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Transitions within a safe road system

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ABSTRACT

As drivers move through the road transport system they are exposed to a range of different situations and road conditions in a relatively short space of time. Drivers' expectations about what will happen on different types of roads have strong effects on their speed choices, and where they look and what they attend to. As a result it is important to assist drivers to change their expectations when they transition from one road type to another. In this experiment we investigated the effectiveness of different centreline road markings in preparing for a horizontal curve as drivers moved from a motorway to a two-lane rural country road. Fifty individuals were recruited to participate in a video-based simulated driving task to compare three centreline marking types in terms of their effects on speed choice and reactions to a driving hazard (horizontal curve). Although a complex marking previously associated with high risk produced the largest speed reductions during the transition from the motorway, it was the centreline more traditionally associated with rural country roads (dashed white centreline) that was associated with the best hazard reactions post-transition (brake reaction time and speed reduction before a horizontal curve). The findings demonstrated that the look of a road needs to convey a clear and unambiguous message to drivers. The transition to a two-star rural road is best achieved by making the road look like a typical two-star road as soon as possible.

1. Introduction

As drivers move through the road transport system they typically encounter different types of roads, often with different kinds of hazards and levels of safety. With experience, drivers learn what to expect on familiar roads and different types of roads. These expectations are an important part of the everyday driving experience and have a powerful influence on drivers' speed choice, visual search strategy, and preparedness to react to road hazards and traffic situations (Briggs et al., 2018; Charlton and Starkey, 2013, 2016; Martens and Fox, 2007; Young et al., 2017).

Although these expectations are generally beneficial to safe and efficient driving, they can contribute to errors when the expectations are inappropriate for the current conditions or road type. Across a wide range of experiments it has been shown that drivers often look but fail to see road signs, other road users, and other important traffic information, because the information had recently changed, it was not in the usual location, or simply because it was not what they expected to see (Borowsky et al., 2008; Harms and Brookhuis, 2016; Martens and Fox, 2007; Young et al., 2017). The effect of these incorrect expectations, in essence a type of mode error (Sarter and Woods, 1995), can range from an incorrect turning at an intersection, choice of an inappropriate speed, or a crash with another road user.

If, for example, traffic signs are located in unusual places experienced drivers often fail to notice them (Borowsky et al., 2008). It has been suggested that this form of inattentional blindness, also called selective looking, results from the development of schemas that guide experienced drivers' visual scanning of the roadway (Borowsky et al., 2010). In one recent study, a professional driver wore eye tracking glasses over the course of 28 repetitions of an 18 km loop (Young et al., 2017). As her familiarity with the route grew, the driver's looking behaviour changed substantially, and overall there was an increase in the amount of time spent looking at non-road relevant areas.

To better understand drivers' schemas for rural roads, Gundy, 1994 conducted a series of studies in which participants were asked to sort photographs of roads into piles that were similar to each other and different from those in other piles. In some cases participants were asked to label the piles to describe the roads or estimate a safe driving speed for the roads. The participants formed stable road categories that reflected the width of the carriageway and the presence or absence of intersections and curves. Interestingly, the subjective road categories identified by the participants were often quite different from the official engineering categories and legal designations (Gundy, 1994). Using a similar photo sort method in a study of rural roads in New Zealand, we

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found that drivers generally agreed on six non-overlapping categories of rural roads (Charlton and Starkey, 2017a). Importantly, these categories correctly predicted the participants' later ratings of the speed limits, driving difficulty, physical comfort, and safety of the individual roads.

The mental categories and expectations evoked by the look of a road can even over-ride the presence of a speed limit sign. In a study of urban roads (Charlton and Starkey, 2017b), participants drove a video-based simulation of familiar urban roads using the vehicle controls to speed up and slow down. When asked the speed limit on the roads they had just driven, the participants were often wrong, choosing speeds that were consistent with roads that looked similar but had different speed limits.

Roads can also be categorised according to their relative risk by assessing the presence or absence of road features that have previously been associated with crash likelihood and severity; features such as lane and shoulder width or the presence of safety barriers. The International Road Assessment Programme (IRAP) is a large-scale programme to categorise road risks that is being undertaken in several countries in Europe, the United Kingdom, Central and South America, Australia, and New Zealand (Waibl et al., 2012). One of the products of IRAP assessments are ratings in which roads are given different numbers of "stars" for the level of safety they offer, ranging from 1 (low safety/high risk) to 5 (high safety). We have previously shown that drivers' perceptions of risk generally correspond to the IRAP-assessed levels of crash risk, but there are areas where drivers significantly under- or over-estimate the risk (Charlton et al., 2014). In addition to these simple misperceptions of risk, a change from a low-risk road to a high-risk road may pose a significant hazard if driver expectations do not change accordingly. In particular, after driving on a low-risk four or five-star motorway, moving to a two-star rural country road may leave a driver unprepared for risks such as traffic at intersections, sudden changes in horizontal alignment, or even misperceptions of the allowable direction of travel for adjacent lanes.

The idea that drivers' perceptions of risk affect their choice of speed is at the heart of many years of research, as well as driver education and enforcement strategies (Benda and Hoyos, 1983; Kanellaidis et al., 2000; Taylor, 1964). For example it has been shown that when asked to categorise filmed scenes containing a road hazard, young drivers rely on superficial elements of the visible hazard as compared to experienced drivers who used their expectancies about the overall situation to classify the movies, resulting in a more consistent set of categories (Borowsky et al., 2009). The accurate recognition of hazards and its relationship to drivers' choice of appropriate speeds is well known, as excessive speed has been shown to increase the probability of a crash, as well as the severity of crashes that do occur (Elvik, 2013; Shinar, 2017). The link between perception of risk and choice of speed was demonstrated in another video-based simulation (where participants could control their speed) on roads with different types of centre median road markings (dashed white lines, double yellow centre lines, wide centre lines) (Charlton and Starkey, 2016). The participants' speeds in the simulator corresponded with the ratings of the risk they felt on the same roads during a subsequent drive, rating risk higher for the roads they had driven more slowly.

Road markings can be used to influence drivers' speeds in a number of ways other than manipulating perceived risk. Road markings known as perceptual countermeasures, such as transverse lines, dragon's teeth, or herring bones, can be applied at specific locations to slow drivers down as they approach hazardous intersections or curves (Agent, 1980; Denton, 1980; Fildes and Jarvis, 1994; Godley et al., 1999). Some of these markings work by attracting drivers' attention and provide an explicit warning signal, whereas others produce speed reductions by affecting drivers' perceptions of how fast they are travelling (Charlton, 2007; Elliot et al., 2003; Montella et al., 2011). Although these road markings have been shown to produce localised speed reductions for specific hazards, the extent to which they confer a more general or long-lasting safety benefit is much less clear (Charlton, 2007; Denton, 1980; Godley et al., 1999). At issue is how long-lasting the speed-reducing effect of these treatments are. For example, the use of herringbone road markings have been shown to be effective in reducing speeds in the short term, but not always over longer sections of road or drive durations (Martindale and Urlich, 2010).

Road markings can also be used to help drivers discriminate different types of roads, an approach related to the concept of self-explaining roads which assists drivers to make appropriate speed choices more or less automatically (Charlton et al., 2010; Theewes and Godthelp, 1992). An important component of this approach is to help drivers form mental schemata and scripts, memory representations that will lead road users to rapidly identify the type of road they are driving upon and activate appropriate expectations and behaviour (Theewes and Godthelp, 1992). In order to help manage drivers' expectations as they move through the transport system, several attempts have been made to provide accurate and reliable cues regarding road type. In one study, readily recognisable road markings were applied to photos of rural roads and participants were shown photographs showing sections of two road categories with an intersection in between (Stelling-Konczak et al., 2011). In order to determine which road markings would help drivers notice transitions between rural road categories (with different speed limits), the participants were asked to rate the speed limits of the roads shown. The markings were chosen on the basis of their recognisability characteristics and participants were either told about the meaning of the markings beforehand, or not. The results showed that physical separation of lanes with different driving directions was the best cue available for participants to discriminate transitions between distributor and through roads. Transitions between distributor and access roads were more readily recognised when no markings on access roads were present. In a simulator 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).

An important and unanswered question is the degree to which indicating a transition from one road type to another with road markings will do more than produce simple localised or short-term speed reductions. In essence, can road markings used during transitions evoke correct expectations and prepare drivers for what lies ahead? As a practical matter, when drivers move from a low-risk motorway to a high-risk rural road can we help drivers to change their mind-set and prepare them to react to hazards? In this case, signalling the transition in road type has a function beyond that of a localised perceptual countermeasure, something more akin to priming an alternative schema or set of expectations.

In order to address this question, the goal of the present experiment was to investigate drivers' transitions from five-star motorways to a two-star rural country roads and their subsequent reactions to hazardous road conditions. Most new motorways in New Zealand are constructed to a "five-star" standard as designated by the IRAP criteria (NZTA, 2014; Waibl et al., 2012). Roads constructed to this standard are divided highways that are predominantly straight, possessing clear line marking, wide lanes and sealed shoulders, safe roadsides and no more than occasional grade separated intersections. In contrast, a two-star road (the predominant rural road type in New Zealand) is described as having poor alignment, poor roadside conditions, narrow lanes, no median protection against head-on crashes, insufficient overtaking provision, and poorly designed intersections at regular intervals. How best to keep drivers safe when they leave the relatively benign conditions of a new five-star motorway and encounter the hazards of the typical two-star rural road was thus of both practical concern and theoretical interest.

In particular we wanted to examine whether signalling this type of transition was best served by providing an alerting or warning cue in