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The effect of motion and signalling on drivers' ability to predict intentions of other road users

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ABSTRACT

Failure in making the correct judgment about the intention of an approaching vehicle at a junction could lead to a collision. This paper investigated the impact of dynamic information on drivers' judgments about the intentions of approaching cars and motorcycles, and whether a valid or invalid signal was provided was also manipulated. Participants were presented with videoclips of vehicles approaching a junction which terminated immediately before the vehicle made any manoeuvre, or images of the final frame of each video. They were asked to judge whether or not the vehicle would turn. Drivers were better in judging the manoeuvre of approaching vehicles in dynamic than static stimuli, for both vehicle types. Drivers were better in judging the manoeuvre of cars than motorcycles for videos, but not for photographs. Drivers were also better in judging the manoeuvre of approaching vehicles when a valid signal was provided than an invalid signal, demonstrating the importance of providing a valid signal while driving. However, drivers were still somewhat successful in their judgments in most of the conditions with an invalid signal, suggesting that drivers were able to focus on other cues to intention. Finally, given that dynamic stimuli more closely reflect the demands of real-life driving there may be a need for drivers to adopt a more cautious approach while inferring a motorcyclist's intentions.

1. Introduction

When two road users meet at a junction, each must estimate the others' intentions in order to decide what to do next. Errors in making such predictions about other road users' actions could result in an accident if the wrong decision is made as a consequence. For instance, we may be more likely to pull out if we think an approaching vehicle is turning off the main road than if we think the approaching vehicle will keep going, but an error could result in a collision. Research suggests that a large proportion of accidents taking place at junctions are due to right-of-way violations (Clark et al., 2004; Sarani et al., 2011). While we are not aware of any data on how many of these are accounted for by failures to predict another road user's behaviour, it is possible that some of these accidents could be averted if road users are properly attuned to the behavioural intentions of others. The importance of being able to predict others' behaviour when making decisions is captured in Situation Awareness Theory (Endsley, 2000), which has been applied to various dynamic contexts including driving. There are three levels within the SA model. Level 1 is the ability to perceive the elements of the scene, while Level 2 involves comprehension and understanding of the scene. In driving, this requires individuals to understand the set of rules on the road, integrating the perceived items of the scene, and understanding them. Level 3, which is the most advanced aspect of situation awareness, involves projection and the anticipation of future events, for example, being able to anticipate the manoeuvre of other road users. It has been suggested that being able to predict the movements or behaviour of other road users is the major antecedent of successful decision making, although it does not necessarily guarantee good decision making about one's own behaviour (Endsley, 2000). Therefore, it is important to understand how accurate drivers are in making predictions about other road users' behaviour, as well as the type of information they rely on to make such judgments.

The majority of previous research on judging the intention of other road users has focused on the judgments of car drivers about the behaviour of cyclists, referred to as Bicycle Motorist Junction Interactions (BiMJIs). Drury and Pietraszewski (1979) conducted a study which asked drivers to predict a cyclist's intentions (turning left, turning right, going straight or stopping) by presenting them with a series of photographs depicting an approaching cyclist at

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a crossroads. It was found that drivers made incorrect judgments about 20% of the time when proper arm signals were provided by the cyclists as a way to communicate their intention, but the accuracy of drivers' judgments varied when they had to rely on other more informal cues while making judgments (such as different positions on the road, trailing a foot, looking over the shoulder).

More recently, Walker (2005) conducted a study which aimed to predict the probability of collisions by classifying drivers' judgments according to the likely consequences. Photos depicted cyclists who either did not or did turn into the side road while making one of four possible signal types (a proper arm signal, no arm signal but glance in the direction of the forthcoming turn, glance back over the shoulder or no indication at all). Participants were told at the beginning of each trial to execute a specific driving manoeuvre, and had to press a button (braking response) when they judged it to be not safe to perform the manoeuvre. Walker went on to categorise different trials to be 'good outcome' (managed to stop and prevent collision with the cyclist) and 'collision' (failed to stop a manoeuvre which would hit the cyclist). Collisions occurred on 7% of trails, and failures to stop were more likely in the proper arm-signal condition as compared to no signal or informal signal. It was also found that successful stop responses were slowest when the cyclist signalled correctly. It was suggested that the proper arm-signal might have caused participants to invoke extra cognitive processing, as it was associated with a communicative act. Therefore, this resulted in participants taking longer in decision making and in some cases failing to do so within the required time frame, resulting in collision.

These studies have demonstrated that drivers are generally able to successfully infer the intention of cyclists from photograph stimuli. However it is possible that the use of static photographs as stimuli could misrepresent drivers' decisions in the real dynamic road environment (Crundall et al., 2008). On one hand, static photographs allow plenty of time for careful inspection of relevant cues to intention which may make it easier for drivers to deduce what the other road user will do. On the other hand, there may be various aspects of motion that could be useful for determining intention, such as deceleration of road users planning to make a turn, the trajectory of road users as they approach the junction, changes in body position, and other antecedent movements.

It has been previously suggested that socio-cognitive processing plays a role in information processing which relates to other human beings, and hence that such processes are invoked when making decisions about intented maoeuvres of cyclists (Walker, 2005). This would be the case for other groups of vulnerable road users who appear as a visible figure of a human on the road, such as pedestrians, but perhaps not for a truck or a car where no human figure is visible (Walker and Brosnan, 2007). This raises the question about how people would make judgments about the intentions of other road user groups especially those where no human figure is visible. Motorcyclists are also a vulnerable group of road users and are clearly visible as a human figure. However, unlike bicycles, motorcycles are equipped with indicators like cars, and should use them to signal their intentions. If a motorcyclist is going to turn into a junction, one would also expect the motorcyclist to glance in the relevant direction and decelerate, although it is not as easy to see the eyes of a motorcyclist as a cyclist, due to the differing nature of their headgear.

The current study aimed to create stimuli depicting real manoeuvres as naturally as possible, comparing two types of approaching vehicle (motorcycles and cars). The study also sought to include dynamic as well as static stimuli for consideration. Participants were required to predict the manoeuvre of the approaching vehicles (turning into the junction or driving straight). One particular road configuration was used (see Fig. 1), which was selected as it has been identified as a particular source of accidents in real life (Stone and Broughton, 2002). In this particular interaction, the participant is located on the main road and has the priority of continuing going straight, while the approaching vehicle on the other side of the main road should stop and give way (if turning). The approaching vehicles' signalling behaviour was manipulated such that there were four kinds of trial: those where the vehicle continued straight and made no signal, those where the vehicle continued straight but made a signal, those where the vehicle signalled and turned and those where the vehicle did not signal but did turn. This enabled us to examine the effects of signal validity on drivers' judgments and evaluate the extent to which drivers rely on signals versus other, less explicit cues to make their judgments.

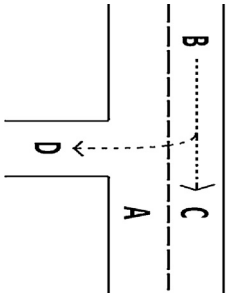

Fig. 1. Initial location of approaching vehicle (B) which either travelled straight (to C) or turned into the junction (to D) and video camera (A).

Three hypotheses were made: (1) Participants would be more accurate in predicting the manoeuvre of approaching vehicles for video stimuli than for photograph stimuli due to there being additional cues which could assist in the judgment. (2) There would be an interaction between stimulus type and vehicle type, whereby dynamic information would be more useful for cars than motorcycles. This is due to the car being a bigger vehicle so movements would be more obvious in the video stimuli whereas the tilt of a motorcycle while turning or other body language of the motorcyclist (i.e. head and body position) might be more obvious on static photographs. (3) Overall, drivers would be more accurate in judging other road users' manoeuvres when a valid signal is provided as compared to an invalid signal. Note that the signal was not predictive of the vehicles' actual intentions in this study.

2. Methods

2.1. Participants

In total 40 drivers were recruited (18 males and 22 females; an *a priori* power analysis confirmed that 32 participants would be needed for a medium effect size). Participants were all students studying for degrees at the University of Nottingham Malaysia Campus. Their average age was 21.75 years (*S.D.* = 3.12) ranging from 18 to 33 years and they reported an average of 3.02 years (*S.D.* = 2.68) of active driving experience since getting their driving license in Malaysia, ranging from 0.17 to 14 years. All participants reported normal or corrected-to-normal vision and were not colour blind. They reported no experience of riding a motorcycle.

2.2. Design

A 2×2 x 2×2 within-subjects design was used. There were four independent variables: type of approaching vehicle (car or motorcycle); manoeuvre of the approaching vehicle (turning into the junction or driving straight); signal validity (valid or invalid); type of stimulus (photographs or videos). The valid signal condition included trials where the approaching vehicle was turning with a signal provided, or going straight with no signal provided.