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Road crossing behavior under traffic light conflict: Modulating effects of green light duration and signal congruency

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ABSTRACT

A large number of pedestrians and cyclists regularly ignore the traffic lights to cross the road illegally. In a recent analysis, illegal road crossing behavior has been shown to be enhanced in the presence of incongruent stimulus configurations. Pedestrians and cyclists are more likely to cross against a red light when exposed to an irrelevant conflicting green light. Here, we present experimental and observational data on the factors moderating the risk associated with incongruent traffic lights. In an observational study, we demonstrated that the conflict-related increase in illegal crossing rates is reduced when pedestrian and cyclist green light periods are long. In a laboratory experiment, we manipulated the color of the irrelevant signals to expose participants to different degrees of incongruency. Results revealed that individuals' performance gradually varied as a function of incongruency, suggesting that the negative impact of a conflicting green light can be reduced by slightly adjusting its color. Our findings highlight that the observation of real-world behavior at intersections and the experimental analysis of psychological processes under controlled laboratory conditions can complement each other in identifying risk factors of risky road crossing behavior. Based on this combination, our study elaborates on promising measures to improve safety at signalized intersections.

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1. Introduction

When approaching a signalized intersection, traffic participants seem to be confronted with a real-world example of one of the most basic experimental psychological paradigms: the go/no-go task (e.g., Eigsti et al., 2006). Just like in the laboratory, individuals are required to execute a response (i.e., to cross the intersection) in the presence of a go stimulus (i.e., a green light), but to withhold responding to no-go stimuli (i.e., a red light). In daily life, however, many pedestrians fail to adhere to these simple task instructions. Observational studies indicate that up to 37% of all pedestrians (Keegan and O'Mahony, 2003; King et al., 2009; Ren et al., 2011) and up to 56% of cyclists (Wu et al., 2012) cross illegally (i.e., against the lights or away from the lights) at signalized intersections.

Illegal road crossing behavior (IRCB) substantially increases pedestrians' crash risk (King et al., 2009) and it is considered a major factor contributing to vehicle-related accidents in cyclists (Zhang and Wu, 2013; but see Bacchieri et al., 2010). Identifying the factors contributing to risky pedestrian and cyclist behavior is crucial to enhance traffic safety (Johnson et al., 2011). Previous studies on the reasons and risk factors of IRCB can be roughly classified into two categories. A first line of research focused on the person. Young (Rosenbloom et al., 2004; Holland and Hill, 2007), male (Tom and Granié, 2011; Rosenbloom, 2009; Rosenbloom et al., 2004), fatalistic (Kouabenan, 1998), and strictly religious (Rosenbloom et al., 2004) pedestrians as well as young and male cyclists (Johnson et al., 2011; Wu et al., 2012) have been shown to be more likely to cross against the lights. A second line of research focused on the situation, i.e., the environment in which traffic rules are violated. Among others, traffic volume (Gårder, 1989; Yang et al., 2006), weather conditions (Li and Fernie, 2010), cultural background (Sueur et al., 2013), and the presence of a median refuge (Jacobs et al., 1968; Li and Fernie, 2010) have been demonstrated to affect the frequency of IRCB in pedestrians. In cyclists, IRCB could be shown to depend on traffic volume (Johnson et al., 2011; Wu et al., 2012), direction of travel (Johnson et al., 2011; Johnson et al., 2013) and the duration of the red light period (Pai and Jou, 2014).

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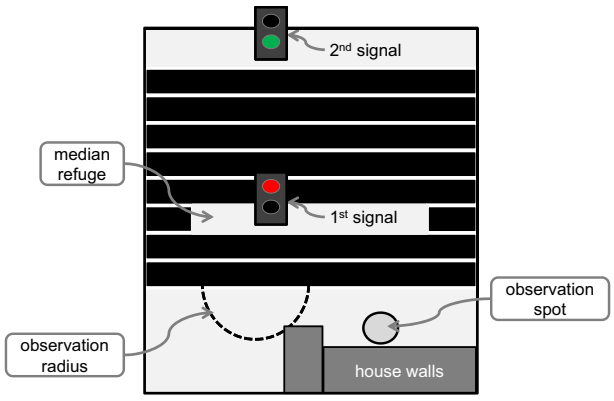

Fig. 1. Traffic light conflict at the signalized intersections investigated by Lange et al. (2011) and in this study. Pedestrians and cyclists are required to obey the relevant first signal on the median refuge. When the relevant signal is red, the irrelevant second signal on the other side of the road can either be red as well (congruent condition) or green (incongruent condition). Figure modelled after Lange et al. (2011). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Most of these studies converge in assuming that, at a signalized intersection, pedestrians and cyclists perceive a familiar no-go stimulus and then decide, depending on their predisposition and the current state of the environment, whether or not they want to obey this signal. An alternative approach, however, suggests that, when crossing at a red light, individuals respond to more than one stimulus (Lange et al., 2011). According to this model, traffic participants are exposed to multiple conflicting stimuli, with only some of them (e.g., the red traffic light, the presence of a police officer, an approaching car) being effective no-go stimuli. At the same time, some stimuli might rather be associated with the go response. For instance, even when a pedestrian faces a red light, other illegally crossing pedestrians or a red light for the crossing vehicles might signal that it is safe to cross at this particular moment. Following this notion, Lange et al. (2011) hypothesized that pedestrians and cyclists should be more likely to cross against the lights in the presence of conflicting go stimuli. They tested their idea at two-stage pedestrian and cyclist crossings with a first, relevant signal on the median refuge and a second signal on the other side of the road which was irrelevant for the first crossing act (see Fig. 1). In an observational setting, they showed that individuals were more likely to ignore a relevant red signal when the irrelevant signal was green. Illegal crossing rates dramatically increased in situations involving conflicting stimuli as opposed to unambiguous situations (i.e., when both the relevant and the irrelevant signal were red; Lange et al., 2011).

These data indicate that crossing at a signalized intersection might, in fact, be more than a simple go/no-go task. Pedestrians and cyclists are not only required to respond to one stimulus. In contrast, they have to resolve the conflict arising from the simultaneous presence of multiple contradictory signals. In order to study processes of conflict resolution, experimental psychologists have developed a set of different paradigms (Eriksen and Eriksen, 1974; Simon, 1969; Stroop, 1935). In the flanker task, for instance, participants have to identify a central target stimulus that is surrounded by distractor stimuli (Eriksen and Eriksen, 1974). Crucially, these distractors can be either response-congruent (i.e., associated with the same response as the target) or response-incongruent (i.e., associated with a different response). Reaction times (RT) and error rates (ER) are typically higher in response to incongruent as opposed to congruent displays. Note that the task structure reflects the situation depicted by Lange et al. (2011) where a response-incongruent distractor (i.e., the irrelevant green light) interfered with responding to the target (i.e., the relevant red light associated with stopping).

The flanker task has already been introduced to the field of traffic psychology. Specifically, Di Stasi et al. (2012) have investigated the impact of incongruent visual information in traffic signs denoting the location of an airport. As expected, participants were slower and less accurate in identifying the airport's location when the head of an arrow and an airplane pictorial pointed in opposite directions.

To show that the same effect can be produced in a paradigm mimicking a signalized intersection with conflicting stimuli (Fig. 1) would be trivial. Instead, the present study aims to examine the factors modulating the congruency effect (i.e., the performance decrements in the presence of incongruent distractors). It is highly unlikely that all conflicting stimuli can be removed from signalized intersections. The conflict between the first and second pedestrian traffic light described by Lange et al. (2011), for instance, is a necessary by-product of the traffic solution at this type of intersections. Reducing the impact of conflicting stimuli on pedestrians' and cyclists' behavior will decrease the rate of IRCB without requiring a complete reconfiguration of the intersection or the signal cycle.

Here, we examined whether the congruency effect could be modulated by manipulating the stimulus dimension most relevant to responding (i.e., the color of the signals). Inspired by the intersection design described by Lange et al. (2011), we designed a variant of the flanker paradigm requiring participants to respond to one color (i.e., the go color), while withholding responses to another one (i.e., the no-go color). On each trial, the relevant target stimulus was surrounded by task-irrelevant distractors that systematically varied in color. On some trials, participants were confronted with congruent conditions (i.e., target and distractor color were associated with the same response), while on others they had to respond to incongruent conditions (i.e., target and distractor color were associated with opposite responses). On another subset of trials, the color of the distractor stimuli varied on a gradient between the go and the no-go color. Hence, stimulus configurations were not only congruent or incongruent, but gradually differed from perfect congruency to perfect incongruency. We hypothesized that participants would perform most poorly in perfectly incongruent conditions and that they gradually improve with increasing dissimilarity between the distractor color and the color associated with the opposite response. In other words, participants were expected to respond more accurately to a relevant red signal when the irrelevant green signal was manipulated to be less green.

By analyzing experimental data from more than 100 participants, we aimed to elucidate whether and to which extent the detrimental effect of incongruent traffic signals can be attenuated by manipulating their color. Before we describe the results from this experiment (Study 2), we report an attempt to replicate the findings by Lange et al. (2011) in an observational setting (Study 1). Based on data from a further intersection, we aimed to investigate whether the association between incongruent traffic light configurations and increased illegal crossing rates is constant across observation sites. Following the study by Lange et al. (2011), we expected that the risk associated with incongruent signal configurations would be lower at this intersection as it involved a longer green light period for pedestrians and cyclists.

2. Study 1

2.1. Methods

2.1.1. Site and sample characteristics

Along the lines of Lange et al. (2011), observations were carried out in the city of Braunschweig, Germany, at a signalized pedestrian and cyclist crossing across a 7-lane urban road that was divided by a median refuge. When arriving at the intersection, pedestrians and

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