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Safety implications of co-locating road signs: A driving simulator investigation

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ABSTRACT

Background: As road complexity increases the requirement for number of road signs also increases, although the amount of road side space does not. One practical strategy to address this is to present multiple road signs on the same gantry (sign co-location). However, there is very little research on the safety implications of this practice.
Method: 36 participants (mean age = 42.25 years, SD = 13.99, 18 females) completed three driving simulator scenarios, each scenario had a different sign co-location condition: no co-location, dual co-location and triple co-location. Each scenario presented similar information using direction signs, variable message signs and variable speed limit signs, under. Each drive included standard motorway driving (100 km/h speed zone) in free flow traffic and one emergency event where a lead vehicle suddenly braked. The scenario order was counterbalanced and the emergency event vehicle varied.
Results: Overall, there was no impact of co-locating signs on general driving performance. No significant difference was observed between conditions for reaction time and minimum headway in response to the emergency event. Participants were able to correctly choose their destination whether the signs were co-located or not.
Discussion: For the particular configuration of signs tested there is no evidence that co-location negatively impacts driving performance. However, there may be some implications for travel speed and the manner in which the emergency event is responded to. Future work should confirm the findings on real roads. These findings provided support for sign co-location as a practical and safe option for displaying multiple road signs in a confined area.

1. Introduction

Driving is a complex task, relying on psychomotor and cognitive processes in order to correctly monitor and understand the road, in order to make and execute appropriate safe driving choices (Dutta, Fisher, & Noyce, 2004; Ma & Kaber, 2005). Road signs are an important part of the road environment, and are designed to help drivers reach their destination efficiently and safely (Möri & Abedel-Halim, 1981; Siogkas & Dermatas, 2006). They do this by providing navigational information, highlighting potential dangers and communicating current traffic conditions (Costa et al., 2014; Fang, Chen, & Fuh, 2003).

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In conjunction with the increasing complexity of our road systems, there is an increasing amount of information that needs to be conveyed to drivers, often in a dynamic way. Therefore there is a need for well-designed road signs to assist drivers (Möri & Abedel-Halim, 1981). However, with limited road side space increasing signage may be difficult to accommodate. One potential solution to this problem is to make better use of the available space by presenting multiple road sign types on the same gantry or sign post, referred to here as co-location.

Road agencies are increasingly viewing co-locating road signs as a positive option, for example where multiple critical messages are required over a short distance of road, or budget constraints limit the number of new gantries that can be installed. Consequently, co-locating road signs has become common practice, particularly in the USA and Europe (Han et al., 2016). Conversely, some jurisdictions impose restrictions stating that different sign types may not be co-located, or they permit only dual co-location. Despite the prevalence of both sign co-location and regulations surrounding the practice, there has been very limited research into the safety implications of co-locating road signs.

Recent developments in technology mean that electronic variable message signs (VMS) and variable speed limits (VSL) are becoming increasingly prevalent. Overall drivers have responded positively to VMS, recognising them as a useful medium for disseminating safety and travel information (Chatterjee, Hounsell, Firmin, & Bonsall, 2002; Chatterjee & Mcdonald, 2004). VSL are also a positive addition, allowing dynamic control of motorway speeds which improves traffic flow and reduces crash potential (Lee & Abdel-Aty, 2008). Furthermore, the effectiveness of VSL for reducing speed can be enhanced by supplementary VMS providing information about why the speed limit is being reduced (Lee & Abdel-Aty, 2008). In this case VMS and VSL were not co-located but presented independently. The most usual forms of co-location are pairing VMS with VSL or direction signs (DS) with VSL (Han et al., 2016).

The safety implications for co-locating road signs are unclear as the findings of the few investigations into this topic are varied. A recent simulator study using low density traffic conditions suggests potentially negative safety implications, as co-locating several sign types (DS, VMS, VSL) together increased glance duration towards the signs (Larue, Schramm, Smith, Lewis, & Rakotonirainy, 2013). Both dual and triple co-location of road sign types increased the mean glance duration towards signs to above the critical two seconds period. Naturalistic driving studies have shown that looking away from the road for a period of two seconds or more increases a driver's risk of crashes and near crashes (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

In contrast to these findings, an investigation into co-locating DS with advertising signs providing information about an approaching service station found no negative safety implications of co-location (Metz & Krüger, 2014). In this series of driving simulator experiments, participants were asked to observe changes made to direction signs that were either not co-located or co-located with advertising signs. In one experiment this observation was made at the same time as responding to the sudden braking of a lead vehicle. Co-location had no effect on either the detection of changes to the direction signs or the response to the sudden braking event. The authors suggest that drivers are able to apply safe search strategies and direct their gaze to the information needed without being subject to distraction (Metz & Krüger, 2014). However, it should be noted that participants of this study were not instructed to go to the service station and therefore the information in the advertising sign was irrelevant to them. It is unclear whether the findings would have been replicated if drivers were required to extract relevant information from the adverting and DS signs. Furthermore, the finding is in contrast to that of Edquist (2009), who reported that irrelevant "visual clutter" slows a driver's ability to detect changes in photographs of road scenes.

Increasing the amount of information on road signs may make it harder for the driver to find the information they require. There are limitations to the amount of information humans can process, with evidence suggesting that only 3–4 items can be attended to simultaneously (Pylyshyn & Storm, 1988; Trick & Pylyshyn, 1994). The more information which is presented at one time, the harder it is likely to be for a driver to accurately process all of it. The location of any particular road sign is fixed, meaning that drivers have limited exposure to the presented information. From the point at which a sign becomes readable a driver has a set amount of time to perceive and understand the information they require. This time is influenced by travel speed. Additionally, the capacity a driver has to look at a road sign is influenced both by any manoeuvre they may be undertaking and by the surrounding traffic. By co-locating signs an increased volume of information is presented to a driver during the same period of time. As a result, this could mean that drivers are less attentive to the road and more likely to experience inattentional blindness (failure to detect an unexpected stimuli while performing a visual resource-consuming activity (Jensen, Yao, Street, & Simons, 2011)), which may impair their ability to respond to an emergency event. To evaluate this, the current work takes a uniformed approach to displaying road sign information relevant to driving, varying only the co-location status of signs and considering how driving performance is influenced. Best practice in terms of sign design e.g. font and colour, and co-location configuration is not evaluated, however it is acknowledged that these aspects may impact the ability of drivers to accurately extract and use relevant information (Schnell, Yekhshatyan, and Kaiker, 2009).

A further negative safety implication posed by road signs is that they can be an external distractor. Distractions external to the vehicle are responsible for approximately 10% of all driving incidents (Young and Mahfoud as cited in Sisiopiku, Hester, Gan, Stavrinos, & Sullivan, 2013). To date, much of the available research on road signs as external distractors has focused on roadside advertising. Although the results of this research have been mixed, there is evidence to suggest that roadside advertising presents a small but significant risk to road safety (Edquist, Horberry, Hoskings, & Johnston, 2011; Lay, 2004). For example, visual distractions, such as advertisements, can impede driver performance by increasing the number and length of off-road glances (Kaber, Liang, Zhang, Rogers, & Gangakhedkar, 2012). Additionally, roadside distractors have also been shown to impair a driver's ability to detect and respond appropriately to hazards as well as their ability to stay within their designated driving lane (Divekar, Pradhan, Pollatsek, & Fisher, 2012). In this case the external distractor