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Problems of sensory- and cognitive conspicuity of motorcyclists at junctions:

A car to motorcycle comparison of visual search and give-way intentions by car drivers, from two angles of approach

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Abstract

It is often assumed that motorcyclists have a relatively higher chance of falling victim to car driver right-of-way violations than cars at junctions. Various studies have pointed out this is particularly the case due to the motorcyclist's poorer sensory- and cognitive conspicuity. The angle of approach between the car driver and motorcyclist may interact differently with conspicuity related causes of crash. However, the angle of approach has not been given sufficient attention in the available literature. There are no experimental studies in which opposite- and perpendicular angles of approach are combined and compared between car driver-to-car and car driver-to-motorcycle interaction. The main goal of the present study was to examine differences in visual search and intentions to give way by car drivers, when motorcycles and cars approached two prior selected, four-legged non-regulated junctions. Video clips of oncoming cars and high- and low-salient motorcyclists were presented to 93 car driver's license holders. Response times and eye-gazes of participants were measured. The results confirmed that car drivers gave way to perpendicularly oncoming motorcyclists later than perpendicularly oncoming cars (measured after first-fixating target vehicle), at one of the two selected junctions. Furthermore, results showed a reversed pattern from what was expected in opposite approaches, in which car drivers gave way to motorcyclists significantly earlier than cars. Lastly, results confirmed that car drivers fixated perpendicularly oncoming high-salient motorcyclists earlier than low-salient motorcyclists, on one of the two selected junctions. We could however not confirm that high-salient motorcyclists were detected earlier in opposite approaches too.

1. Introduction

Typical car-motorcycle crashes occur at T-junctions, when the car driver fails to give way to the oncoming motorcyclist (Clarke, Ward, Bartle and Truman, 2007; Crundall, Humphrey and Clarke, 2008; Pai, Hwang and Saleh, 2009). These types of errors are referred to as right-of-way violations (ROWVs). Not motorcyclists, but car drivers appear to be responsible in the majority of ROWV occurrences (Brown, 2005; MAIDS, 2009). Even though motorcyclists only represent about 3% of road users in Europe (SafetyNet, 2009), they are over-represented in crashes with cars in the Netherlands (SWOV, 2014), France (de Lapparent, 2006), the United Kingdom (DETR, 2000) and several other European countries (MAIDS, 2009). Motorcyclists often suffer from severe injuries after a crash (Vlahogianni, Yannis and Golias, 2012) and are 20 times more likely to be in a deadly accident than car drivers (SWOV, 2014). It is often assumed that motorcyclists have a relatively higher chance of falling victim to car driver ROWVs than cars at junctions (Brown, 2005; Pai, 2011), while little attention has been given to differences in the angle of approach.

A study by de Craen, Doumen and Norden (2014) suggest that the general assumption of higher risk for motorcyclists may only be applicable to opposite approaches, when the car driver turns left, not perpendicular approaches. Their analysis of police crash-records in the Netherlands between 2000 and 2009 show car drivers failed to give way 32% of the time in opposite car-motorcycle crashes, compared to only 13% in opposite car-car crashes. This finding is in accordance with the general assumption. However, no difference was found given the same comparison but assessing perpendicular approaches instead. Here, the result was 56% versus 56%. This is partly contradictory to the general assumption, and calls for experimental validation. Two major causes of car-motorcycle crashes have been considered throughout the literature, in which direction of approach may interact differently.

The first one being poor sensory conspicuity of the motorcycle and its rider, causing a slow anticipatory response or detection failure by the car driver (Brown, 2005; Pai, 2011). Sensory conspicuity is derived from an object's (e.g. motorcycle) physical characteristics such as size, luminance, contrast and colour compared to its surroundings (Wulf, Hancock and Rahimi, 1989). These characteristics contribute to the object's saliency and its ability to attract bottom-up attention (Torralba, Oliva, Castelhano and Henderson, 2006). Visual selective attention enables car drivers to focus on processing relevant features or objects while ignoring irrelevant ones, within the context of a limited attentional- and/or processing capacity (McAvinue et al., 2012). Bottom-up attention may therefore be drawn to a highly competing, clearly visible vehicle or other high conspicuous objects, rather than a less conspicuous motorcycle. A motorcycle may be more easily 'overlooked' due to its relatively small size, camouflaged by the surrounding background or obscured by bigger vehicles (Pai, 2011). In post-crash interviews, car drivers often claim to have missed the motorcycle, or to not have seen it until the very last moment before crashing (Brown, 2005; Pai, 2011). This, even though claiming to have looked in the appropriate direction (Labbett & Langham, 2006). This type of error has been termed 'looked-but-failed-to-see' or LBFTS (Labbett & Langham, 2006) and may be a problem of the car driver's perception rather than a problem of poor sensory conspicuity of the motorcyclist (Brown, 2005).

Perceptual (and attentional) problems contribute to the second major cause of car-motorcycle crashes, which is poor 'cognitive conspicuity'. Problems of cognitive conspicuity, such as poor speed-spacing judgments of the car driver facing a motorcycle are argued to be related to ROWVs (Pai, 2011). Results from an observational gap-acceptance study by Keskinen (1998) are in accordance with this suggestion. They measured safety margins of car drivers pulling out in front of an oncoming motorcycle or car, at three different T-shaped junctions. Car drivers were observed to accept smaller gaps, leaving less space when pulling out in front of a motorcycle compared to a car. An experimental study by Underwood, Humphrey and van Loon (2011) assessed whether vehicle saliency of oncoming motorcycles and cars would affect the participants' safety-decisions, in merging the main carriageway of a T-junction. These oncoming vehicles were presented using photographs. Participants made significant more 'safe to pull out' decisions when the nearest vehicle was a motorcycle compared to a car, regardless of vehicle saliency. These experimental results are in accordance with observations by Keskinen (1998) but suggest a relatively higher risk for motorcyclists in crashing with car drivers in perpendicular approaches too, unlike results from de Craen et al. (2014) indicate. Results of another study (Crundall, Crundall, Clarke and Shahar, 2012), in which participants also observed motorcycles and cars at a T-junction are somewhat contradictory to Keskinen (1998) and Underwood et al. (2011). Participants responded significantly slower in their 'safe to merge' decisions when facing a motorcycle compared to facing a car. Participants provided more space for motorcycles to pass safely, showing more caution. However, safety decisions were measured after the oncoming vehicles had passed a predefined safety-point, at which pulling out in front of the vehicle was precluded. The participants' motivations in decision making when facing a motorcycle may have been very different in the two situations, and may explain the contradictory behaviour of participants, who acted more safe in one study (Crundall et al., 2012) but less safe in the other (Underwood et al., 2011).

Poor speed-spacing judgments or speed underestimation may also be attributed to the smaller size (e.g. frontal surface) of a motorcycle (Pai, 2011). Delucia (1991) described a 'size-arrival-effect', which shows that smaller approaching objects are perceived to arrive later than larger ones. Horswill, Helman, Ardiles and Wann (2005) demonstrated such an illusion by presenting video clips to participants of different types of opposite oncoming vehicles (a van, car, big- and small motorcycle). They measured their participants' estimation of arrival-time of oncoming vehicles, shortly after removing all visual cues by shutting off the screen. Even though the actual arrival times and vehicle speeds were identical, participants significantly estimated opposite oncoming motorcycles to arrive later than cars. The effect was found to be related to the overall size of the vehicle (i.e. the smaller the vehicle, the slower the response) which is in accordance with Delucia (1991). This clearly demonstrates that problems of sensory conspicuity (e.g. small vehicle size) and problems of cognitive conspicuity (e.g. misperception due to the smaller vehicle size) can be interrelated.

Poor cognitive conspicuity may also be related to a lack of (driving) experience with motorcycles. Apart from measuring response times (RTs), Crundall et al. (2012) also captured eye-gazes of participants and analyzed differences between novice-, experienced- and dual-drivers (both car- and motorcycle-license holders). Experienced drivers failed to reduce their gaze-eccentricity when facing a motorcycle, shortly after the vehicle in which the participant was driving came to a stop at the crossing (i.e. in the 1-2 second temporal bin after stopping). Both novice- and dual-drivers did not show this behaviour. The authors suggest this may point towards an 'over-learned strategy' of experienced car drivers, "encouraging drivers to search beyond a motorcycle once it has been spotted". They further argue this over-learned strategy may "reduce chances of spotting the motorcycle at all" (Crundall et al., 2012, p. 93). Durations of gaze were also analyzed. Experienced drivers made significantly longer 'first gazes' at cars than motorcycles. Shorter first gazes may reflect easier processing of the object, but may also reflect failure to process the object entirely (Crundall et al., 2012). Oncoming vehicles were observed from perpendicular angles of approach, which again seems to suggest motorcyclists may not only have higher chances of crashing with cars given opposite angles of approach only.

Finally, expectations of car drivers to be confronted by motorcyclists may also be contributory. Given motorcyclists only represent about 3% of road users in Europe (SafetyNet, 2009), meeting one at a junction may actually be a relatively rare event. LBFTS is argued to be related to phenomena such as inattentional blindness (Clarke et al., 2007), in which an individual fails to recognize an unexpected stimulus (Owsley & McGwin, 2010). Expectations may also be related to the concept of schemata (Norman & Shallice, 1986), which help us to perform quickly and efficiently in frequent reoccurring (routine) tasks, without consciously needing to attend to them. Schemata may influence selective attention and increase chances of noticing and responding to things anticipated by the scheme (Vlakveld, 2011). Non-routine actions, such as giving way to a motorcycle (due to a lesser expectancy) may therefore be a more cognitively demanding task than giving way to a car which are more expected. Behavioural measurements such as give-way RTs after fixating a vehicle may be helpful in recognizing difficulties in cognitive processing. After all, problems of sensory conspicuity are mostly related to detection, which has presumably already taken place after an individual fixated the object/vehicle.

In sum, problems of sensory- and cognitive conspicuity as discussed provide some understanding as to why motorcyclists are over-represented in crash-reports with car drivers and how motorcyclists are more susceptible to car driver ROWVs at junctions. However, there are no experimental studies in which car driver-to-car and car driver-to-motorcycle interactions are compared, in both opposite- and perpendicular angles of approach. An opposite angle of approach may be an important predictor of car driver ROWV when facing a motorcyclist at a junction (de Craen et al, 2014). Illusory conjunctions such as the size-arrival-effect (Delucia, 1991) and experimental findings by Horswill et al. (2005) are in accordance with this assumption. Nonetheless, gap-acceptance studies such as Keskinen (1998) and Underwood et al. (2011) suggest perpendicular approaches may also be problematic for motorcyclists. The present study is intended to examine whether there are differences in visual search and intentions to give way by car drivers, when motorcycles and cars approach a junction from an opposite- and perpendicular (i.e. right) angle. We suggest (h1) car drivers to give way to opposite oncoming motorcycles later than opposite oncoming cars, due to problems of cognitive conspicuity related to speed underestimation of small approaching objects (Delucia, 1991; Horswill et al., 2005). Furthermore, we suggest (h2) car drivers to give way to perpendicular oncoming motorcycles later than perpendicular oncoming cars (after first-fixating target vehicle), due to problems of cognitive conspicuity related to difficulties in motorcycle processing. Finally, we suggest (h3) car drivers to fixate high-salient motorcycles earlier (faster) than low-salient motorcycles in both angles of approach, given theory about bottom-up attention, according to which attention is driven by the object's saliency (Torralba et al., 2006).

Video clips of oncoming cars and motorcycles were presented to participants on a single screen. Participants were instructed to imagine they were driving the car from which scenarios were filmed (forward driver perspective). The participants' car and oncoming vehicle were driving simultaneously towards two prior selected junctions (four-legged non-regulated, in- and outside a built-up area). During the approach, participants could give way to oncoming vehicles by pressing a button. Give-way decisions and RTs were registered. Eye-gazes/-fixations were captured using an eye-gaze tracker.

2. Methods

2.1 Participants

Ninety-three participants volunteered to take part in the experiment, between 19 and 77 years of age (mean age = 50.3; SD = 16). Participants consisted of 57 males and 36 females, all car driver's license holders. 76% of participants drove a minimum of 5.000 kilometers per year of which 38% above 10.000 kilometers. All participants had normal or corrected-to-normal vision. They were recruited through an existing participant database (SWOV: Institute for Road Safety Research), build up from earlier studies, an advert in a local supermarket and the experimenter's social network. Participants were offered a 15 euro gift coupon in exchange for their efforts.

2.2 Design

The study employed two designs, combined into a single experiment. A 2x2 within subject design was used to assess differences between angular approach (opposite/perpendicular) and oncoming vehicle type (car/motorcycle). Furthermore, a 2x2 between subject design was implemented to assess differences between angular approach (again; opposite/perpendicular) and motorcycle to background contrast (high-/low-salient). Motorcycle saliency was manipulated between subjects. The motorcycle's colour, motorcyclist's vest and helmet were altered to create the low-salient condition (see section 2.3.2). The dependent variables included response times (RTs) in giving way to an oncoming vehicle (in seconds), give-way RTs measured after first-fixating target vehicle (in seconds) and fixation-time ('speed of detection', in seconds).

2.3 Stimuli and apparatus

We selected two types of priority situations (opposite- and perpendicular approaches) in which oncoming cars and motorcycles were displayed at two different four-legged, non-regulated junctions. Stimuli were captured/recorded by means of video. Several video clips were presented to the participants, displayed as if it were a single ten minute car drive.

2.3.1 Filming

All clips were filmed in and around The Hague, the Netherlands, over a two-week period. Clips were recorded using a GoPro 3.0 Silver Edition camera, filming in 1080p HD-resolution (1920x1080, 16:9 aspect ratio) with a 170° field of view. A video frame rate of 30 fps was used. The camera was placed inside the car, mounted on top of the dashboard (central area) to capture the forward driver's perspective. All clips were filmed during daytime and bright weather conditions.

Experimental clips in which specific hypotheses (see section 1) could be investigated were recorded. The filming car approached three urban, four-legged non-regulated junctions selected in the week prior to filming. The oncoming car or motorcycle approached the same junction simultaneously, from an either opposite- or perpendicular angle (see Figure 1). Perpendicular scenarios displayed oncoming vehicles appearing from the right side of the junction. We choose one junction inside a residential district (built-up area) surrounded by houses, gardens and parking spots (#1), one located at an industrial area (outside built-up area) (#2) and one surrounded by greenhouses (outside built-up area) (#3). Scenarios were recorded on multiple junctions to be able to present multiple trials of the same condition, without having to present the exact same clip more than once (to minimize predictability).

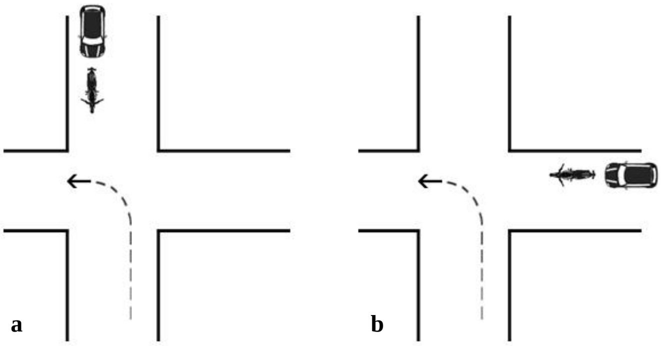

Figure 1. The filming car (deriving from the arrow symbol) approached the junction, meeting an oncoming car or motorcycle from an opposite- (a) or perpendicular (b) angle, eventually changing course by turning left after giving way.

A car driver and motorcyclist were recruited to drive the two oncoming vehicles. The motorcyclist drove a black/chrome coloured Triumph Bonneville t100, with an orange/white coloured tank. The car driver drove a black coloured Mini Cooper (2012), with chrome details on frontal- and side areas. See Figure 2 for a visual impression of both vehicles. Furthermore, the motorcyclist was wearing black pants, a yellow motorcycle vest on top of a black jacket and a white helmet to increase the overall saliency of the motorcyclist.

The filming car approached each junction at a constant speed of 30 k/m per hour. Oncoming vehicle approach speeds where somewhere between 20- and 30 k/m per hour. The oncoming car and motorcycle drove similar speeds in similar scenarios. In each clip, the filming car ended up reducing its speed and coming to a near stop, just before crossing the oncoming vehicle's path. Reducing the filming car's speed and coming to a near stop was performed at a relatively late stage in the approaching scenario, by hitting the brake long after the oncoming vehicle made its appearance. In each experimental clip, the oncoming vehicle drove straight ahead, across the junction without changing its course. The filming car gave way to the oncoming vehicle and changed its course by making a left turn, shortly after the oncoming vehicle had passed. Several clips of each experimental approach towards the junctions were recorded, to have multiple options to choose from when selecting stimuli for the final experiment (see section 2.2.2).

Figure 2. Showing the opposite oncoming motorcyclist (a) and car (b), crossing junction #2.

Besides recording experimental clips, filler clips were also recorded. Filler clips were non-staged and recorded what happened on the road at that particular moment in time, while driving through and around the city. A wide variety of priority and non-priority type of situations were recorded, with all sorts of oncoming road users (e.g. bicycles, trucks, pedestrians). Filler clips included situations of the junctions at which experimental clips were staged (e.g. no oncoming vehicle or multiple vehicles at the same time). In each experimental encounter (and some of the filler clips), the car made a left turn.

2.3.2 Editing and clip selection

30 clips were selected, from which 8 experimental clips and 22 filler clips were combined into a ten minute video stimulus. A second ten minute video stimulus was produced, in which the order of experimental clips differed. The two ten minute videos were played back in a fixed order. We made sure consecutive experimental clips differed from the last presented experimental clip by either the confronted vehicle type or angle of approach. The experimental clips were equally distributed throughout the video. Motorcycle clips were altered to create different saliency conditions: two high-saliency (original video) and two low-saliency (altered video) conditions on either one of the junctions. Besides the altered motorcycle clips, each video contained two other unique clips. These were initially selected as experimental clips (junction #3), but implemented as filler because of inconsistencies in timing as to the car- and motorcyclist's approach. Each clip lasted for about ten to 30 seconds. Filler clips were added to reduce the predictability of experimental clips.

Both colour and lighting properties of experimental motorcycle clips were altered using Adobe Photoshop CS6. Colour saturation of the orange-white coloured tank, yellow vest and helmet were reduced by 100% (frame by frame). This way, colour properties were fully transformed into blacks, whites and grey tones. Lightness settings of these same parts were reduced by 40%, creating a much darker but still natural looking vehicle/driver. See Figure 3 for an impression of the original and altered motorcycle, along with the car. VirtualDub 1.10.4 was used to decode the recorded .mp4 videos into separate, uncompressed .tga frames, and encode them back into uncompressed .avi videos after alterations were applied.

All clips were combined and edited in Adobe Premiere Elements 11.0, by using a cross-fade transitional effect. Altered motorcycle clips cross-faded into the original clip, after the motorcycle appeared at the most frontal part of the junction. This was done to prevent observers from recognizing the motorcyclist's altered appearance between high- and low-salient conditions. A pilot study (n= 9) was performed to test whether this was the case or not. None of the participants observed alterations or differences between motorcycle stimuli.

Animations of a left- and right pointing indicator were situated on congruent sides of the video stimuli. These lid up and flashed like a traditional indicator, informing the participant about the car's directional chance.

Figure 3. Showing the perpendicular oncoming high-salient motorcyclist (a), low-salient motorcyclist (b) and car (c), about to cross junction #2.

2.3.3 Experimental set-up

A single 21.5-inch, Philips223V screen was used to present the videos. A screen resolution of 1920x1080 was used, displaying in 16:9 aspect ratio. Underneath the monitor, a Gazepoint GP3 eye-gaze tracker (non-intrusive, free head motion) was mounted to capture the participant's eye-gazes and record movies of their faces, using a GP3 VESA Mount. Participants were seated on a chair, behind a desk approximately 60cms away from the screen. A Logitech K400r Bluetooth cordless keyboard was provided which participants could situate on top of the desk, to their likings. The keyboard provided a single push button to capture the participant's response. The monitor was placed upon a Plexiglas stand, adjustable in height, to create vertical visual angles close to 0° from the center of the screen. This stand was removed for participants who wore glasses, to create a steeper vertical visual angle. It reduced the amount and intensity of light reflecting into the eye-tracker's camera, which it had difficulties coping with sometimes. An HP-ProBook 650 laptop running Windows 7 including Gazepoint Analysis Professional Edition 2.5.0 was used to play back the video stimuli, perform a 9-point calibration and record the eye-data.

2.3.4 Areas of Interest

Areas of interest were drawn around the oncoming car and motorcycle to be able to capture the participant's fixation-time on-vehicle. The areas of interest increased in size, relatively to the vehicle's size as it was approaching the junction.

2.4 Procedure

Participants were informed that they were about to watch a ten minute video from the car driver's viewpoint, and had to imagine they were the driver. They were told that the purpose of the study was to evaluate how people respond in priority-situations, by measuring their eye movements and decisions whether to give way or not. They were unaware that the study evaluated motorcycle conspicuity. Participants were instructed to press the button when they would give way to other road users (e.g. felt the need or necessity to). This could be different from the formal traffic regulations (i.e. the study objective was not to measure traffic rule knowledge). Furthermore, they were informed that pressing the button (giving way) wouldn't change the outcome or course of the video. Participants were made sure decisions would be registered, even though they wouldn't receive feedback about their decision or lack thereof throughout the experiment. They were instructed to keep an eye on the directional indicator. Finally, they were instructed to try to sit still, without moving their upper body or head too much, because of the eye-tracker's sensitivity to movement and sensitivity to changes of environmental lighting. Before the ten minute video started, participants watched a one minute demo clip to get familiar with the types of stimuli, a few priority situations in which they were inclined to give way and the directional indicators. After calibrating, the experimenter started the ten minute video. After finishing the experiment, participants were debriefed.

3. Results

We excluded eye-gazes of seven participants due to calibration problems, mostly caused by participants wearing glasses. After visually reviewing all trials for each participant, another five participants showed major abnormalities and were excluded too. We defined major abnormalities as inaccuracies of gaze, due to insufficient calibration or change of posture during the experiment. For example, some of these participants were clearly paying attention (i.e. following a moving vehicle with their eyes), but gazes showed up ten to 15 centimeters above target (on screen). For another 12 participants, only some but not all trials were excluded (28 trials excluded). Here, the eye-gaze tracker mistakenly captured something else, other than the participants' eyes (e.g. hair shine or reflection from the participants' glasses). Furthermore, 17 participants showed minor abnormalities of gaze. They were clearly following objects and vehicles, but were only marginally off. Small corrections were made if abnormalities were consistent throughout all trials, with a maximum of 100 pixels on the X- and/or Y-axes. For all participants and trials in which gazes were excluded, give-way RTs were still included for analysis to which gaze was not relevant (h1).

3.1 Evaluation of missing RTs

Evaluation of missing give-way RTs revealed 88 misses out of 744 trials. 92% of misses occurred in opposite approaches compared to only 8% in perpendicular ones. Misses were only marginally more occurring at junction #1 compared to junction #2 (59% vs. 41%). Also, there appeared to be no relation with vehicle type. Motorcycle and car misses occurred about equally (46% vs. 54%). Missing RTs did not seem to be related to the participant not fixating target vehicle. 12 Participants failed to fixate one or more target vehicles in only 16% of opposite missing trials. In all other missing trials (84%), participants did fixate target vehicle but failed to give way, which may be due to various reasons (see section 4).

We evaluated whether the order of appearance of experimental clips, which differed between the two ten minute videos, could explain the higher amount of opposite misses. Both versions of the video presented an opposite approach type as their first condition. Analysis revealed the first two conditions (two out of 16) to be responsible for 49% of missing trials (41). Half of these misses (20) occurred during the first opposite motorcycle condition. This same motorcycle condition revealed only a single missing RT in the other version of the video, in which the condition was presented last[1]. Comparing the two car conditions revealed a similar pattern, showing 21 misses when presented first, compared to 12 misses when presented sixth. These results indicate that overall performance in consecutive trials improved (in pressing the give-way-button), with an average reduction of 68% of misses after the first condition was observed.

3.2 Hypothesis 1

We suggested give-way RTs for opposite oncoming motorcycles to be longer than for opposite oncoming cars, due to problems of cognitive conspicuity related to speed underestimation of small approaching objects (Delucia, 1991; Horswill et al., 2005). Give-way RTs from junction #1 and #2 were combined in a single, overall average per vehicle (regardless of motorcycle saliency). Participants were excluded from the analysis if either motorcycle or car RT on either junction was missing. RTs were captured between the target vehicle's appearance and the first frame at which the vehicle was no longer visible on screen, after passing the junction. Only 39 out of the 93 participants made it to the combined analysis, because of opposite missing responses (see section 3.1). A paired-samples t-test indicated participants gave way to opposite oncoming motorcycles significantly earlier than cars; $t(38)=2.62$, $p < .05$. This is a reversed pattern from what we expected. Participants seem to respond more cautiously facing opposite oncoming motorcycles. When analyzing the junctions individually, more participants were included in the analysis. The reversed pattern was significant at junction #1. There was no significant difference at junction #2 (see Table 1 for statistics).

[1] We should note that the motorcyclist's saliency differed between both versions of the condition, because we manipulated saliency between groups. However, vehicle type and junction number were identical. The first presented condition (20 misses) included the high-salient motorcyclist. The last presented condition (one miss) included the low-salient motorcyclist.

Table 1. Response times (in giving way) when the vehicle approached the junction from the opposite direction. When the criteria for parametric testing were met, a paired-samples t-test was applied (p-s t). Significant p-values ($p < .05$) are printed in bold.

Intersection	Angle of approach	Vehicle	Mean RT (s)	Test	*df*	Test value	*p*	Effect size (r)
Combined (*n*= 39)	Opposite	Motorcycle	7.26 (1.30)	p-s t	38	2.62	**.013**	-.19
		Car	7.72 (1.12)					
#1 (*n*= 53)	Opposite	Motorcycle	6.64 (1.22)	p-s t	52	-3.933	**.00**	-.27
		Car	7.35 (1.28)					
#2 (*n*= 56)	Opposite	Motorcycle	8.10 (1.91)	p-s t	55	-.979	.332	
		Car	8.31 (1.70)					

3.3 Hypothesis 2

We suggested give-way RTs for perpendicular oncoming motorcycles to be longer than for perpendicular oncoming cars (measured after first-fixating target vehicle), due to problems of cognitive conspicuity related to difficulties in motorcycle processing. Give-way RTs from junction #1 and #2 were combined in a single, overall average per vehicle (regardless of motorcycle saliency). Participants were excluded from the combined analysis if either motorcycle or car RT on either junction was missing. We also analyzed each junction individually. No significant differences were found in the combined analysis. A Wilcoxon Signed-ranks test on RTs from junction #2 indicated participants gave way to perpendicular oncoming motorcycles significantly later than cars; $Z(68)= -2.44$, $p < .05$. This does confirm our hypothesis. However, no significant difference was found at junction #1 (see Table 2 for statistics).

We also performed analysis on combined give-way RTs, regardless of when participants first-fixated target vehicle. A Wilcoxon Signed-ranks test revealed participants gave way to perpendicular oncoming motorcycles significantly later (M=2.81, SD=.41) than cars (M=2.72, SD=.39); $Z(79)= -2.88$, $p= .004$, $r= -.32$.

Table 2. Response times (in giving way) when the vehicle approached the junction from the perpendicular direction, recorded after first-fixating target vehicle. When the criteria for parametric testing were met, a paired-samples t-test was applied (p-s t). If not, the Wilcoxon Signed-ranks test (W) was applied. Significant p-values ($p < .05$) are printed in bold.

Intersection	Angle of approach	Vehicle	Mean RT (s)	Test	*df*	Test value	*p*	Effect size (r)
Combined (*n* = 62)	Perpendicular	Motorcycle	1.34 (.38)	p-s t	61	1.205	.233	
		Car	1.28 (.36)					
#1 (*n* = 72)	Perpendicular	Motorcycle	1.19 (.35)	p-s t	71	1.051	.297	
		Car	1.23 (.32)					
#2 (*n* = 68)	Perpendicular	Motorcycle	1.5 (.56)	W	68	-2,444 (Z)	**.015**	-.30
		Car	1.35 (.56)					

3.4 Hypothesis 3

We suggested high-salient motorcycles to be fixated earlier than low-salient motorcycles given theory about bottom-up attention, according to which attention is driven by the object's saliency (Torralba et al., 2006). An independent-samples t-test of perpendicular first-fixations at junction #2 indicated participants fixated high-salient motorcycles significantly earlier than low-salient motorcycles; $t(65)= -2.66$, $p < .05$. Levene's test indicated unequal variances ($F= 4.78$, $p=.032$), so degrees of freedom were adjusted from 77 to 65. This does confirm our hypothesis. However, no significant difference was found at junction #1. Also, no significant differences were found in opposite approaches. For a visual representation of average fixation-times for all approach types/junctions, see figure 4 (for statistics, see Table 3).

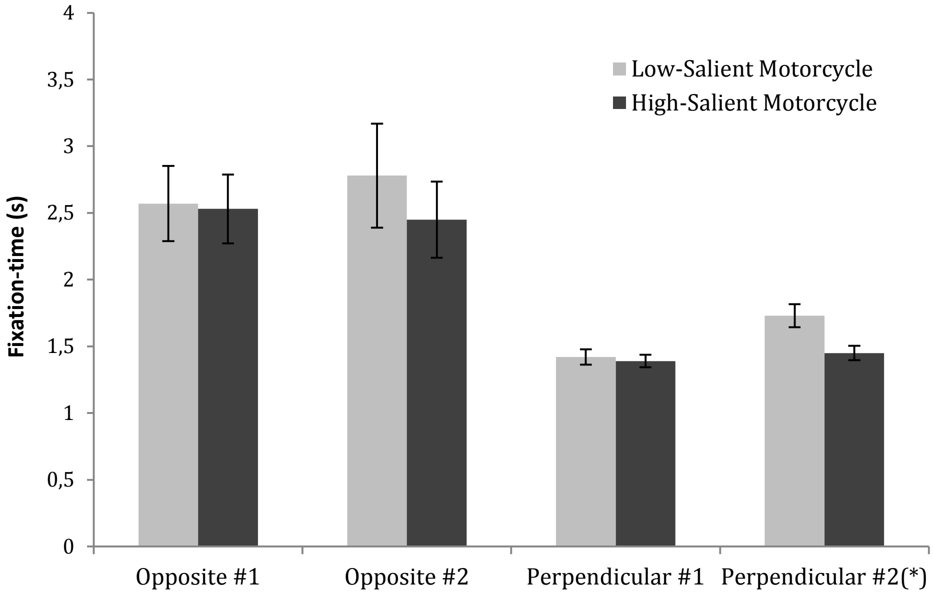

Figure 4. Mean fixation-time ('speed of detection') of opposite- and perpendicular oncoming motorcycles, presented in high- and low saliency at junction #1 and #2 (with standard error bars added). Significant differences (*p* < .05) are marked with a (*) sign.

Table 3. Mean fixation-time ('speed of detection') when the low (L) and high (H) salient motorcycle approached the junction from a perpendicular or opposite direction. When the criteria for parametric testing were met, an independent-samples t-test was applied (i-s t). Significant p-values (*p* < .05) are printed in bold.

Intersection	Angle of approach	Vehicle	Mean FT (s)	Test	*df*	Test value	*p*	Effect size (r)
#1 (*n*= 74)	Opposite	Motorcycle (L)	2.57 (1.69)	i-s t	72	.105	.917	
		Motorcycle (H)	2.53 (1.59)					
#2 (*n*= 71)	Opposite	Motorcycle (L)	2.78 (2.24)	i-s t	69	-.708	.482	
		Motorcycle (H)	2.45 (1.76)					
#1 (*n*= 77)	Perpendicular	Motorcycle (L)	1.42 (.36)	i-s t	75	.473	.638	
		Motorcycle (H)	1.39 (.29)					
#2 (*n*= 79)	Perpendicular	Motorcycle (L)	1.73 (.55)	i-s t	65	-2.661	**.010**	.31
		Motorcycle (H)	1.45 (.34)					

3.5 Homogeneity of groups

Results from an independent-samples t-test of junction #1 indicated participants fixated perpendicular oncoming cars significantly earlier in group A (M=1.34, SD=.27) than in group B (M=1.48, SD=.24); t(77)=2.40, p= .019, r= .26. Given both car conditions were identical but presented in a different order between groups (second and third), this may indicate to problems with counterbalancing. Man and woman were equally distributed, and mean age did not differ either between the two groups (M=50.04 and M=50.51).

4. Discussion

The main goal of the present study was to examine differences in visual search and intentions to give way by car drivers, when motorcycles and cars approached a junction from an opposite- and perpendicular angle. We suggested three hypothesis in which measurements of sensory- and cognitive conspicuity were assessed. In the first hypothesis (h1) we suggested car drivers to give way to opposite oncoming motorcycles later than opposite oncoming cars. Results showed a reversed pattern, in which car drivers gave way to motorcycles significantly earlier than cars. Separate analysis of the two selected junctions revealed a significant reversed pattern at junction #1, and no significant difference at junction #2. In the second hypothesis (h2) we suggested car drivers to give way to perpendicular oncoming motorcycles later than perpendicular oncoming cars (after first-fixating target vehicle). Results showed a significant effect in accordance with our suggestion on one of the two junctions (junction #2). In the third hypothesis (h3) we suggested car drivers to fixate high-salient motorcycles earlier (faster) than low-salient motorcycles, in both directional approaches. Results showed a significant effect in accordance with our suggestion in one of the two conditions; the perpendicular approach, but only at junction #2.

Overall, the findings were partly in accordance with expectations. We did not expect to find differences between the two junctions, even though they were not homogenous (in- and outside a built-up area). We implemented two different junctions to assess multiple trials of the same condition, without having to present the exact same video clip more than once (minimizing predictability). Some participants specifically mentioned they experienced approaches towards junction #1 as unpleasant or dangerous, due to perceived higher vehicle speed. The approach speed of the filming car was approximately the same on both junctions, without exceeding the speed limit. However, we were not able to keep speed at an exact rate due to filming on a public road. Sometimes, minor speed adjustments were necessary to avoid other conflicting road users in our approaches. Therefore, the speed of the filming car may have been a little higher at junction #1 compared to junction #2. Environmental circumstances at junction #1 such as parked cars alongside the road, proximity of buildings (i.e. houses) and a narrower approach road may also have induced this perception of increased vehicle velocity. Participants may also have referred to a discomfort with driving at such speed (as in the video) in an urban area, what they perceived as unsafe. After the experiment, some participants mentioned they wanted to “hit the brake” or press the give-way-button early at junction #1, before they’d reached the crossing or noticed any vehicle with whom they could conflict. Although we made sure to exclude all give-way responses before any conflicting vehicle was visible on screen, a high vehicle speed at junction #1 or percept thereof may have induced an increased state of alertness/arousal in participants. Increased levels of arousal can influence selective attention (Kahneman, 1973) thus influence performance. Give-way responses of participants may have been facilitated in the present study, regardless of vehicle type or vehicle characteristics. This may explain why we did not find a significant effect of hypothesis 2 at junction #1 or in the combined analysis. However, a significant effect in the combined analysis was revealed when we analyzed perpendicular give-way responses of participants, regardless of when target vehicle was fixated. This result seems relevant, even though we wanted to address problems of cognitive conspicuity in particular, after oncoming vehicles were already detected. This demonstrates that a combination of sensory- and cognitive factors may contribute to less safe behaviour of car drivers facing motorcyclists.

An explanation for finding a reversed pattern from what was expected given hypothesis 1 may be related to the time by which participants were able to notice oncoming vehicles and the time by which they were supposed to act (by giving way). This time-gap was elongated in opposite approaches compared to perpendicular ones. Perpendicular oncoming vehicles were initially blocked by objects such as buildings and trees, and only visible to participants just before they reached the crossing. Here, fast give-way responses were necessary in order to avoid conflict. Opposite oncoming vehicles were visible much earlier to the participant. Participants gained plenty of time to not only look at, but also perceive opposite oncoming vehicles and become fully aware of their characteristics. More cognitive top-down processes may have interacted with early stages of vehicle processing. These may have enabled participants to respond much differently compared to situations in which visibility (i.e. sensory conspicuity) would be limited and/or decision times are narrower (as in the perpendicular approaches). Top-down interaction may have triggered different motivations in participants, which may have led to tendencies to avoid risks of crashing with vulnerable road users, for example. This may explain the reversed pattern, of car drivers being more cautious facing motorcycles compared to cars in opposite approaches. Results from Crundall et al. (2012) revealed a similar pattern, in which participants gave motorcycles significantly more passage room than cars at a T-junction, before merging into the passing vehicle’s lane.

A different explanation for not finding the suggested effect given hypothesis 1 may be related to task difficulty. There were no other oncoming vehicles present during the approaches. In a real traffic situation, competing road users may draw upon the car driver's limited attentional- and/or processing capacity, argued to be related to LBFTS (Brown, 2005). Sensory conspicuous vehicles may distract the car driver from less sensory conspicuous vehicles (e.g. a motorcycle). Early assessment of the motorcycle, when the vehicle was far ahead and relatively small, may still have failed to trigger a precautionary response in participants due to speed underestimation (Delucia, 1991; Horswill et al., 2005). However, participants had plenty of time to reassess the speed of the oncoming motorcycle in our experiment, not only due to absence of competing road users but also due to elongated time-gaps in opposite approaches, explained earlier.

There may be two explanations why high-salient motorcyclists were not fixated earlier in opposite approaches compared to low-salient ones, referring to what was expected given hypothesis 3. The first explanation is related to our eye-gaze tracker, which was not as accurate as our participants fixations were. In theory, the eye-gaze tracker could accurately measure within 0.5 to 1 degree of visual angle. Even though we excluded participants which showed major abnormalities of gaze and manually corrected minor abnormalities (see section 3), calibration was not always as consistent as we would have liked. This especially affected the analysis between high- and low-salient opposite oncoming motorcyclists, because they were visible relatively early, when they were still far ahead from the crossing and appeared to be very small on screen. Thus, even though participants may still have detected high-salient motorcyclists earlier than low-salient ones in the present study, our eye-gaze tracker may not have been able to register this. The second explanation is related to theory about bottom-up attention, according to which attention is not only driven by the object's saliency (Torralba et al., 2006), but also by the object's motion or characteristics thereof (Tsotsos, 2001). Perpendicular oncoming motorcycles were moving much faster over our participants' fovea, right after they made their appearance which was relatively late during the approach. Opposite oncoming motorcycles moved much slower over our participants' fovea, at least initially, because they were at greater distance from the car driver after they appeared on screen. Rapid- or sudden motion of perpendicularly oncoming motorcyclists may have facilitated bottom-up attention in participants. Saliency of the motorcycle and its rider may have interacted differently between the perceived slow- and faster moving vehicle.

We also have to consider the relatively high amount of missing give-way responses in opposite- compared to perpendicular approaches, regardless of vehicle type or junction at which the car driver failed to give way (see section 3.1). It may be an indication that opposite angles of approach are more difficult for car drivers in general, and perhaps be an indication of occurrences of LBFTS. However, we had no real indication that participants did not detect the opposite oncoming vehicles in these missing trials. Analysis of eye-gaze only revealed 16% of opposite missing trials during which participants failed to fixate the vehicle entirely. We are unsure whether participants really failed to see or failed to notice these vehicles, because lack of fixation doesn't necessarily equal not having detected it. Also, use of peripheral vision may have succeeded in detecting the vehicle, without participants showing further interest by shifting the center of gaze towards the vehicle. Furthermore, the eye-gaze tracker was not accurate enough to detect fixations on-vehicle in the early stages of vehicle appearance, mentioned earlier. Nevertheless, a fixation on-vehicle doesn't necessarily equal seeing or noticing it, but can be used as an estimate.

There may be a different explanation for the relatively high amount of opposite missing responses. Most misses (49%) occurred early in the experiment, in the two first observed conditions of both groups (two out of 16). Participants perhaps didn't perceive the first presented oncoming vehicle to be relevant to the task (i.e. perceiving it as a potential candidate to give way to). Shortly after the first condition was presented, at least three participants mentioned they should probably have given way, referring to the fact they'd supposedly made a mistake by not responding, even though they proclaimed to have observed a vehicle. This does indeed suggest participants failed to perceive opposite oncoming vehicles to be relevant to the task, at least initially. A more general explanation for the high amount of opposite misses is lack of appraised danger in participants, and may be related to the manner in which opposite scenarios were filmed. Opposite oncoming motorcycles and cars did not seem to directly conflict (head-on) with the filming car's trajectory at the crossing. Perpendicular oncoming vehicles did actually seem to conflict, explaining the small amount of misses in these scenarios. Also, participants knew they had no direct influence on the outcome of the video or movement of their own car whatsoever. The participants' car came to a stop by itself when a conflicting vehicle presented itself. This may have happened before participants realized they had to give way. Perhaps there was no incentive for participants to press the give-way-button after their own vehicle had already come to a stop, and the oncoming vehicle had already begun crossing the junction. Of course, this is only speculative.

We had some indication of problems with counterbalancing, because participants in one group fixated the perpendicularly oncoming car on junction #1 significantly earlier (faster) than participants in the other group. The condition consisted of the exact same video clip.

Participants were equally distributed between the two groups in which gender or mean age did not differ. Order of playback between the two ten minute video versions differed however, and may have been responsible for causing this difference in performance. Both experimental clips were observed relatively early in the experiment, presented second and third. The worse performing group may have had different expectations, because they already observed a different video clip of this same junction in the beginning of the experiment, in which the car did not approach perpendicularly but from opposite direction. We had no further indications that the order of playback of experimental clips was a matter of concern in the remaining parts of the two ten minute videos.

Finally, we have to consider two limitations in relation to the present study's results and external validity. The first one being the field of view (FOV) in which participants observed the stimuli. Clips were filmed with a 170° horizontal FOV, which is only about 10° off given the human's forward-facing horizontal FOV (approximately 180°). However, participants were observing clips on a single 21.5 inch screen from which they were seated approximately 60cms away. Thus, the driver's visual world got projected onto a rather small part of the participants' fovea, much smaller compared to when actually looking through the front window of a moving car. Shahar, Alberti, Clarke and Crundall (2010) demonstrate that presenting a wider FOV by using a three-screen setup as opposed to a single-screen setup enhances the participant's ability to detect hazardous road events, showing less misses and shorter RTs. They argue differences in findings may be attributed to (a) wider scanning of the visual scene with shorter fixations; (b) a more immersive experience causing different, more realistic search patterns and/or; (c) lower criterion thresholds or increased sensitivity for detecting hazards. Therefore, RTs of the present study may have been underestimated. However, we were interested in relative differences between various vehicle types, which may be unaffected by the FOV.

The second limitation concerning external validity is the difference between watching someone else driving (in a video) compared to the experience of driving a real car yourself. Even though participants had to imagine and act (by giving way) like they were driving themselves, both are intrinsically different. The amount of mental workload when driving an actual car is much higher compared to observing a video and pressing a give-way-button. Participants did not have to steer, shift gears or physically break and could fully devote their attention to what was visually presented to them. Also, search strategies applied in both situations may differ from one another. For example, actual car drivers have to obtain position-in-lane information and road curvature information in order to maintain trajectory, affecting eye-gazes (Chattington, Wilson, Ashford and Marple-Horva, 2007). When watching a video, there is no incentive to obtain this kind of information for the viewer, because one cannot influence the car's trajectory and no steering corrections have to be made. Furthermore, the experimental setup did not require participants to turn their head left and right, looking for oncoming vehicles as one would do in a real driving experience. Also, there were no side- or rear-view mirrors participants could attend too. Although this seems less relevant to opposite and perpendicular oncoming vehicles, presence of mirrors may still affect eye-gazes. Lastly, no auditory information was added to the experiment. A running engine of a motorcycle may, for example, be used as a cue and trigger bottom-up attention, enhancing its detectability. On the other hand, sounds from a different vehicle or object in the surrounding environment may also distract the car driver or prevent him or her from detecting the motorcycle.

In conclusion, despite the present study's limitations and only partly confirmative results, we believe to have provided relevant insights into car driver-motorcycle interaction and the motorcyclist's susceptibility to ROWVs in two angles of approach. We have demonstrated differences in visual search and intentions to give way by car drivers, when motorcycles and cars approached a junction from a perpendicular- and opposite angle. When traffic situations are highly demanding, the speed at which a car driver detects a motorcyclist and the speed at which he is able to respond may be crucial. We confirmed that a high-salient motorcyclist can attract a car drivers' attention faster than a low-salient motorcyclist, when the motorcyclist appears from the right side of the car driver (perpendicularly). This favors enhancement of sensory conspicuity of the motorcycle and its rider, such as wearing a highly conspicuous white helmet or yellow vest while driving. Also, we confirmed that car drivers have more difficulties with giving way to perpendicularly oncoming motorcycles compared to cars, needing more time to respond when facing a motorcyclist after its detection. However, the exact mechanisms behind this remain unclear and should be studied further. We were not able to confirm motorcyclists to be at increased risk in opposite angles of approach too. Instead, we found contradictory results in opposite approaches (a reversed pattern from what was expected, car drivers behaving more cautiously), which may have been caused by the manner in which opposite scenarios were filmed and/or task difficulty. Our suggestion for future research is to try and reproduce the current study's findings in a driving simulator study. In such simulation, external validity concerns can be addressed and opposite approaches can be analyzed more extensively. Also, one can increase or decrease traffic density or vary with vehicle speeds under more controlled circumstances, putting the driver's limited attentional- and/or processing capacity to the test. One can even add various unexpected events to divert the car drivers' attention from oncoming motorcycles and cars. Also, one may be able to standardize different types of junctions and analyze whether particular circumstances may be of particular influence, given car-motorcycle interaction. Furthermore, simulation may enable us to study the motorcyclist's sensory conspicuity to greater extent, by presenting car drivers with various oncoming motorcycles which differ in size, colour, saliency and have various types of riders wearing different motorcycle-gear. This may enable us to find optimal levels of sensory enhancement, which may actually be applicable to motorcyclists and used as a preventative measure. Finally, it is uncertain whether the current study actually triggered a genuine LBFTS error in one of its participants, given we have not further analyzed trials in which participants did not give way and failed to fixate the oncoming vehicle. Future research may focus on trying to reproduce LBFTS errors under controlled circumstances. Thorough analysis of eye-gazes may be helpful, in order to fully understand characteristics of such an event. Reproduction of driver error in car drivers may prove to be a challenging task still, because even though studies suggest motorcyclists to be more susceptible to ROWVs at junctions, most cases in which car drivers and motorcycles meet do not end up in a crash.

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