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Visual in-car warnings: How fast do drivers respond?

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ABSTRACT

We investigate how quickly drivers can change lanes in response to a visual in-car warning. Our work is motivated by technological developments, in which beacons along the road can trigger in-car warnings, for example when a driver is approaching a lane closure. What is not known, however, is at what distance such an in-car warning still allows for a timely lane change. We measured how quickly drivers respond to a visual in-car warning in a driving simulator. The driving task was combined with an audio task that provided different levels of cognitive distraction. We found that the initial reaction time to in-car warnings was significantly larger for drivers that were distracted by the audio task. Although the majority of drivers responded in time for a safe lane change, some drivers occasionally missed these signals, pointing at a serious potential hazard. Indeed, the results of a simulation model, used to investigate how this might extrapolate to regular traffic conditions, suggest that around 50% of drivers might not make a timely lane change in response to a last-minute warning. This indicates that these signals might be insufficient on their own when applied in the real world. This work can inform the design and evaluation of safer roads and in-car interfaces.

1. Introduction

Roadwork sites have a higher crash rate than the same roads without roadworks (Khattak, Khattak, & Council, 2002). For example, a meta-review of accidents in the Netherlands (van Gent, 2007) suggests that a failure to miss roadwork signs can result in various accidents such as rear-end collisions and crashing into roadwork safety trailers. Given the safety risks of such accidents, it is important to consider ways to prevent them.

One option to potentially reduce these accidents is the use of in-car technology to timely signal a critical event, such as an upcoming lane closure, to the driver. A specific technology that has been identified for this effort is to place beacons that can transmit wireless messages to cars equipped with an appropriate receiver (cf. IEEE, 2010). This technology can be used to display visual warnings in a car and as such allows for warning a driver for an upcoming traffic event. These beacons could be used on roadwork safety trailers (Fig. 1) to inform drivers of an upcoming lane closure.

What is unknown, however, is whether an additional warning within the reach of the trailer beacon would allow the driver sufficient time to make a timely, and safe lane change. Current estimates of the reach of such beacons is approximately 500 m (Gozálvez, Sepulcre, & Bauza, 2012; Paier, Faetani, & Mecklenbrauker, 2010). Moreover, in some countries like the Netherlands these roadwork trailers are also preceded by portable rumble strips (also known as sleeper lines), which serve

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Fig. 1. Roadwork safety trailer. Used with permission from Rijkswaterstaat. Source: https://beeldbank.rws.nl, Rijkswaterstaat.

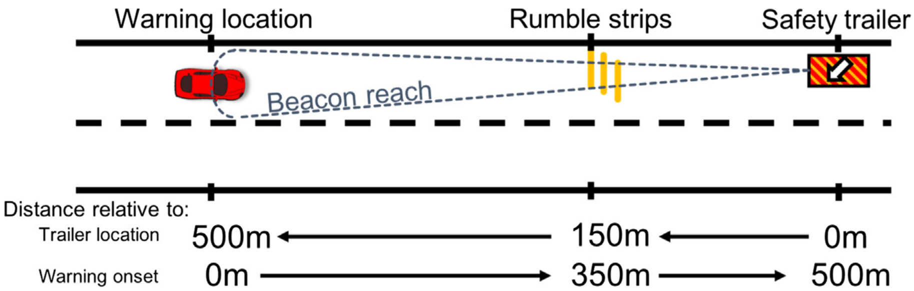

Fig. 2. A typical roadwork scenario as you can encounter it in the Netherlands: a beacon, placed on a roadworks trailer, warns for an upcoming lane change. Distances can be expressed relative to the trailer and relative to the location where the car first received the warning, as determined by the beacon's reach (i.e., 500 m). Please note that in Dutch roadwork scenarios, a trailer is typically preceded by rumble strips. Our experiment provides a controlled version of this scenario, in which a warning is given, but no trailer or rumble strips are visible to the participant.

as a tactile warning and are the last resort to warn people to change lanes. Usage of rumble strips is prescribed by guidelines (e.g., for the Netherlands these are: CROW, 2013). In the Netherlands rumble strips are placed 150 m before the trailer, which already takes up 150 m of the beacon's reach. In effect, usage of rumble strips reduces the distance to make a lane change after receiving the in-car signal to 350 m (500–150 m), as also shown in Fig. 2. However, is this enough distance to make a fast and safe lane change? We investigate this in the current study, by studying how fast drivers are able to respond to a sudden in-car warning that informs them about upcoming roadwork.

More specifically, we investigated lane change performance while placing drivers under different levels of cognitive distraction using an audio task (cf. Kunar, Carter, Cohen, & Horowitz, 2008). Previous naturalistic driving studies have shown that drivers are distracted by various tasks such as eating, smoking, conversations, and making phone calls (Dingus et al., 2016; Klauer et al., 2014), similar to how distraction plays a role in many other professional and private situations (e.g., Janssen, Gould, Li, Brumby, & Cox, 2015). Even tasks that do not require you to take your hands off the wheel, such as holding a conversation (e.g., Iqbal, Ju, & Horvitz, 2010; Janssen, Iqbal, & Ju, 2014) or responding to cued words (e.g., Kunar et al., 2008; Strayer & Johnston, 2001), can distract from driving and result in longer response times. In effect, such distractions lead to a higher accident risk (Dingus et al., 2016; Klauer et al., 2014). It is therefore important that the performance of changing lanes within a distance of 350 m is investigated under different levels of cognitive distraction.

1.1. Preceding studies on lane changing

Lane changing is, next to lane keeping, a common practice on motorways. A lane change is defined as a driver maneuver that moves a vehicle from one lane to another where both lanes have the same direction of travel (Fitch, Lee, Klauer, Hankey, & Sudweeks, 2009). Lane change has been the topic of several studies (e.g., Finnegan & Green, 1990; Hetrick, 1997; Wakasugi, 2005) in which, for example, timings, crash rate, and the use of indicators has been studied.

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