Accident Analysis and Prevention 117 (2018) 288–297

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Using road markings as a continuous cue for speed choice

Samuel G. Charlton*, Nicola J. Starkey, Neha Malhotra

Transport Research Group, School of Psychology, University of Waikato, New Zealand

ARTICLE INFO

Keywords:
Driving simulator
Explicit instructions
Implicit cues
Road markings
Speed perception
Essential recognisability characteristics

ABSTRACT

The potential for using road markings to indicate speed limits was investigated in a driving simulator over the course of two sessions. Two types of experimental road markings, an "Attentional" set designed to provide visually distinct cues to indicate speed limits of 60, 80 and 100 km/h, and a "Perceptual" set designed to also affect drivers' perception of speed, were compared to a standard undifferentiated set of markings. Participants (n = 20 per group) were assigned to one of four experimental groups (Attentional-Explicit, Attentional-Implicit, Perceptual-Explicit, Perceptual-Implicit) or a Control group (n = 22; standard road markings). The Explicit groups were instructed about the meaning of the road markings while those in the Implicit and Control groups did not receive any explanation. Participants drove five 10 km simulated roads containing three speed zones (60, 80 and 100 km/h) during the first session. The participants returned to the laboratory approximately 3 days later to drive five more trials including roads they had not seen before, a trial that included a secondary task, and a trial where speed signs were removed and only markings were present. The findings indicated that both types of road markings improved drivers' compliance with speed limits compared to the control group, but that explicit instruction as to the meaning of the markings was needed to realise their full benefit. Although previous research has indicated the benefit of road markings used as warnings to indicate speed reductions in advance of horizontal or vertical curves, the findings of the present experiment also suggest that systematically associating road markings with specific speed limits may be a useful way to improve speed limit compliance and increase speed homogeneity.

1. Introduction

After 80 years of driver behaviour research, speed choice and speed management remain among the most challenging problems in road transport. The focus of the research described in this paper was to explore the potential for using road markings to indicate speed limits to drivers. The simulator experiment described in this paper represented a first step in comparing different types of centre and edge line marking schemes in terms of their effect on speed choice, compliance with speed limits, and comprehension of their meaning. If effective, road markings would provide continuously available information to drivers, and increase safety by reducing unsafe speeds and increasing speed homogeneity.

From a system perspective, speed management has significant consequences for both safety and efficiency. The Power Model suggests that high speeds increase both the severity and frequency of crashes (Elvik, 2013; Nilsson, 2004), and speed heterogeneity both increases the risk of crashes and decreases the efficiency or throughput of the road network (Garber and Ehrhart, 2000; van Nes et al., 2010).

From the driver's perspective, speed choice can be difficult because speed signs are only periodically present and in most jurisdictions the physical appearance of a road is not a reliable indicator of the enforced speed limit. Further, signs often go unnoticed by drivers, either because they are driving on "auto pilot" in a familiar environment or because their attention is focussed elsewhere (Charlton and Starkey, 2013; Harms and Brookhuis, 2016). In addition, even when speed limit signs are noticed, drivers may not find them credible due to a mismatch between the posted speed and the look and feel of the road (Charlton and Starkey, 2017a; Goldenbeld and van Schagen, 2007).

In a study of drivers' compliance with reduced speed limits (from 90 to 70 km/h), drivers were found to increase their speeds as their distance from the last speed limit sign increased (Jongen et al., 2011). In driving scenarios where the speed limit signs were repeated less frequently, drivers were more likely to exceed the speed limit. The authors concluded that "speed control measures additional to speed limit signs are necessary to correctly manage speed" (p 782). Similarly, in a study of drivers' speed limit beliefs and speed choices we found that residential roads where the speed limits had been reduced from 50 to 40 km/h were consistently judged as having 50 km/h speed limits, even though the participants had just seen the 40 km/h speed limit signs

* Corresponding author at: Transport Research Group, School of Psychology, University of Waikato, Private Bag 3105, Hamilton, New Zealand.
E-mail address: samuel.charlton@waikato.ac.nz (S.G. Charlton).

https://doi.org/10.1016/j.aap.2018.04.029
Received 24 October 2017; Received in revised form 9 April 2018; Accepted 30 April 2018

when driving the same roads in a video-based driving simulation and speed choice task (Charlton and Starkey, 2017a).

Although static speed limit signs are the conventional method of communicating speed limits to drivers, several alternatives have been explored. One combined field trial and simulator experiment explored continuous indication of the speed limit by adding either 0.5 m dashed lines adjacent to the road's painted edge lines every 50 m or painting the number "7″ alongside the edge lines at 50 m intervals to indicate a reduction in speed from 90 to 70 km/h (Daniels et al., 2010). In this case, the additional markings did not improve speed limit compliance in either the field study or the simulator experiment. The researchers suggested that the markings may not have been sufficiently conspicuous for drivers to notice them, in spite of the presence of an information panel explaining the markings in the field trial. This was supported by the finding that fewer than half of the simulator participants, who were not told of the additional markings beforehand, reported noticing the additional markings when asked at the end of the experiment. Even when specifically identified to them, fewer than one third of the participants recalled seeing the additional markings on the simulated roads.

The presence of the additional markings, however, did result in a shift in drivers' lane position closer to the marked centre line, indicating that the additional markings were processed implicitly (perceptually) even if they were not attended to consciously (attentionally). When the simulator participants were asked to perform a secondary task (paced serial addition task; PASAT) while driving, speeds were reduced by about 4 km/h before the speed transition, particularly in the presence of the additional dashed lines (although two of the participants demonstrated extreme speeds of 120 km/h) (Daniels et al., 2010). Even though speeds were lower on the approach to the transition in the high mental workload condition, speeds at the point of transition to the 70 km/h zone were higher, speed reductions took longer, and the participants' final speed in the 70 km/h zone was 3–4 km/h higher compared to the low mental workload condition (i.e., without the PASAT).

Another suggestion has been to use colour coded road markings to indicate the speed limit such that roads with different speed limits would have different coloured centre and edge lines (Campagne, 2005). In this system, centre and edge lines would be painted red in low speed zones (35 km/h), yellow in moderate speed zones (50 km/h) and blue or green for higher speed zones (90 km/h and 130 km/h respectively). These colour coded road markings have not been tested to our knowledge, and issues such as night-time visibility of the markings and potential for confusion bycolour blind drivers would need to be addressed.

One approach that has been tested used combinations of centrelines, edge lines, physical separation, as well as colours (Aarts and Davidse, 2008; Stelling-Konczak et al., 2011). The goal of these tests were to identify essential recognisability characteristics (ERC) that could be used to indicate different categories of road with different speed limits and overtaking permissions. In a simulator-based study comparing two recognisable road marking systems to standard road markings, the recognisable markings led to speeds reliably under the speed limit, with no difference between participants who had been told about the meaning of the markings before the simulated drive and those who had not been given any information beforehand (Aarts and Davidse, 2008). In a related study participants were asked to sort photographs of roads with and without the ERC markings and estimate the speed limit for the roads shown in the photographs (Aarts and Davidse, 2007). The participants were quite accurate in classifying access roads based on the ERC road markings (82%–89% accuracy), but somewhat less accurate for distributor and through roads (52%–69% accuracy).

Other sorts of road markings, sometimes called perceptual countermeasures, have been used over the years to produce changes in drivers' speeds at specific locations (Denton, 1980; Fildes and Jarvis, 1994; Godley et al., 1999). Most of these markings, such as dragon's teeth, herring bones, and transverse rumble lines, have been designed and employed to produce speed reductions in advance of hazardous intersections or curves, functioning as an alert to catch drivers' attention (Agent, 1980; Charlton, 2007a; Elliot et al., 2003). Other perceptual countermeasures can result in lower speeds by virtue of their effect on drivers' perception of how fast they are traveling (Herrstedt, 2006; Martindale and Urlich, 2010; Montella et al., 2011; van der Horst and Hoekstra, 1994). For example, one proposal to manage speeds on rural roads is to progressively reduce the spacing of dashed centre and edge lines as speed limits decrease so that lower speed roads have a higher "flicker rate" (and provide an inflated sense of speed) (Herrstedt, 2006). This proposal is related to an underlying approach called self-explaining roads which encourages the use of road markings and other road features that enable drivers to readily discriminate different road types, and possess perceptual properties that afford appropriate speed choices (Charlton et al., 2010; Theewes and Godthelp, 1992).

As can be inferred from the above brief review, the use of road markings to influence drivers' speeds have been explored in two distinct, but complementary, ways. First, road markings have been used to attract drivers' conscious attention and provide an alerting function or convey information about rules or hazards. Examples of this include warnings related to vertical or horizontal curves, also referred to as attentional processing (Ariën et al., 2017; Charlton, 2007a; Montella et al., 2015). A second function of road markings is to affect drivers' perception of speed or lane width at an implicit or unconscious level, referred to as perceptual processing (Charlton and Starkey, 2017a; Lewis Evans and Charlton, 2006; Liu et al., 2016; Montella et al., 2011). In practical terms, however, these two effects of road markings are often interrelated and inseparable.

The focus of the present research was to test different configurations of road markings to indicate speed limits on rural New Zealand roads. Conveying speed limit information through road markings could potentially increase compliance with speed limits and result in greater speed homogeneity by making speed cues continuously available and reducing uncertainty for drivers. The use of road markings could also offer a potential advantage for distracted drivers by affecting their implicit or unconscious speed control. Elsewhere we have shown that drivers are quick to detect and react to changes in road markings, even when not explicitly attending to the driving task (Charlton, 2007b; Charlton and Starkey, 2013).

Specifically, the present research: (1) compared two sets of road markings conveying speed limit information to the standard sign-only approach; (2) compared the effectiveness of explicitly informing drivers of the meaning of the markings to an implicit no-instruction condition; (3) investigated whether the effectiveness changed under conditions of high cognitive workload; and (4) assessed driver satisfaction with the use of road markings to indicate speed limits.

2. Method

2.1. Participants

One hundred and seventeen individuals with a full New Zealand driver's license were recruited for the study via notices placed on community and university webpages and through direct email invitations to participants from previous simulator studies. Fifteen drivers withdrew from the study (due to eyestrain, dizziness or other discomfort) or failed to return for the second session leaving a sample of 102 participants completing the study (55 females). The average age of these participants was 34.07 years (*SD* = 13.23, range 18–64 years). The participants reported holding a driver's license for an average of 16.57 years (*SD* = 14.11, range 1–49 years). The participants reported driving on average 163.45 km per week (*SD* = 195.95). Fifty-one of the participants reported being involved in a crash at some point during their driving history. Ethical approval for the recruitment and test protocols was received from the local research ethics review board. Participants received a $20 gift voucher for each of the sessions they attended.