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Comparing drivers' gap acceptance for cars and motorcycles at junctions using an adaptive staircase methodology

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ABSTRACT

A disproportionate number of road deaths occur at intersections where one vehicle is a motorcycle. Previous research has not systematically varied the type of vehicles presented in a controlled environment.

We compared drivers' (n = 54) gap acceptance when either a car or motorcycle was approaching a junction. We used a QUEST adaptive staircase to estimate gap acceptance thresholds for cars and motorcycles separately. On each trial, drivers saw a car approaching from the left and a vehicle (car or motorcycle) approaching from the right. The driver had to stop for the car from the left, but could choose whether to pull out in front of the vehicle from the right, or to wait for it to pass. Participants completed the task in either a medium-fidelity simulator (steering wheel and pedals, 180-degree screen) or a high-fidelity simulator (fully instrumented car, 360-degree screen).

Participants accepted significantly smaller (riskier) gaps in front of motorcycles than in front of cars, particularly in the high-fidelity simulator. The speed of crossing the junction did not differ between vehicle types, meaning that drivers were closer to the motorcycle than the car during the manoeuvre. There was one instance that appeared to replicate a 'Look But Fail To See' error, where a participant pulled out in front of an oncoming motorcycle resulting in a crash. This suggests that drivers accept riskier gaps around motorcycles than cars, which may be due to a difference in attitude towards different vehicles or differences in optic flow properties. These results help to explain the disproportionate involvement of motorcycles in real junction crashes.

1. Introduction

1.1. The problem

Intersection safety is a major problem worldwide, with crash data suggesting that there are higher risks in these segments of the road compared with other road segments. Many accidents at intersections can be attributed to inappropriate gap selection by drivers who are pulling out of a side road and entering a carriageway with approaching vehicles (Hoareau, Candappa, & Corben, 2011). This suggests that there is a need to better understand drivers' gap acceptance behaviour to develop strategies that can support drivers' decision making at intersections.

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When inspecting intersection crash data, a large number of intersection crashes involve motorcycles. Data from the UK show that motorcycles are involved in a disproportionate amount of road crashes given the distance travelled, with 122.3 motorcycle fatalities compared with 1.8 car driver fatalities per billion miles (DfT, 2015). In many road crashes involving motorcyclists, car drivers are solely at fault, with the main cause of motorcycle crashes in the UK consisting of right of way violations (ACEM, 2009). These crashes occur when another road user, usually a car, pulls out of a side junction into the path of a motorcycle on a main carriageway (Clarke, Ward, Bartle, & Truman, 2007). These crashes in the previous literature are commonly known as 'Look But Fail To See' errors, with it being typical in these accidents that a driver reports being careful and attentive with their visual checks but nonetheless fails to see an oncoming motorcyclist (Brown, 2002). However, there are many reasons why a driver may report afterwards that they failed to see an oncoming motorcycle. The driver may not want to admit to a driving error, for example, accepting a risky gap between traffic.

1.2. Gap acceptance literature

There is a growing literature investigating drivers' behaviour at intersections in regards to their response to different gaps in traffic. Gap acceptance tasks ask the driver to decide between acceptable and unacceptable gaps to move into. These methods produce rich sources of data, compare gaps which are accepted or rejected by drivers, and estimate the 'critical gap'. This 'critical gap' has been defined as 'the minimum time gap a driver is ready to accept' (Brilon, Koenig, & Troutbeck, 1999, p. 2).

Previous research has used both naturalistic observations and experimental studies (Beanland, Lenné, Candappa, & Corben, 2013; Keskinen, Ota, & Katila, 1998; Scott, Hall, Litchfield, & Westwood, 2013; Yan, Radwan, & Guo, 2007). In most experimental studies the researchers have presented approaching vehicles at a limited and predetermined set of distances. This method allows for vehicles at selected distances to be repeatedly presented to participants. For example, Scott et al. (2013) investigated the effect of driving experience on visual attention at junctions, using a gap acceptance design which included a series of gaps between vehicles which increased in 1.5 s increments. It was found that young experienced drivers distribute their gaze more evenly across the junction, whereas older and novice drivers made sweeping transitions. However, due to the time constrained nature of the task, the study was only able to complete a single manoeuvre with each participant, with the authors concluding that future studies need to investigate drivers' gap acceptance using a larger sample so more gaze sequences can be analysed.

In addition, Beanland et al. (2013) used time gaps which varied from 3 to 11 s to measure a driver's gap acceptance (whether the driver accepted or rejected a given gap), accepted lag (the time of arrival of the target vehicle when participants have accepted the gap in front of it) and turn time, for two different manoeuvres (turning across traffic and merging with traffic). Drivers appear to vary their gap acceptance strategy depending on the intended manoeuvre, with drivers accepting smaller gaps when turning across traffic compared to merging with traffic. As drivers can vary their behaviour dependent on manoeuvre type, this would suggest that it is possible for drivers to vary their behaviour dependent on approaching vehicle type, for example, motorcycles.

Despite the pressing need, few studies of gap acceptance have systematically varied the type of vehicles presented. A review of published articles examining drivers' gap acceptance behaviour found that there are substantial experimental research studies investigating drivers' gap acceptance when intersecting with cars however, relatively fewer research efforts have been made to investigate gap acceptance behaviour when intersecting with motorcycles, despite the high number of crashes occurring with this type of vehicle (Pai, 2011).

Gap acceptance studies when intersecting with motorcycles are also extremely important in developing countries, where the number of motorcycles can be very high (Lee & Sheppard, 2017). Serag (2015) focussed on drivers' gap acceptance in developing countries, conducting a field study in Egypt. It was found that when estimating drivers' gap acceptance (where the driver was 50% likely to accept the gap), these gaps were less than those in developed countries, suggesting riskier behaviour from drivers' in developing countries. Many of these countries have a different traffic composition which needs to be taken into account, especially the characteristics of motorcycles. Ibrahim and Sanik (2007) conducted a field study in Malaysia at T-junctions, investigating drivers' gap acceptance behaviour as a function of approaching vehicle type. The results indicated that there were significant differences in drivers' gap acceptance for cars and motorcycles, demonstrating smaller gaps for motorcycles compared to cars. These results suggest that there may be a specific problem associated with gaps accepted around motorcycles, however, without experimentally controlling the behaviour of different vehicles it is not possible to decide whether it is the vehicle type, or its behaviour that brings about the differences in gap acceptance (motorcycles may be approaching with different speeds and directions than other traffic).

One of the few simulator studies investigating gap acceptance towards motorcycles and cars was conducted by Mitsopoulos-Rubens and Lenné (2012). Three time gaps of 5.0, 7.0 and 9.0 s were used, which were associated with a 20% (i.e. low), 50% (i.e. medium) and 80% (i.e. high) rate of gap acceptance, respectively. It was found that when the time gap was short and long, participants were more likely to accept fewer trials with an approaching motorcycle than car, however, this effect was reversed with the medium time gap.

Although the method of constant stimuli used in previous studies (Beanland et al., 2013; Mitsopoulos-Rubens & Lenné, 2012; Scott et al., 2013) can be argued to be satisfactory in some circumstances (e.g. Crundall, Humphrey, & Clarke, 2008), it may lead to participants being repeatedly exposed to stimuli that may be a long way from their personal threshold. Previous gap acceptance literature highlights that drivers are neither wholly consistent (e.g. always rejecting gaps lower than the critical gap and accepting gaps higher than the critical gap) or homogeneous, with some drivers accepting smaller gaps than