motorcyclists and cars crossing the road, may result in collisions and near-crashes (Uchida et al., 2011; White and Caird, 2010). Failing to perceive changes in road signs results in incorrect interpretations of the information provided on which drivers base their driving behaviour (McGuire, 1968). This may lead to drivers speeding involuntarily and unknowingly (Harms and Brookhuis, 2016); to drivers failing to realise that the priority at a familiar intersection they are about to cross has changed (Martens and Fox, 2007); and eventually to fatal accidents, as shown by Muller and Verweij (1991). They investigated a fatal collision between a tram and a car at a signalised intersection. Whereas the tram driver stated he had perceived his sign giving him right of way, analysis of the traffic control system revealed that in fact this was not the case. Although the sign usually gave the tram driver right of way, this time it signalled to yield; a change the tram driver had failed to notice.

Research on change blindness has shown that the lack of motion signals is a large contributor in the origin of change blindness (Galpin et al., 2009; Grimes, 1996; O'Regan et al., 2000; Rensink, 2002; Rensink et al., 1997; Uchida et al., 2011). Unless one is carefully and intensely focussing on a specific location, motion cues by nature attract attention to the stimulated visual event (Corbetta and Shulman, 2002). Moreover, adding motion transients to the change or its location may improve detection rates (see e.g. Klein et al., 1992; Scholl, 2000; Zheng and McConkie, 2010). Since changes in electronic speed limits lack motion transients for most drivers, adding them might possibly attenuate change blindness. However, motion cues may also become distractors. For example, when two changes happen simultaneously, change detection for the changing target is attenuated (O'Regan et al., 1999; Rensink et al., 2000). It is therefore uncertain whether motion cues such as commonly used flashing amber lights will attenuate or increase change blindness for changes in electronic speed limits.

Studies have also shown that it is more difficult to detect a change when already visible information changes, as compared to information that is added to a scene (for a review see Rensink, 2002). For example, Mondy and Coltheart (2000) found that when the meaning of a scene or object remains unaltered, changes to whole objects are identified more often than changes to objects which are part of a larger object. Similarly, Davies and Beeharee (2012) found that newly inserted objects on a smartphone screen are more often correctly identified than changes within on-screen objects. These findings are particularly interesting for electronic road signs, as road authorities may choose to either display speed limits on them continuously or only in case of deviations. The first approach would lead to continuously changing speed limits, which can be considered as an information change. The latter results in electronic signs which are alternatingly blank or displaying a speed limit. This can be considered an information addition.

3. Method

3.1. Experimental design

Based on the literature review described in the Theory section, adding motion signals and turning the change into an information addition have been identified as possible countermeasures and are described in more detail below. Both were assessed by showing participants a short video which represented a motorway equipped with three gantries displaying variable speed limits on electronic signs per driving lane. The video was shown fifteen times and was preceded by a practice video. To familiarise participants with the motorway and its surroundings, the first, experimental, video was displayed unchanged and viewed thirteen times (see also Harms and Brookhuis, 2016; Martens and Fox, 2007). To prevent any interference from participants who might expect the change to happen in the last (15th) video, the change was introduced in the 14th video. In this video, the speed limits were changed from 100 km/h to 80 km/h on the second and the third gantries. To ensure that changes would be attributed to elements of the road and its surroundings, no other traffic was present in the videos. Video 15 consisted of a recollection test. Table 1 gives an overview of all speed limits encountered per video. Route-familiarity was promoted to resemble real-life conditions, as most journeys are driven on familiar roads (Dicke-Ogenia, 2012). This is relevant, as drivers who have driven a road repeatedly, have a tendency to shorten their glance duration for traffic signs. Thus, making them more prone to make change detection errors (Martens and Fox, 2007).

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.apergo.2016.12.005.

To detect whether participants noticed a change, an intentional approach – commonly used for change blindness paradigms – was used. With this approach, the observer is instructed to fully expect a change and devotes all available resources to detecting it (cf. Simons and Mitroff, 2001). Despite all resources being allocated to the task, change blindness is generally found under these conditions (e.g. Galpin et al., 2009; Grimes, 1996; Lee et al., 2007; O'Regan et al., 2000; Rensink et al., 1997; Velichkovsky et al., 2002).

In a 2×3 design, change detection was measured for the type of change (Information Addition and Information Change), under three conditions of information discriminability (Control, Flash and Wave, see Table 2). For Information Addition, the electronic

Table 1
The four speed limits participants encountered per video. The first was displayed on a fixed roadside sign and the others on electronic signs on subsequent overhead gantries. For video 14, * is the first changed speed limit and ** is the second changed speed limit. Video 15 did not display any speed limits as it was a recollection test.

	Speed limit 1 roadside sign	Speed limit 2 gantry 1	Speed limit 3* gantry 2	Speed limit 4** gantry 3
Video 1–13	100 km/h	100 km/h	100 km/h (see Fig. 1)	100 km/h
Video 14	100 km/h	100 km/h	80 km/h (see Fig. 2)	80 km/h (see Fig. 3)