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Differential effects of traffic sign stimuli upon speeding in school zones following a traffic light interruption

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ABSTRACT

Motorists whose journey has been interrupted by signalized traffic intersections in school zones resume their journey at a faster vehicle speed than motorists who have not been required to stop. Introducing a flashing "check speed" sign 70 m after the traffic intersections counteracts this interruptive effect. The present study examined which aspects of a reminder sign are responsible for reducing the speeding behavior of interrupted motorists. When a sign that combines both written text and flashing lights was introduced, interrupted motorists did not speed, traveling on average 0.82 km/h below the 40 km/h speed limit when measured 100 m from traffic intersections. Alternatively, when only the flashing lights were visible the interrupted motorists sped 3.36 km/h over the 40 km/h speed limit. Similar vehicular speeds were observed when only the written text was visible and when no sign was present (7.67 and 7.49 km/h over the 40 km/h speed limit, respectively). This indicates that static reminder signs add little value over the absence of a school zone reminder sign; the presence of both cues is necessary to fully offset the interruptive effect. This study also highlights the benefit of using exogenous visual cues in traffic signs to capture drivers' attention. These findings have practical implications for the design and use of traffic signs to increase compliance with posted speed limits.

1. Introduction

Traffic signs play an important role in regulating road traffic. They are the most commonly used devices to provide crucial information such as warnings, required direction of travel, speed regulation, and other types of regulatory messages to drivers on the road (Al-Madani and Al-Janahi, 2002). Traffic signs are also used to deliver warnings and advice to motorists. However, the success of traffic signs in regulating or advising driver behavior is not absolute. The overall probability of a traffic sign being noticed by a passing motorist may be no higher than 0.5 (Johansson and Backlund, 1970). Traffic sign effectiveness can also suffer from a number of problems (Zhang and Chan, 2014). These can include: late or failed detection (Möri and Abdel-Halim, 1981), low comprehension (Kirmizioglu and Tuydes-Yaman, 2012; Shinar et al., 2003), or behavioral non-compliance. These issues are problematic, as the failure of traffic signs to regulate behavior is considered a major contributor to road traffic crashes (Kirmizioglu and Tuydes-Yaman, 2012). As a result, models for understanding why individuals recognize, and fail to recognize traffic signs, have been proposed.

Zhang and Chan (2014) provide a useful framework for how traffic signs may be processed by individuals. In this model, information flows sequentially through four stages: recognition, comprehension, benefit–cost evaluation, and behavior. In the recognition stage, a traffic sign should be first recognized by the motorist. For this to occur, the traffic sign must have sensory or attention conspicuity so that it can catch and hold the viewer's attention as in the complexity of the driving environment drivers do not typically search for warnings (Cole and Hughes, 1984; Wogalter et al., 2002). Following this recognition stage, drivers must then comprehend the message given by a sign, and then the response required by the message must be clearly interpreted. Failure to do so may result in either no response or an inappropriate behavioral outcome (Charlton, 2006) which can contribute to traffic incidents and crashes (Al-Madani, 2000). A form of benefit–cost evaluation is then undertaken, where drivers decide whether they will comply with the perceived instruction of the sign. When drivers perceive that the benefit of compliance outweighs the cost, compliance is favored; when cost outweighs the benefit, non-compliance is favored. In the final stage of the model, a behavioral response is carried out.

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Zhang and Chan (2014) propose that at each stage of the model there are factors that may facilitate or hinder the conspicuity of traffic signs on the road. These can include: sign features such as color, shape, size, or graphic boldness (Castro and Horberry, 2004; Lai, 2010; Mace et al., 1994); environmental features such as luminance (Mayeur et al., 2010; Schnell et al., 2009; Tsang et al., 2012; Turatto and Galfano, 2000) and location (Borowsky et al., 2008); and individual characteristics such as age (Ho et al., 2001), affective state (Jiamsanguanwong and Umemuro, 2013), gender (Borowsky et al., 2008), and driver experience (McCarley et al., 2014). For the purposes of the present study, the following discussion will focus on sign characteristics that enhance sign effectiveness, with particular focus on the capacity of flashing signs to improve driver compliance with traffic signs.

Traffic signs are most effective when they command attention, convey a clear message, and give adequate time for a proper response. Thus, signs need to be designed carefully to first attract drivers' attention so they can be correctly comprehended. Adding vivid color to a sign can attract attention and reduce the search time needed to make a driving response (Ng and Chan, 2008; Turatto and Galfano, 2000). Similarly, increasing the height of a sign can benefit drivers, as sign height is associated with improving the legible distance of traffic signs (Mace et al., 1994). Another strategy to enhance the sensory conspicuity of the traffic signs is to equip them with flashing lights. In a study investigating traffic sign effectiveness in school zones, Roper et al. (2006) found that drivers traveled 3.5 km/h more slowly, on average, when school zone signs flashed compared to non-flashing, static school zone signs. According to Jamson et al. (2010), flashing signs may engage bottom-up, automatic processing as they are more salient and 'pop out' from the complex driving environment. Alternatively, static signs may reflect less efficient top-down processing as drivers are required to seek out the sign and actively interpret whether, in this instance, school zones are in operation. Motorists are therefore more likely to notice and attend to flashing signs and adjust their speed accordingly.

It has also been suggested that traffic sign stimuli may tap into two different mechanisms to facilitate appropriate driving behavior: early perceptual processing through repetition priming, and semantic processing influencing cognitive processes (Gehlert et al., 2012). Simple or symbol signs may exert their influence through repetition priming, where they inform the driver about a traffic situation ahead and activate behavioral response preparation. Signs that utilize semantic processing may not be identical to the specific road situation but they are semantically related to the traffic situation. These mechanisms may have different effects on prompting behavior. For example, Koyuncu and Amado (2008) found that signs which only tap into repetition priming (e.g., symbol signs) produce slower reaction times compared to signs which only tap into semantic processes (e.g., verbal, or written signs) and signs that combine the two processes (e.g., signs that have both symbols and written words).

The present study aims to examine the differential effects of traffic sign stimuli in reducing the speeding behavior of interrupted motorists in school zones. Speeding behavior in school zones is an issue, with the Auditor-General of New South Wales (2010) reporting that in only two schools zones out of 12 that were studied were vehicle speeds close to the 40 km/h speed limit. This study extends the findings from a recent paper by Gregory et al. (2014) where interrupted motorists in school zones were found to travel at faster vehicle speeds upon resumption of driving than motorists who were not interrupted at the traffic intersections. The authors argued that this was due to prospective memory error. Prospective memory is defined as memory for intended future actions without an explicit prompt (Einstein and McDaniel, 1990, 1996). Individuals commonly forget to perform an intended task after an interruption (Heathcote et al., 2015). To counteract this interruptive effect, the authors introduced a reminder sign 70 m following the traffic light intersections. The sign included a combination of repetition priming (i.e., a flashing symbol) and semantic processing (i.e., a "check speed" text). Following the introduction of the sign, vehicle speeds reduced to the posted maximum speed limit of 40 km/h. This represented a 50% reduction of the fatality risk should a pedestrian-collision occur at these locations (Peden et al., 2004; Rosén and Sander, 2009). What components of the reminder sign best facilitated this vehicular speed reduction remains unclear. In the present study we examined speed differences for interrupted and noninterrupted motorists when a lights-only sign, a text-only sign, and the combination sign was introduced following an intersection within a school zone. We also included baseline data where no sign was used for comparative purposes. We predicted an Interruption by Sign interaction. We expected the combination sign to be the most effective at reducing motorists' speed, and predicted that there would be no difference between interrupted and noninterrupted motorists when measured 100 m from the traffic intersection. For both the text-only and lights-only sign conditions, we expected interrupted motorists to record faster vehicle speeds than noninterrupted motorists. However, since flashing signs are more effective at capturing motorists' attention than static signs, we predicted that for the lights-only condition there would be less of a difference between interrupted and noninterrupted motorists than for the text-only condition. We predicted the baseline condition would be the least effective in reducing vehicle speeds, with interrupted motorists recording faster vehicle speeds than noninterrupted conditions.

Table 1
Number of vehicles per condition.

Condition	Noninterrupted	Interrupted	Total
Baseline	383	156	539
Combination sign	331	120	451
Text-only sign	256	64	320
Lights-only sign	188	79	267
Total	1158	419	1577

2. Method

For the purposes of the present article, a shortened method section will be presented. For more details regarding the vehicle selection and location criteria see the Gregory et al. (2014) paper.

2.1. Participants

A sample of motorized vehicles was observed traveling through a signalized road intersection in a designated school zone area in metropolitan Sydney, New South Wales (NSW), Australia. In total, the vehicle speeds from 1577 motorists were recorded (see Table 1 for the breakdown of vehicle numbers per condition). A criterion value of 3 s between vehicles was used to determine whether individual vehicles were to be included in noninterrupted conditions. Thus, if a target vehicle had a following distance of less than 3 s, then the vehicle was considered to be in a platoon (i.e., where the following distance between vehicles is minimal and drivers do not have full discretion over their speed) and the observed speed was not recorded. If a target vehicle had a following distance greater than 3 s, then the vehicle was used for speed analysis. For interrupted conditions, only the first row of stationary vehicles waiting at the intersections were considered for analysis. If a bus stopped at the bus stop situated 15 m from the signalized traffic intersection, vehicle speeds were not recorded in any condition for the duration