Allocating Attention to Detect Motorcycles: The Role of Inattentional Blindness

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Objective: To determine whether inattentional blindness (IB) can be used to understand the psychological mechanisms around looked-but-failed-to-see (LBFTS) crashes involving motorcycles

Background: IB occurs when an observer looks directly at an object yet fails to see it, thus LBFTS crashes may be a real-world example of IB. The study tests a perceptual cycle model in which motorcycles are detected less frequently because they fall lower on the attentional hierarchy for driving.

Method: A driving-related IB task with photographs of driving situations investigated whether an additional stimulus, a taxi or motorcycle, would be more likely to be missed by participants. In Experiments 2 and 3, the "threat value" of objects in the scene were varied to determine the degree to which this influences participants' tendency to notice motorcycles.

Results: Participants were twice as likely to miss a motorcycle compared with a taxi. Moreover, participants reported that they would expect to miss a motorcycle on the road. In Experiments 2 and 3, participants modulated their attention to accommodate motorcycles when necessary, suggesting that motorcycles are afforded the lowest level of attentional bandwidth.

Conclusion: Inattentional blindness forms a good psychological framework for understanding LBFTS crashes, particularly in the context of attentional set, such that LBFTS crashes occur because motorcycles do not feature strongly in a typical driver's attentional set for driving.

Application: The findings here are important because LBFTS crashes can be reduced if we can change the expectations of road users around the presence of motorcycles on the road.

Keywords: attention, perceptual cycle, driving, situation awareness, inattentional blindness.

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HUMAN FACTORS
Vol. 60, No. 1, February 2018, pp. 5–19
DOI: 10.1177/0018720817733901

In Australia, motorcycles comprise only around 4.2% of all vehicles on the road, compared with cars, which represent approximately 75.9% of vehicles (Australian Bureau of Statistics, 2012). Similarly, compared with cars on Australian roads that demonstrate approximately 44 billion vehicle kilometers traveled (VTK) per year, motorcycles show a VTK of only .51 billion (Australian Government Department of Infrastructure and Transport, n.d.). Despite this, motorcyclists are 30 times more likely to be killed in crashes compared to car drivers (Johnson, Brooks, & Savage, 2008). This is consistent with crash statistics the world over. For example, in France, motorcyclists are 25 times more at risk of death or serious injury compared with car drivers (Clabaux et al., 2012), and in Southeast Asia, motorcyclists constitute approximately 35% of deaths or serious injuries of all road users (Ivers, 2012). Thus, motorcyclists are some of the most vulnerable road users, which may be attributable to the low proportion of "road time" that motorcyclists take up compared to other vehicles, combined with their physical vulnerability in driving a vehicle that affords very little protection in the event of a collision.

The most common type of crash involving a motorcycle is one in which a vehicle pulls out in front of an oncoming motorcycle at an intersection, junction, or driveway, violating the oncoming motorcyclist's right of way and leaving little or no time for the motorcyclist to respond with an avoidance maneuver (Clabaux et al., 2012; Clarke, Ward, Bartle, & Truman, 2007; Hurt, Ouellet, & Thom, 1981; Pai, 2011; Pai, Hwang, & Saleh, 2009; Williams & Hoffmann, 1979). That such crashes are common on the roads has been recognized for decades (e.g., Meares et al., 1972; Robertson, McLean, & Ryan, 1966; Williams & Hoffmann, 1979), but why they occur is still unclear. Indeed, reading the review by Williams and Hoffmann in 1979 suggests that little or no traction has been made on this problem in almost 40 years.

Why such crashes occur generally (but not exclusively) appear to fall into one of two categories. In one of these categories, the driver of the other car sees the motorcyclist but makes an incorrect judgment about how far away or how fast it is going in a way that overestimates their time to respond. Such collisions are typically believed to occur because a motorcycle's size, shape, and contrast affords it poor visual cues as to its speed and subsequent closing distance (Caird & Hancock, 1994; Crundall, Humphrey, & Clarke, 2008; Horswill, Helman, Ardiles, & Wann, 2005). The importance of this type of collision is that the driver reports clearly seeing the motorcyclist but makes a decision error (Crundall, Clarke, Ward, & Bartle, 2008). The second—and more worrying—type of collision is the one in which the driver reports simply failing to see the oncoming motorcyclist. This is also known as a looked-but-failed-to-see (LBFTS) crash (Brown, 2002; Clabaux et al., 2012; Herslund & Jorgensen, 2003; Treat, 1980). These are the most troublesome collisions; not only are they the most common crash involving motorcycles (see ACEM, 2009), they are also the most difficult to understand; in clear conditions, with no other hazards or distractions and no other driving risks (e.g., alcohol, age, or fatigue), a driver will look in the direction of the oncoming motorcycle—indeed in some cases will appear to look directly at the oncoming motorcycle (Pai, 2011)—but still pull out because they report simply not seeing them.

One of the most obvious reasons that a motorcycle may not be detected in a LBFTS collision is because it is genuinely harder to see because of its size, speed, shape, or color. These are referred to as the conspicuity factors of the motorcycle (e.g., Clabaux et al., 2012; de Craen, Doumen, & van Norden, 2014; Mitsopoulos-Rubens & Lenne, 2012). Conspicuity can be understood as how easily an object can be detected relative to its surrounds. By and large, motorcycles and motorcyclists demonstrate low conspicuity on the road. Motorcycles are small relative to other vehicles, typically have a single headlight, are dark, and have low contrast relative to the road and surrounds. The cumulative effect is that motorcyclists are simply harder to detect on the road compared with other vehicles such as cars. This makes perfect sense, and as a consequence, a large amount of research and resources have been devoted to increasing the conspicuity of motorcyclists, such as changes to headlight design and use (Hole & Tyrrell, 1995; Janoff, 1973; Janoff & Cassel, 1971), bright protective clothing (Watts, 1980), and reflective components on the motorcycle itself (Olson, Hallstead-Nussloch, & Sivak, 1981).

However, low conspicuity cannot be the whole story when it comes to LBFTS crashes involving motorcycles. If motorcycles were simply harder to see, then we would expect incidences of motorcycle crashes to increase under conditions of decreasing visibility. Thus, if motorcycles are harder to physically detect than other vehicles, then more motorcycle crashes should be reported when visual conditions are poor, such as in the rain, fog, or dark, as the conditions would render the motorcycle even less visible by further reducing the contrast, color, and brightness. However, this does not appear to be the case. Indeed, the most common LBFTS motorcycle crash occurs under good daytime visibility, in urban driving, with an experienced driver (Clabaux et al., 2012; Hancock, Oron-Gilad, & Thom, 2005), although it must also be acknowledged that this may be mitigated by the fact that motorcyclists are more likely to be on the road under such conditions. Therefore, in addition to conspicuity factors, failing to see motorcycles must also have something to do with the way that drivers approach the driving situation and allocate attention when driving. It implies that for your average driver, motorcyclists simply fail to hit conscious awareness when they are encountered on the road, even in situations where they are easy to see.

How we move our attention around the world to select items of interest while rejecting other items is a topic of continuous debate in psychology. However, it is of enormous interest when considering human factors in driving because of the uniqueness of the driving situation. Driving a vehicle is a demanding visuo-manual task, involving fast attentional shifting, selecting items of importance to process, but at the same time filtering out unimportant information while physically steering the vehicle. In many cases, the driving environment is highly complex and distracting, resulting in the driver needing to mentally juggle an array of complex, competing information to make critical decisions. Nothing in evolution has prepared the human attentional system to cope with such a cognitive load on such a frequent basis. As a consequence of this, the attentional system has to take mental shortcuts to deal with the barrage of information.

The first of these mental shortcuts is that rather than the visual-attentional system dealing with what is *actually* "out there," it constrains the parameters by dealing with what it *expects* to be "out there." One way to understand this is through the perceptual cycle (Neisser, 1976). According to the perceptual cycle model, our initial exploration of the world is constrained by what we expect to see, which in turn is derived from our experience. For example, we approach the driving situation with an "attentional set" (Most, Scholl, Clifford, & Simons, 2005) consisting of cars, roads, pedestrians, traffic lights, crash barriers, street lights, and so on. Thus, what we see in the world is directed by what we expect to see, and our attentional set (or schema) can become strengthened as we encounter more objects that reinforce it. The notion of the perceptual cycle and attentional set may partially explain why objects of low frequency—such as motorcycles—may be involved in LBFTS crashes; it is possible that some LBFTS crashes involving motorcycles occur because the attentional set of the driver prioritizes other objects on the road that are more likely to be detected, thus relegating motorcycles way down on the perceptual cycle hierarchy. The psychological link between the perceptual cycle model and LBFTS crashes can be nicely illustrated by inattentional blindness (IB).

In cognitive psychology, LBFTS crashes are consistent with the phenomenon known as IB (e.g., Mack & Rock, 1998; Simons, 2000). IB describes a person's failure to notice an unexpected object that is in plain sight when their attention is engaged elsewhere or in another task. In the seminal static IB paradigm (Mack & Rock, 1998), participants were shown a cross for 200 milliseconds across several trials, and their primary task was to judge whether the vertical or horizontal arm of the cross was longer in each trial. Then, in one of the final trials—the critical trial—an unexpected or additional stimulus would appear. The additional stimulus was an object not present in the previous trials, such as a square that appeared near the right arm of the cross. In such studies, approximately 25% of participants fail to notice the additional stimulus appear in the critical trial. The observation that participants are less likely to notice an unrelated stimulus when their attention is engaged elsewhere is consistent with a large amount of subsequent research that has varied the nature of the primary task (Koivisto, Hyona, & Revonsuo, 2004; Macdonald & Lavie, 2008; White & Amiola Davies, 2008) and/or the nature of the unexpected stimulus (Hyman, Boss, Wise, McKenzie, & Caggiano, 2009; Koivisto & Revonsuo, 2008; Most, 2013). The overarching message from this body of research is that not everything in an observer's visual field is noticed, particularly when they are engaged in another task. Thus, a large number of motorcycle crashes can be seen as examples of LBFTS, which may be examples of IB. Therefore, understanding motorcycle detection in the context of IB may help us understand why motorcycles are overrepresented in road crash statistics.

Most and Astur (2007) conducted a study in which participants were required to navigate a car through a city environment in a driving simulation task, following either yellow or blue arrows. Their hypothesis was that drivers fail to detect motorcycles because motorcycles are less well represented in the driver's attentional set for driving. It was found that participants were significantly less likely to notice a motorcycle appearing when its color was incongruent with the color of an arrow they were following (i.e., yellow arrows, blue motorcycle; 36% collision rate) than when it was congruent (i.e., yellow arrow, yellow motorcycle; 7% collision rate), and those who did notice the motorcycle braked significantly more slowly. This study demonstrates that noticing a motorcycle appears to be contingent on whether the color of the motorcycle matches the target the participant is monitoring. Thus, if a driver has an attentional set for "yellow-ness," then they are more likely to miss a motorcycle that does not fit with that attentional set. Pammer and Blink (2013) used a static driving IB study to demonstrate that participants were more likely to miss seeing a kangaroo as an unexpected object when judging images of driving situations taken in a city environment compared with a rural environment. Therefore, similar to Most and Astur, when an attentional set had been established for "rural driving" versus "city driving," participants were more likely to miss an unexpected object that was incongruent with the attentional set. Similarly, Summala, Pasasen, Rasanen, and Sievanen (1996) found that drivers are less likely to notice a bicycle coming from an unexpected direction, indicating that the attentional set for driving may include the driver's expectations of the direction to look for oncoming traffic. Elaborating on this idea, Koustanai, Van Elslande, and Bastien (2012) demonstrated that drivers are less likely to notice an oncoming car if it does not seem to be relevant to the maneuver they are completing, for instance noticing an oncoming car in the opposite lane while turning.

Thus, IB and the perceptual cycle may provide a reasonable framework for understanding LBFTS crashes involving motorcycles. Why is this important? Because it is not enough to know that something happens—in this case high rates of motorcycle collisions—it is only when we understand why it happens can we be in a position to put in place targeted intervention. If we can document the psychological factors that might be in play that underlie LBFTS crashes, we will be in a better position to deal with them. The other advantage of using IB to understand LBFTS collisions in general is that as a laboratory task, it is cognitively closer to what happens in the real driving environment compared to many other computer-based driving tasks. A typical experimental design for computer-based motorcycle research is a visual search task, where observers have been primed to the appearance of a motorcycle or explicitly asked to search for a motorcycle. This is in direct contrast to the on-road experience where the presence of motorcycles is often unexpected and drivers typically are not looking specifically for them. Thus, IB can be one of the few ways that we can explore motorcycle detection within the framework of the perceptual cycle and thus understand how expectation and attention may influence attentional allocation toward motorcycles, thus influencing their detection.

The aim of the present experiment is to examine LBFTS crashes with motorcycles using the IB paradigm. Consistent with traditional IB paradigms (for a review, refer to Simons, 2000), we will use static driving examples to explore whether motorcycles are more likely to be missed compared with other vehicles such as taxis. In the current series of experiments, we would expect in the first instance that even with conspicuity factors controlled for, people are less likely to detect a motorcycle in a normal driving environment, and this would occur in conjunction with their expectations of detecting a motorcycle on the road. In subsequent studies, we expect that motorcycle detection will vary in accordance with the threat level of various hazards, reflecting the decreasing attentional prioritization of motorcycles on the road, which in turn reflects their detection in the driving environment.

EXPERIMENT 1

Participants

Fifty-six participants were recruited for the experiment (M_{age} = 38.42, *SD* = 12.10) and were randomly assigned between conditions. Participants were recruited from Questacon, the local public National Science and Technology Centre/Museum, and voluntarily took part in the experiment. The environment at Questacon is freely open to the public, but the current experiment was set up in one of the display rooms as one of the interactive exhibits on human perception. It was not possible to see the computer display from the public display gallery, and participants took part after reading the banner and discussing the study with the experimenter. As the experiment was conducted in a public museum, it contained more attentional challenges than would have been the case in a quiet laboratory; however, we have conducted many IB studies in this location as well as in the laboratory and have not demonstrated a difference in responding between the two locations. Moreover, as Experiments 1, 2, and 3 were all conducted in the same location, any attentional differences would be the same over all conditions and experiments. The mean driving experience was 17.94 years (*SD* = 10.22). Participants' data were excluded if they failed to notice the additional object on the full attention trial ($N = 0$), had a motorcycle license ($N = 10$), or were over 70 years of age ($N = 0$). This resulted in 23 participants in each of the two conditions. All participants provided informed consent and reported normal or corrected to normal vision.

Materials

Visual stimuli were displayed on a 17.3" Dell Precision laptop, operating at a frame rate of 60 Hz and a spatial resolution of 1,920 × 1,080 pixels. Stimuli were programmed with Inquisit 3 (Millisecond software). The stimuli were photographs of a driving situation taking up 90% of the screen.

The experiment consisted of 10 two-second presentations, with three practice presentations and five control presentations, presented in a random order (Figure 1). The practice and control trials were photographs of driving situations from a city environment taken from the driver's perspective, with additional items added using Adobe Photoshop CS5.1. There was one critical trial (Trial 9), followed by a full attention trial (Trial 10); both trials were identical and contained an additional item. The additional item was either a taxi (approximately 5.6° × 7° visual angle [VA]) or motorcycle (approximately 5.06° × 7° VA) located in the center on the right side of the photograph (subtending approximately 12.9° VA from the center point of the screen). The additional item was placed in this location to make it appear as natural as possible within the photograph to ensure ecological validity of the experiment as well as exclude the possibility that the salience—such as unusual location—of an additional item may confound the results. The taxi was chosen as a proxy for a car because it is a common type of car that is easily identifiable and thus easily reported. The taxi versus motorcycle images constituted the two experimental conditions, and participants were randomly allocated to one of the two conditions as a between-subjects design.

The motorcycle and taxi critical stimuli were matched as much as possible by using the same colors, yellow, white, and black, and turning the motorcycle on its side and making it slightly larger than normal so that it was as close as possible in size to the front of the taxi. Thus we attempted to match the physical features of the taxi and motorcycle as much as possible while still maintaining ecological validity. In addition to this, the contrast of the taxi was reduced slightly, and the brightness of the motorcycle increased (in the following figures, the images are represented in their original brightness so that they can be clearly seen in the smaller resolution of a manuscript). Saliency of the additional objects was measured using Saliency Toolbox (Walther & Koch, 2006), such that the two different stimuli were compared on the number of iterations before the program "found" them. This comparison revealed no significant difference in saliency between the taxi and motorcycle, $t(18) = 2.1$, $p = .38$. The brightness and contrast of the taxi and motorbike were measured in the context of the overall image. The brightness of each stimulus was measured using a hand-held Minolta LS-110 photometer, under daytime, bright, and indoor lighting conditions, which was the same as the visual conditions experienced by the participants. Ten measurements were taken of each stimulus from approximately the same viewing distance as in the experiment. The average luminance was 103.3 cd/m^2 for the taxi and 101 cd/m^2 for the motorcycle. Contrast for the stimuli was calculated relative to the surround, again using 10 recordings surrounding the image and 10 recordings of the image itself. Michelson contrast demonstrated contrast of 0.59 for the taxi and 0.54 for the motorcycle. Internal contrast of the images was unstable because the motorcycle is of a higher spatial frequency than the taxi and so was not calculated. Other similar objects, such as pedestrians, motorcycles, or bicycles, were removed from the critical trial and all presentations leading up to the critical trial. In an IB task, the critical trial can only be presented once, thus limiting the ability to present multiple different unexpected objects. The driving scenario pictures for all trials did not explicitly vary in terms of the "danger" of the scenario—they were all relatively normal driving situations. The objective of the primary task was to require the participant to engage in the stimuli and provide a valid and reasonable "cover story" for the experiment.

Each presentation was preceded by a grey screen with a fixation cross in the center and followed by a mask consisting of randomly positioned black lines.

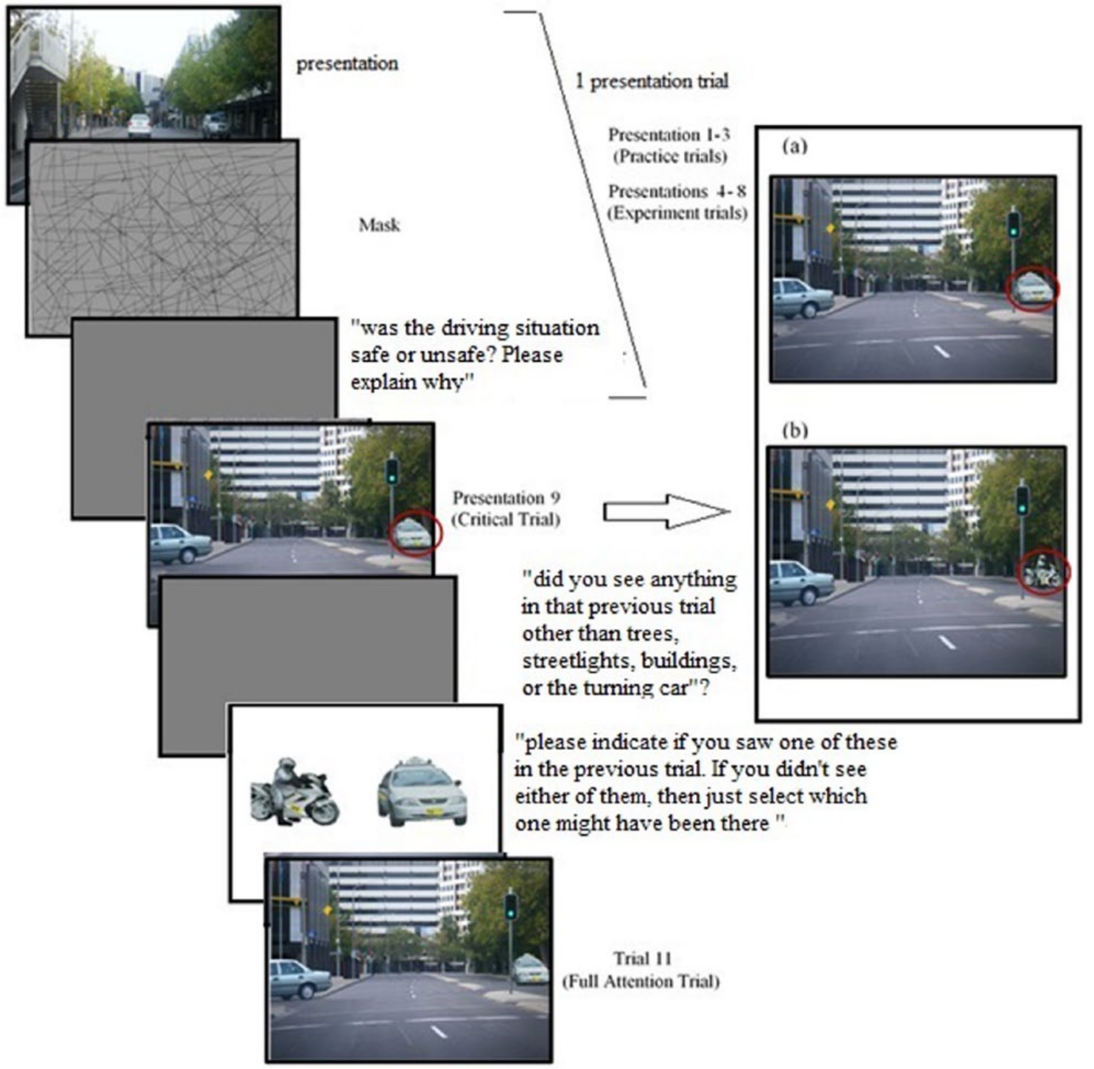

Figure 1. Sequence of presentations. Each presentation was 2 seconds long, and a full trial consisted of the image presentation followed by a mask, followed by the requirement to respond whether the image represented a "safe" or "unsafe" driving environment. Trials 1 through 8 contained only the driving situation. Trial 9 was the critical trial, containing the additional object (a) taxi or (b) motorcycle.
Source. Adapted from Pammer and Blink (2013, p. 958).

A survey was administered to gauge the participant's perceptions of the general likelihood of taxis and motorcycles to be on the road as well as their perceptions of the likelihood of them missing a taxi and motorcycle on the road. The questions were, "What is the likelihood of a taxi/motorcycle to be on the road?" and "What is the likelihood of you missing a taxi/motorcycle on the road?" These ratings were measured using a visual analogue scale 100 mm in length that corresponded to an 11-point Likert scale. Participants marked on the line to indicate their rating, resulting in a score between 0 (*very unlikely*) and 10 (*very likely*).

Procedure

Participants were tested individually and informed that the purpose of the experiment was to investigate people's decision-making processes in making driving judgments on briefly shown driving situations.

Participants were positioned approximately 30 cm from the screen and asked to imagine they were in the driver's seat of their car and the photograph was the situation they can see through their windshield. After looking at each photograph, participants made a decision whether the photograph shown to them depicted a "safe" or "unsafe" driving situation for themselves as drivers or for other drivers on the road. Judging driving situations was chosen as a primary task as it was consistent with the tasks drivers make when driving, such as judging whether it is safe to cross an intersection. They were instructed to press the 1 key to indicate the scene was safe or 2 to indicate it was unsafe. They were also asked to briefly explain their decision to the experimenter before the next photograph was shown. This was repeated after each trial. A typical response might be "This was safe because the driver in front stopped at a red light."

After the critical trial, participants were asked if they had noticed an additional item in the trial and were asked "Was there anything in that previous trial other than the trees, buildings, street signs, and car turning that had not appeared in any previous trials?" Participants who noticed the extra object were asked to describe what they saw and point out the location in the photograph where they had seen the item. Then, they were shown a forced choice sheet containing the two possible objects and asked to point out which item they had seen in the photograph. The survey on perceptions of motorcycles and taxis was also administered. In IB, once the participant has seen the critical trial, they are no longer considered naïve. Thus the next—and final—trial was the full attention trial, where participants were instructed to just look at the photograph without making a judgment. The purpose of this trial was to ensure all participants—but in particular the participants who failed to detect the additional object—understood the instructions of the task and were physically able to detect the additional object when not engaged in the task (Mack & Rock, 1998). The data of participants who did not notice the additional object on the full attention trial were excluded from the analysis. No participants were excluded on this basis. The dependent variable is whether observers notice the additional object (a taxi vs. motorcycle) in the critical trial.

At the conclusion of the experiment, participants were debriefed to the true purpose of the experiment, and they completed an additional survey with questions on demographic information as well as questions about driving experiences, possession of a motorcycle license, and knowledge of IB paradigms.

RESULTS

The accuracy of judgments made by the participants for each of the driving situations shown was not analyzed as there is no specific correct/incorrect response for each situation. The purpose of the judgments was just to have the participants engaged in a primary task akin with other IB paradigms. However, all participants generated plausible responses on all trials, indicating that they had engaged in the task.

Overall, 48% of participants did not report noticing the unexpected stimulus. This IB rate differed across the two conditions, $\chi^2(1, N = 46) = 5.02, p = .02$. This indicated people were significantly more likely to miss detecting the motorcycle (65%) on the critical trial than the taxi (31%). Furthermore, the strength of association was moderate, $\varphi = .3$, indicating that condition explains 9% of the variance in IB.

Perceptions of Taxis and Motorcycles

The non-noticers' ratings of the likelihood of a taxi and motorcycle on the road as well as their ratings of the likelihood of them missing a taxi and motorcycle on the road were analyzed using a paired t test. It was found that there was no significant difference between the ratings of the likelihood of a taxi ($M = 6.08$, $SD = 3.11$) to be on the road compared with a motorcycle ($M = 5.72$, $SD = 3.03$), $t(23) = 0.553$, $p = .586$. It was also found there was a significant difference between the ratings of the likelihood of missing a taxi ($M = 4.15$, $SD = 2.85$) compared with a motorcycle ($M = 5.4$, $SD = 2.08$), $t(23) = -3.707$, $p = .001$, indicating that non-noticers thought they were more likely to miss a motorcycle on the road compared with a taxi.

In regards to the choices that non-noticers made on the forced choice sheet, it was found there was no significant difference in correctly choosing the additional stimulus in either condition, $\chi^2(1, N = 22) = 1.500, p = .221$, indicating that their perceptions of taxis and motorcycles did not influence their item choice.

CONCLUSION EXPERIMENT 1

The results from Experiment 1 are consistent with the proposal that observers are less likely to notice a motorcycle as an additional unexpected object in a static driving IB task. These results may be consistent with the IB findings elsewhere, demonstrating that drivers are slower to respond to motorcycles in simulated driving environments (Most & Astur, 2007), resulting in a higher crash rate. The difference between the current study and Most and Astur (2007) is that in the latter, most participants did in fact respond (with the exception of two participants who entirely failed to apply the brakes), braking more slowly such as to result in a collision with the motorcycle. In the current study, we rely less on driving behavior and more on what the participant actually reports seeing in the scene. Given that motorcycles are less common on the roads than cars, one possible explanation for the results is that motorcycles may not fit the expectations of drivers as much as cars and thus be less well represented in the attentional set for driving. This is consistent with Crundall et al.'s (2008c) suggestion that looked-but-failed-to-see crashes may occur because drivers fail to process the motorcycle because it is less common, thus less familiar, and consequently may not allocate enough attention toward its presence.

An important finding in this study that supports the proposal that a driver's attentional set does not include motorcycles is that participants reported that they would probably miss a motorcycle on the road. Although participants thought that taxis and motorcycles were equally likely to be on the road, participants rated that they were significantly more likely to miss a motorcycle than a taxi. This extends one of Mannering and Grodsky's (1995) reasons why car drivers are likely to have collisions with motorcycles: drivers' expectations that cars will be the only vehicle representing a collision danger. Furthermore, a survey conducted by Crundall et al. (2008a) found a correlation between negative ratings of motorcyclists (e.g., believing motorcyclists are more likely to perform illegal movements), participants who rated motorcyclists difficult to see, and participants predicting near crashes with motorcycles. These results suggest that the expectations of drivers toward motorcyclists may have a direct influence on the attentional set for driving and thus contribute to whether a driver is more or less likely to see a motorcyclist when driving.

However, the results for Experiment 1 may be affected by the difference in perceived relevance of the additional stimuli. While the taxi appears as though it is driving toward the observer, the motorcycle stimulus faces away from the intersection and looks as though it is turning out of the scene. Thus, it could be argued that in Experiment 1, the taxi may be perceived as being more likely to result in the driver requiring to react to its presence—such as avoiding a crash—compared with the motorcycle and thus more likely to be detected because it is more immediately relevant to the driving situation (e.g., Pammer, Bairnsfather, Burns, & Hellsing, 2015). Previous research shows that the perceived likelihood of a crash can affect the rate of IB in driving situations involving motorcycles. Crundall et al. (2008c) compared the perception of motorcycles and cars in a static study using images of each vehicle at near, intermediate, or far distances from the observer. The task was to determine whether it was safe to pull out of a T-intersection with the vehicles at each of those distances, and like the current experiment, the participants were given a short period of time to view the image. No significant difference was found in the rate of noticing the vehicle at a near distance. However, when the vehicles were at a far or intermediate distance—and therefore less of a threat—cars were noticed significantly more than motorcycles, particularly in the far condition.

The aim of Experiment 2 is to determine whether threat perception and relevance to the immediate driving situation influenced the results obtained in Experiment 1. In Experiment 2, there will be an additional condition—a motorcycle that is facing toward the intersection. If detection of

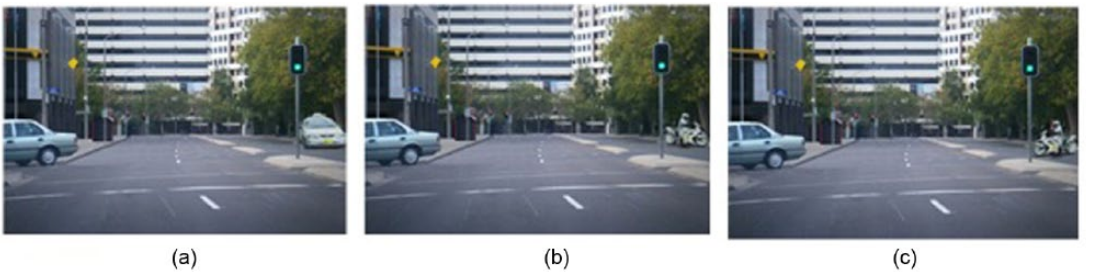

Figure 2. The three conditions of the critical trial: (a) taxi, (b) motorcycle facing away from the intersection, or (c) motorcycle facing toward the intersection.

motorcycles on the road is moderated by the requirements of the situation, such as threat relevance, the rate of IB will be higher for the motorcycle facing away from the intersection than the motorcycle facing toward the intersection.

EXPERIMENT 2

Participants

The location and environment of the data collection were the same as Experiment 1. Seventy-six participants were randomly assigned into one of three conditions that differed according to the additional unexpected stimuli. The same selection criteria were applied as in Experiment 1, such that the data for 11 people were removed as they rode a motorcycle and 1 participant was aged over 70. The remaining participants were aged between 17 and 63 years (M = 37, SD = 13.1) with driving experience ranging from 6 months to 45 years (M = 18.17, SD = 12.6) and were 52.2% male. All participants reported having normal or corrected to normal vision and were appropriately attending to the study in that they all detected the additional object in the full attention trial, so no additional exclusions were necessary. Two of the conditions were identical to Experiment 1: the taxi (N = 21) and motorcycle (N = 23) facing away from the intersection. The third condition was a motorcycle facing toward the intersection (N = 20). No participants participated in Experiment 1.

Materials and Procedure

Experiment 2 was conducted in the same way as Experiment 1. The only difference from Experiment 1 was the addition of the condition with the motorcycle facing toward the intersection, which was the same image but reversed to appear as if it were naturally crossing the intersection (refer to Figure 2). Similarly, the forced choice sheet presented to participants after the critical trial now included all three stimuli, and participants were not asked about their perceptions of motorcycles on the road.

RESULTS

As with Experiment 1, the judgments made in each driving situation were not analyzed. Again, all participants responded plausibly to each situation, indicating engagement with the task.

Overall, 28 participants (44%) did not notice the additional object. Consistent with the planned comparisons for Experiment 2, there was a significant difference between the motorcycle toward and away conditions, $\chi^2(1, N = 44) = 4.4$, $p = .03$, $\varphi = .32$, suggesting that participants were more likely to miss the motorcycle facing away from the intersection (62%) than they were to miss a motorcycle facing toward the intersection (33%) on the critical trial.

Comparing Experiment 1 with Experiment 2 for the taxi and motorcycle away conditions, there was no significant difference in the rates of IB between Experiments 1 and 2 for the motorcycle away conditions, $\chi^2(1, N = 44) = 0.82$, $p = .53$, or the taxi conditions, $\chi^2(1, N = 43) = .51$, $p = .36$. Of the participants who did not notice the additional object, there was not a significant difference in choosing the correct additional stimulus on the forced choice sheet across all three conditions.

CONCLUSION EXPERIMENT 2

The results suggest that the rate of IB is higher for those in the condition with the motorcycle facing away from the scene than in the condition with the motorcycle facing toward the intersection. However, this effect was small, suggesting that the perception of "threat" or relevance to the driving situation only partially accounts for the finding that participants are more likely to fail to detect a motorcycle in a driving situation. This finding would appear to be both good news and bad news to motorcycle riders. The bad news is that they are significantly less likely to be detected on the road compared to other visually matched vehicle but that this may be partially mitigated if the motorcycle is directly relevant to the driving situation. In other words, the evidence is consistent with research that we have conducted elsewhere (Pammer & Blink, 2013; Pammer et al., 2015), which suggests that drivers engage in a pre-attentive or preconscious sweep of the environment as they are driving, selecting objects for attention based on their relevance to the situation. Thus, in driving, objects considered irrelevant or less important to the driving situation never hit conscious awareness. The evidence from Experiments 1 and 2 is that there is only a small tendency for motorcycles to hit conscious awareness even when they are directly relevant to the driving situation.

The finding that noticing a motorcycle may be mitigated by its immediate relevance to the driving situation is one that is worth exploring. Indeed, based on these findings, one might predict that placing an immediately relevant driving hazard into the scene might further mitigate noticing motorcycles. For example, if drivers prioritize the importance of objects in the driving environment, as has been demonstrated by Pammer et al. (2015), and motorcycles appear to be de-prioritized (Experiment 1) unless they are relevant (Experiment 2), then one might hypothesize that in a situation where attention should be drawn to a more relevant object in the driving scene, there should be a decreasing order of noticing depending on the relevance of the object in the scene. So in Experiment 3 we place the car that is turning out of the scene further into the scene so that it is of immediate relevance. We predict that IB would then increase for the taxi and motorcycle conditions, with the motorcycle having the least priority and thus highest rates of IB.

EXPERIMENT 3

Participants

There were 56 participants included in this experiment and were evenly distributed in each of the two conditions. As with Experiments 1 and 2, all participants were visitors to Questacon, the National Science and Technology Centre in Canberra. All participants provided informed consent and had normal or corrected to normal vision, and all participants possessed a driver's license. The same selection criteria applied as with Experiments 1 and 2, resulting in 22 participants in the new taxi condition and 21 participants in the new motorcycle condition. The average number of years driving was 22.9 years (SD = 11.3, range = 6 months–50 years). The average age was 42 years (SD = 11.2, range = 17–65 years), and there were 48% males. No participants participated in any of the previous experiments.

Materials and Procedure

The design and execution of Experiment 3 was the same as Experiment 1 except that the image was adjusted so that the car that appeared to be leaving the scene in Experiments 1 and 2 now appears to be a more direct and relevant threat to the situation by turning in front of the oncoming car (refer to Figure 3, Panels A and B).

RESULTS

There was no significant difference in the IB rates between the taxi and the motorcycle conditions, $\chi^2(1, N = 43) = .45, p = .33$. However, there are clearly now significantly higher rates of IB in both the taxi and motorcycle conditions compared to the results in Experiments 1 and 2 (refer to Figure 4). The overall chi-square for IB over all four conditions is significant, $\chi^2(3, N = 130) = 12.18, p < .007$, and the significance is due to lower rates of IB in the taxi condition compared to the other conditions. Thus, rates of IB were the same for the taxi versus motorcycle conditions in Experiment 3, compared to the motorcycle condition in Experiments 1 and 2, $\chi^2(2, N = 87) = .42, p = .81$.

Figure 3. A and B represent the two new motorcycle and taxi conditions where the grey car is now presented centrally appearing as a potential hazard as it is turning directly in front of the driver. Item C is the taxi condition from Experiments 1 and 2. It is presented as a comparison to show the relative positioning of the central grey car. Only images A and B were presented in Experiment 3.

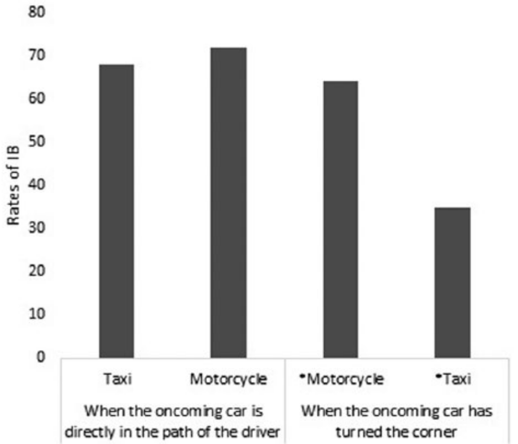

Figure 4. Rates of inattentional blindness in the taxi and motorcycle conditions in Experiment 3 when there is a potential hazard directly in front of the driver, compared to when there is no potential hazard. The motorcycle and taxi conditions here are combined from Experiments 1 and 2 because they are identical stimuli and procedures.

Analysis of Item Choice in Non-Noticers

It was found that the taxi was the item most likely to be chosen by non-noticers (32%), $\chi^2(5, N = 97) = 36.918, p \leq .001$, in the taxi condition; however, there was no significant effect of item choice for non-noticers in the motorcycle condition. These results suggest that non-noticers in the taxi condition were most likely to correctly choose the additional object from the forced choice sheet, although they were unable to explicitly report its presence after the critical trial, whereas participants in the motorcycle condition were unable to identify the correct object either implicitly or explicitly.

CONCLUSION EXPERIMENT 3

The results demonstrated that when a car was of immediate relevance to the driving situation, there were high rates of IB for both motorcycles and taxis. The high rates of IB were the same as those for motorcycles when there is no immediate threat, while taxis are noticed most frequently when there is no other immediate threat in the environment. Figure 5 is a summary of the outcomes over the three experiments. Moreover, within each condition, it was found that the non-noticers in the taxi condition were most likely to correctly choose the item from the forced choice sheet even if they could not explicitly report the presence of that item when asked after the critical trial. This was the only condition where non-noticers were able to correctly choose the item from the forced choice sheet; in the other three conditions, the non-noticers were not as likely to choose the correct item.

GENERAL DISCUSSION

Motorcyclists commonly refer to the term *SMIDSY*: “Sorry mate I didn’t see you.” The term can be found on t-shirts and is common parlance among the motorcycle community, such as “Sorry I’m late, I had a SMIDSY on the way here.” In other words, the looked-but-failed-to-see incident

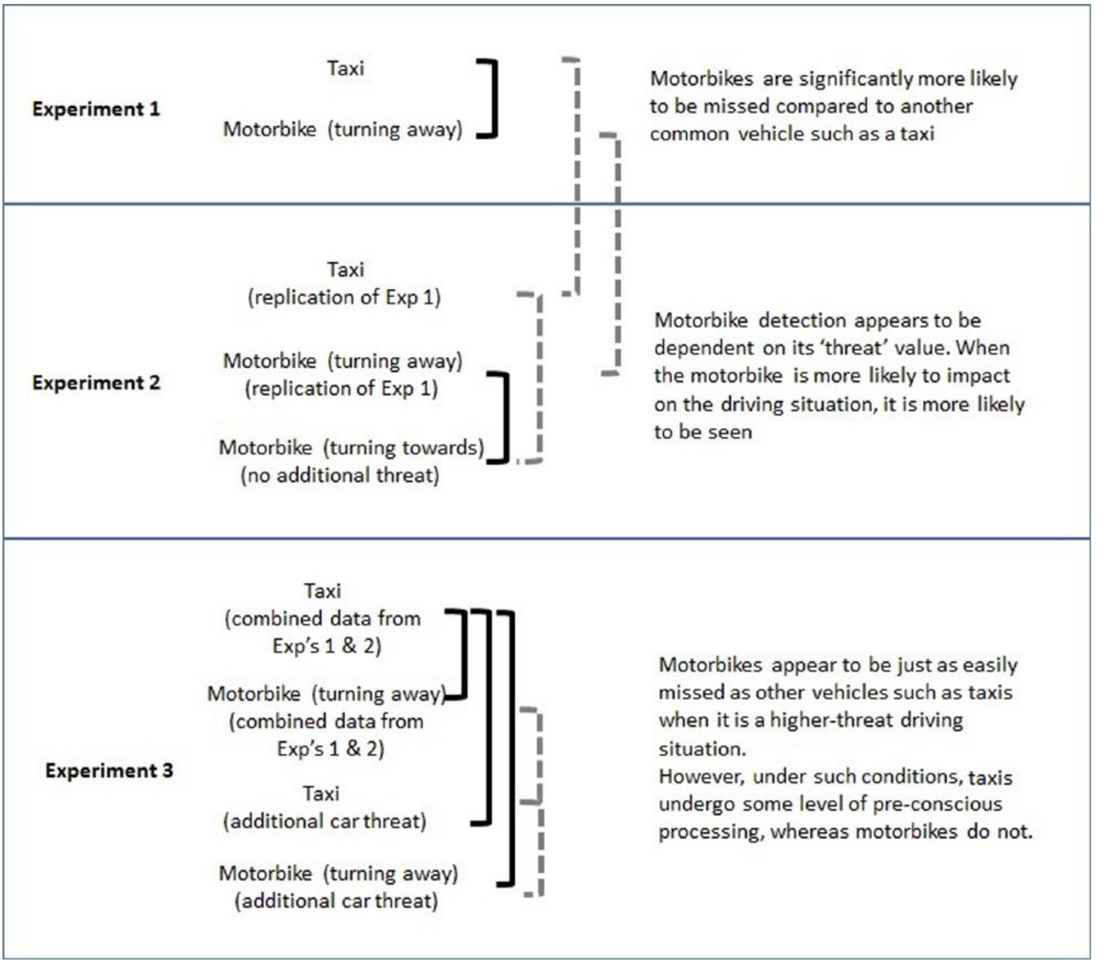

Figure 5. A summary of analyses, with a basic interpretation. Black lines represent statistically significant comparisons, while dotted lines represent comparisons that were not significant.

is so common in the motorcyclist's experience that there is a well-known acronym for it. These types of crashes might be partly explained by a phenomenon known in psychology as IB. Thus, using an IB design, we demonstrated that motorcycles are less likely to be detected on the road, compared with detecting a taxi, and appear to be less likely to capture preconscious attention in driving, which is critical for effective hazard detection (Pammer & Blink, 2013; Pammer et al., 2015).

Driving a car safely requires enormous visuospatial resourcing. One way in which the brain deals with the magnitude, speed, and complexity of the visual information it receives is to constrain the parameters by "setting" attention to detect the objects that could reasonably be expected to be seen. For the average driver, these parameters are all the things that one would regularly encounter when driving. Thus, the perceptual cycle is an iterative process such that we regularly see particular items when driving, such as cars, traffic lights, and road signs. This creates an expectation of seeing such items when driving, which in turn constrains our detection of objects to those that most closely fit the expectations. Using this model, we hypothesized that one of the reasons that motorcycles are overrepresented in crash statistics is that people don't expect to see them in the driving environment because they are rare on the road compared to other road users. Thus, we predicted that in an IB paradigm in which participants are not expecting or looking for a motorcycle, it would be less likely to be detected. This was supported in Experiment 1; moreover, participants reported that they would have a lower expectation of seeing a motorcycle on the road. This latter finding reflects an interesting level of hindsight in participants, which may be helpful in the future in leveraging intervention strategies. Given that the first hurdle of behavior change is recognizing a problem, the high level of insight offered by the participants suggests that changing drivers' perceptions and expectations of motorcycles on the road can be used to educational advantage.

The results from Experiments 2 and 3 develop the perceptual cycle model in the context of motorcycle detection by investigating the hypothesis that the expectation of objects in the driving scene have orders of priority, with motorcycles being lowest down on the priority list, but their detection may be moderated by their relative importance to the driving situation. Thus, participants should explicitly prioritize information either toward or away from motorcycles as the situation demands. Experiment 2 demonstrated that when a motorcycle is positioned as moving toward the path of the driver, it is more likely to be detected compared to when it is positioned away; however, when a car is positioned as the critical element in the driving scene, motorcycles have the lowest level of attentional priority.

The current study is a static task, and although it was designed to simulate some of the decision-making cognition that occurs when driving and is consistent with other driving studies (e.g., Huestegge, Skottke, Anders, Musseler, & Debus, 2010; Koustannai et al., 2012; Pammer & Blink, 2013; Scialfa, Borkenhagen, Lyon, & Deschenes, 2013; Scialfa et al., 2012; Wetton et al., 2010), it still only represents a rough facsimile of the real, dynamic driving situation. For example, motion provides drivers with information about the speed of a vehicle to determine whether it is safe to proceed (Caird & Hancock, 1994). Including motion in future experiments would allow the investigation of the size-arrival effect, another explanation for looked-but-failed-to-see crashes with motorcycles (Horswill et al., 2005). This effect suggests motorcycles are involved in these crashes because drivers may underestimate the speed at which a motorcycle will pass. Similarly, it is well known anecdotally that looked-but-failed-to-see crashes are ubiquitous in the driving community; however, there is very little research interrogating the proportion of motorcycle-vehicle crashes that can be attributed to looked-but-failed-to-see scenarios and little research investigating such crashes from the perspective of the motorcyclist. Understanding how, when, where, and how often such incidences occur will contribute enormously to increasing road safety to these vulnerable road users. We are currently in the process of collecting such data, and in the words of most of our participants when asked about their experiences of looked-but-failed-to-see-crashes, the response is "Which one? They happen almost daily."

ACKNOWLEDGMENTS

We would also like to acknowledge Questacon Science and Technology Centre staff in their assistance in providing resources for data collection and anonymous reviewers on previous versions of this manuscript. This research was supported by the Australian Research Council and the NRMA-ACT Road Safety Trust (Grant No. LP13010081).

KEY POINTS

- Motorcycle crashes are overrepresented in international road crash statistics, and many of these incidences are looked-but-failed-to-see crashes.
- Looked-but-failed-to-see crashes are difficult to reconcile in the hazard detection literature because the participant looks directly at the vehicle yet still fails to see it.
- Inattentional blindness (IB) provides a good psychological framework for understanding looked-but-failed-to-see crashes and thus provides a good psychological framework for understanding why looked-but-failed-to-see crashes occur with motorcycles.
- Using an IB design, we demonstrated that motorcycles are less likely to be detected compared with detecting other vehicles on the road, but this may be modulated by the threat value of objects on the road, and it may be that motorcycles are afforded a lower level of attentional bandwidth.

- This may partly be because drivers typically have an attentional set that does not include motorcycles, namely, they don't expect to see motorcycles on the road, but conversely, people are good at dynamically allocating attentional resources as required.
- This finding is important because it suggests that raising the expectation or experience of having motorcycles on the road—such as including them as part of driver training programs and targeted media programs—could substantially alleviate incidences of looked-but-failed-to-see crashes.

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Date received: December 19, 2016
Date accepted: August 29, 2017