Low Conspicuity of Motorcycles for Car Drivers: Dominant Role of Bottom-Up Control of Visual Attention or Deficit of Top-Down Control?
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Low Conspicuity of Motorcycles for Car Drivers: Dominant Role of Bottom-Up Control of Visual Attention or Deficit of Top-Down Control?

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Objective: The aim of this study was to evaluate whether the low visibility of motorcycles is the result of their low cognitive conspicuity and/or their low sensory conspicuity for car drivers.

Background: In several cases of collision between a car and a motorcycle, the car driver failed to detect the motorcyclist in time to avoid the collision.

Method: To test the low cognitive conspicuity hypothesis, 42 car drivers (32.02 years old) including 21 motorcyclist motorists and 21 non–motorcyclist motorists carried out a motorcycle detection task in a car-driving simulator. To test the low sensory conspicuity hypothesis, the authors studied the effect of the color contrast between motorcycles and the road surface on the ability of car drivers to detect motorcycles when they appear from different parts of the road.

Results: A high level of color contrast enhanced the visibility of motorcycles when they appeared in front of the participants. Moreover, when motorcyclists appeared from behind the participants, the motorcyclist motorists detected oncoming motorcycles at a greater distance than did the non–motorcyclist motorists. Motorcyclist motorists carry out more saccades and rapidly capture information (on their rearview mirrors and on the road in front of them).

Conclusion: The results related to the sensory conspicuity and cognitive conspicuity of motorcycles for car drivers are discussed from the viewpoint of visual attention theories.

Application: The practical implications of these results and future lines of research related to training methods for car drivers are considered.

Keywords: sensory conspicuity, cognitive conspicuity, color contrast, car-driving simulator

INTRODUCTION

The percentage of motorcyclists (riders or passengers) injured or killed in 2006 compared to the percentage of deaths caused by the same mode of transport in 1997 increased by 13%, while the percentage fell for all other modes according to a study based on data from 19 European countries (Leitner et al., 2008). The most frequent vehicles involved in collisions with motorcycles were passenger cars (in 60% of accidents recorded between 1999 and 2001 in France, Germany, Italy, the Netherlands, and Spain), and the primary cause of motorcycle collisions was human error (Association of European Motorcycle Manufacturers, 2005). These accidents may be explained, at least in part, by the low conspicuity of motorcycles for car drivers. The concept of conspicuity is made up of two related aspects: sensory conspicuity and cognitive conspicuity.

Sensory Conspicuity

Sensory conspicuity refers to the extent to which an object can be distinguished from its environment because of its physical characteristics: angular size, eccentricity in relation to the point of gaze, brightness against the background, color, and so on (Cole & Hughes, 1988; Engel, 1971, 1974; Hancock, Wulf, Thom, & Fassnacht, 1990; Wulf, Hancock, & Rahimic, 1989). In other words, sensory conspicuity reflects an object’s ability to attract visual attention and to be precisely located as a result of its physical properties.

Wells et al. (2004) quantify the accident risk associated with motorcycles by comparing the characteristics of motorcyclists involved in accidents with those of randomly selected motorcyclists. They identified a relationship between helmet color and accident risk. Comelli et al. reach a similar conclusion by analyzing
Accidents for which the recorded cause is the low conspicuity of the motorcycle (Comelli, Morandi, Magazzu, Bottazzi, & Marinoni, 2008). However, more important than the color of the motorcycle is the contrast between the motorcycle and the background against which it appears (Hole, Tyrrell, & Langham, 1996; Watts, 1980). In a recent experiment carried out with a car-driving simulator, the sensory conspicuity of motorcycles riding between lanes of vehicles was improved through a modification in the level of color contrast between the motorcycle and the traffic (Rogé, Ferretti, & Devreux, 2010). It was found that a high color contrast improves the conspicuity of motorcycles in certain speed and traffic conditions. This effect is also dependent on the age of the car drivers. Note that, in this experiment, the participants had to detect the motorcycles only in their rearview mirrors and only in traffic. It seems sensible to consider whether the positive effect of a high level of color contrast could be partly (or mainly) the result of the possibility of anticipating from where and in what circumstances (e.g., in a stream of vehicles) the motorcycle might appear. To remove this doubt, the task used in this new study consisted of detecting a motorcycle appearing from one of several directions in the road environment. Since motorcycles travel in various traffic conditions, the level of color contrast varies, in the current study, between the motorcycle and the background (i.e., the gray macadam of the road surface).

Our sensory conspicuity hypothesis is that a significant contrast between the color of the road surface and the color of the motorcycle increases the visibility of the motorcycle for car drivers, even if the drivers cannot anticipate the direction or position of the motorcycle.

Cognitive Conspicuity

According to Theeuwes (1991b), attentional focusing is not merely exogenously controlled (i.e., automatically determined by the physical properties of the environment) but could be dependent on the demands of the task. This means that a highly salient object does not automatically and unintentionally attract attention to its location. Visual selection is considered to be endogenously controlled when search is mediated by expectations about the properties of objects relevant to the task such as location, color, shape, luminance, or size. Endogenous control is most clearly in operation when attention is directed to the location of where a target is likely to be found. Given a search objective, the activation of a scene schema based on global features would lead to a search path to those locations, where, given the prototypical representation of the scene, the search objective is likely to be found.

For Theeuwes, the momentary need for information could play a key role in the process of actively directing the driver’s attention. The driver would be able to engage in active filtering based on knowledge related to the nature of probable stimulus inputs. These top-down processes have been put forward to explain, at least in part, the low conspicuity of motorcycles. Some researchers have suggested that failed and/or late detection of a motorcycle on the road is not exclusively related to its sensory conspicuity (Comelli et al., 2008; Hancock et al., 1990; Langham, Hole, Edwards, & O’Neil, 2002; Magazzu, Comelli, & Marinoni, 2006; Olson, 1989; Wulf et al., 1989). The driver’s decisions in relation to a motorcycle or the ability to detect a motorcycle could also depend on its cognitive conspicuity (Hancock et al., 1990). This processing takes into account elements that are specific to each driver. Cognitive conspicuity is linked to the fact that an observer’s focus of attention is strongly influenced by his or her expectations, objectives, and knowledge. Cognitive conspicuity therefore highlights top-down processes. According to Hole et al. (1996), in many cases, inappropriate expectations may be more important in accident causation than the motorcyclist’s physical properties.

It is possible that some car drivers might have inappropriate expectations about what is likely to happen next based on their previous experience because of infrequent exposures to the situation (Hole & Tyrrell, 1995; Hurt, Ouellet, & Thom, 1981; Langham et al., 2002; Rumar, 1990; Wulf et al., 1989). It is also possible that car drivers misinterpret what they see or where the motorcycle might appear from (Brown, 2002; Horswill, Helman, Ardiles, & Wann, 2005; Langham et al., 2002; Wulf et al., 1989). The corollary of these suggestions is that car drivers who also ride a motorcycle...
(motorcyclist motorists) could therefore use their riding knowledge or practical experience of motorcycles when they drive a car, and this may help them to detect and avoid collisions with motorcycles. Two observations support this reasoning: A high proportion of car drivers involved in collisions with motorcyclists do not have a license to ride a motorcycle, and car drivers owning a motorcycle license have been shown to be responsible for fewer motorcycle–car collisions than drivers who do not have one (Comelli et al., 2008; Hurt et al., 1981; Magazzu et al., 2006; Wulf et al., 1989).

Motorcyclists and car drivers have been shown to differ in their visual search patterns. For Nagayama et al., motorcyclists look frequently at the road surface immediately ahead (compared to car drivers), and the proportion of the road surface in their visual field is larger to detect any surface irregularities or other road-surface-based hazards (Nagayama, Morita, Miura, Watanabe, & Murakami, 1980). Moreover, mean fixation duration is longer in driving a car than in riding a motorcycle. Tofield and Wann (2001), for their part, found that motorcyclists who were driving a car looked farther ahead than car drivers who had no motorcycle riding experience. It is therefore possible that motorcyclists, when driving a car, use some special visual strategies that they have learned specifically from motorcycle riding.

In the current study, the cognitive conspicuity hypothesis is that car drivers who also have a motorcycle license and who ride regularly detect motorcycles easily, even if the motorcycle appears from different parts of the road. These drivers may use specific visual strategies compared to non–motorcyclist motorists.

**METHOD**

**Participants**

The sample consisted of 42 car drivers (32.02 years old, SD = 5.2), 21 motorcyclist motorists (M = 30.38 years, SD = 4.8), and 21 non–motorcyclist motorists (M = 33.6 years, SD = 5.0) with a visual acuity greater than or equal to 8/10. The sample included 10 women and 11 men in the group of non–motorcyclist motorists and 9 women and 12 men in the group of motorcyclist motorists. As the experiment involved the use of an eye tracker, we recruited participants who normally drive without glasses to ensure that the ocular data collected were of an acceptable quality. All the participants had held a license to drive light vehicles for more than 14.1 years (SD = 5.4), and the motorcyclist motorists had also held a motorcycle license for more than 9 years (SD = 6.5). This group of participants rode their motorcycles regularly (4.8 times per week, SD = 6.8).

**Equipment**

The test took place in a car-driving simulator (the Sim^2^ simulator in the LEPSIS unit at IFSTTAR), which enabled the same driving conditions (especially traffic) to be reproduced for all participants and ensured absolute safety for the participants. This fixed-base simulator includes a cabin (Renault Espace), four computers, and four screens, onto which the simulated images are projected. Three of the screens (total size = 1.25 m × 1 m; angle of vision = 150° × 40°) are used for the road scene ahead, and one large screen is used for the rear view (size = 2.15 m × 3.15 m, located 3.16 m behind the participant). The participants were able to see the rearview using two flat rearview mirrors: the off-side wing mirror (4.43° × 2.60°) and the inside rearview mirror (9.91° × 2.77°). The road images were projected at an average refresh rate of 55 Hz, and driving data were recorded at the same frequency. The Face LAB 4 system (from Seeing Machines Ltd) was used to measure ocular behavior in real time during the test. This system records data relating to the position and inclination of the participant’s head in 3-D as well as the direction of his or her glances, especially at the mirrors. These data were recorded at a frequency of 60 Hz.

**Procedure and Experimental Task**

The first stage of the experiment was to measure the visual acuity of the participants (using the Monoyer test). The participants then followed a 30-min training program on the car-driving simulator, during which time they practiced different tasks. These included following a vehicle, driving on trunk roads and a motorway, and crossing junctions. The Face LAB system was then adjusted for the test
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Throughout the experiment, the participants had to detect motorcycles that differed according to their level of color contrast. To modify their sensory conspicuity, the color of the body of the motorcycle, the clothes, and the helmet of the motorcyclist were modified to have a high level of color difference (CIE x,y chromaticity coordinates of 0.46/0.31; luminance = 7.6 cd/m² for the red motorcycle) or a low one (CIE x,y chromaticity coordinates of 0.28/0.32; luminance = 23.28 cd/m² for the gray motorcycle) with the background (CIE x,y chromaticity coordinates of 0.30/0.36; luminance = 28.32 cd/m² for gray road surface). For the high level of contrast between the motorcycle and the gray macadam of the road surface, the Weber luminance contrast was ΔL = −0.73 and the color difference was ΔE*ab = 43.06. For the low level of contrast between the motorcycle and the gray macadam of the road surface, the Weber luminance contrast was ΔL = −0.18 and the color difference was ΔE*ab = 10.79. The luminance and contrast measures were carried out with a spectroradiometer set at the car driver’s eye line and focused on the front screen. The order of the 16 motorcycles (eight with a low level of color contrast and the eight motorcycles with a high level of contrast) was mixed randomly and did not change during the experiment. The order of the color contrast between the motorcycles and the road surface (high level–low level) for the 16 motorcycles was reversed for half of the participants.

The visibility distance of the motorcycle was estimated with the distance (in meters) on the road between the participant and the motorcycle at the moment when the participant flashed his or her headlights (note that only the responses given while a motorcycle was displayed on the front screens or in the mirrors have been taken into account). The greater the distance, the more visible the motorcycle is to the driver.

Several ocular indices calculated from the data recorded with the eye tracker throughout the experiment were computed: saccades, eye fixations (on the environment, including elements in the virtual environment and in the participant’s car), glances at the mirrors, and glances at the vehicles displayed on the screens in front of the participant.
The amplitude of the saccades was recorded on the vertical plane and on the horizontal plane in a Cartesian coordinate system where gaze angle is the angle at the observer’s eye in the right triangle defined by the eye, the center of the field of vision, and the fixation point. A glance at the rearview mirrors can be constituted by single or consecutive eye fixations. Short glances (i.e., when the glance only passes over the mirror without data processing) have been eliminated from the data according to the method used in the study by Rogé et al. (2010). A threshold for each participant (average + [1/4 × standard deviation] of the distribution of all recorded glances throughout the experiment) has been calculated. When the duration of a glance in the mirrors is equal to or longer than this threshold, it is counted as a glance. A specific method was developed for the analysis of glances at the zones of interest (the vehicles in the virtual environment appearing on one of the three screens in front of the participant). The data recorded with the eye tracker and those recorded with the car-driving simulator were resynchronized (since the two databases had different sampling frequencies), and a replay program run to determine if the vehicles had been glanced at by the participant during the experiment. Each time a vehicle was totally or partly looked at by the participant (i.e., located within an area covering 3° around his or her gaze), the duration of the glance was calculated and stored.

Statistical Analyses

Analysis of the variance of the visibility distance took into account one between-subjects factor, namely, the group of car drivers (motorcyclist motorists vs. non–motorcyclist motorists), two repeated measures for the color contrast between the motorcycle and the road surface (low vs. high), and two repeated measures for the arrival position of the motorcycle (a motorcycle that appeared in front of the participant vs. a motorcycle that appeared behind the participant). The mean values of each ocular behavior index (number and amplitude of saccades, mean duration of eye fixations, number and duration of glances at the mirrors, and number and duration of glances at vehicles) were calculated for the two
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Each ocular index was analyzed individually. Analysis of the variance of mean values of each ocular index took into account one between-subjects factor, namely, the group of car drivers (motorcyclist motorists vs. non–motorcyclist motorists).

The assumptions underlying the ANOVA (i.e., normality and uniformity of variance of residuals) were checked with the Kolmogorov–Smirnov test and the Levene test (Zar, 1984). For all these analyses, comparisons of means were conducted with the post hoc Fisher least significant difference (LSD) test, and the means were considered as significantly different when the probability of a Type I error was less than or equal to .05.

RESULTS

Visibility Distance of the Motorcycle

The group of car drivers did not have a significant effect on the visibility distance, $F(1, 40) = 1.83, p = .18$. The motorcyclist motorists detected the motorcycle at an average distance of 61.38 m ($SD = 31.0$) and the non–motorcyclist motorists at a distance of 55.56 m ($SD = 34.8$).

The distance when the motorcycle had a high color contrast was 60.20 m ($SD = 35.8$) and 56.74 m ($SD = 30.0$) when it had a low color contrast and the difference between these means was not significant, $F(1, 40) = 1.47, p = .23$.

The arrival position of the motorcycle had a significant effect on the visibility distance, $F(1, 40) = 285, p < .0001$. The drivers detected the motorcycle at a much greater distance when the motorcycle appeared in front of them (average = 83.44 m, $SD = 21.1$) than when it appeared behind them (average = 33.50 m, $SD = 21.9$).

The interaction of the arrival position of the motorcycle and the group of car drivers on the visibility distance was significant, $F(1, 40) = 4.51, p = .04$. The visibility distances are shown in Figure 2.

A comparison of the averages shows that the group of car drivers affected the visibility distance only when the motorcycle appeared behind the participant (significant Fisher LSD test with an error probability of $p = .02$). The visibility distance was higher for motorcyclist motorists (average = 39.55 m, $SD = 23.9$) than the distance for non–motorcyclist motorists (average = 27.45 m, $SD = 18.2$). These results are consistent with our cognitive conspicuity hypothesis. Car drivers who also had a motorcycle license and who rode regularly detected the motorcycle when it was farther away.

The interaction of the color contrast between the motorcycle and the road surface and the arrival position of the motorcycle on the visibility distance was significant, $F(1, 40) = 5.29, p = .03$. The visibility distances are shown in Figure 3.

When the motorcycle appeared in front of the participants, they detected the motorcycle with a high level of color contrast at an average distance of 88.27 m ($SD = 22.0$) and the motorcycle with a low color contrast at an average distance of 78.62 m ($SD = 19.2$). The difference between these two means was significant according to the Fisher LSD test (significant test with an error probability of $p = .01$). When the motorcycle appeared behind the participant, the color contrast had no significant effect. These results are partially consistent with our sensory conspicuity hypothesis. Indeed, a
significant contrast between the color of the road surface and the color of the motorcycle increased the visibility of the motorcycle only when the latter was displayed on the front screen.

The interaction of the color contrast between the motorcycle and the road surface and the group of car drivers on the visibility distance was not significant, \( F(1, 40) = 0.63, p = .43 \). The interaction of the color contrast between the motorcycle and the road surface, the arrival position of the motorcycle, and the group of car drivers on the visibility distance was not significant, \( F(1, 40) = 0.0002, p = .99 \).

**Ocular Indices Collected Throughout the Experiment**

Note that these analyses were carried out on the data recorded for 39 participants (19 non–motorcyclist motorists and 20 motorcyclist motorists); the data collected for 3 participants were not of an acceptable quality.

The group of car drivers had a significant effect on the number of saccades, \( F(1, 37) = 6.03, p = .02 \). The motorcyclist motorists carried out more saccades (average = 2,864.5, \( SD = 649 \)) than did the non–motorcyclist motorists (average = 2,376, \( SD = 589 \)).

The difference of the saccade amplitude between these two groups was not significant with the amplitude of the saccades on the vertical plane, \( F(1, 37) = 0.23, p = .63 \) (averages for the motorcyclist motorists = 6.31°, \( SD = 1.0 \), and for the non–motorcyclist motorists = 6.15°, \( SD = 1.1 \)), or with the amplitude on the horizontal plane, \( F(1, 37) = 0.0002, p = .96 \) (averages for the motorcyclist motorists = 12.19°, \( SD = 1.7 \), and for the non–motorcyclist motorists = 12.96°, \( SD = 1.9 \)).

The group of car drivers had a significant effect on the duration of eye fixation, \( F(1, 37) = 7.04, p = .01 \). The motorcyclist motorists had a shorter fixation duration (average = 487.4 ms, \( SD = 155.6 \)) than did the non–motorcyclist motorists (average = 646.3 ms, \( SD = 214.9 \)).

The number of glances at the mirrors showed no difference between the two groups, \( F(1, 37) = 0.54, p = .46 \) (averages for the motorcyclist motorists = 244.7, \( SD = 54.7 \), and for the non–motorcyclist motorists = 229, \( SD = 76.7 \)).

The group of car drivers had a significant effect on the duration of glances at the mirrors, \( F(1, 37) = 5.47, p = .02 \). The motorcyclist motorists explored their mirrors more quickly (average = 655.8 ms, \( SD = 149.4 \)) than did the non–motorcyclist motorists (average = 781.6 ms, \( SD = 185.2 \)).

The number of glances at vehicles showed no difference between the two groups, \( F(1, 37) = 2.39, p = .13 \) (averages for the motorcyclist motorists = 557.2, \( SD = 325.8 \), and for the non–motorcyclist motorists = 742, \( SD = 416.3 \)).

The group of motorists had a significant effect on the duration of glances at the vehicles, \( F(1, 37) = 4.25, p = .05 \). The motorcyclist motorists looked at vehicles more quickly (average = 106.6 ms, \( SD = 45.9 \)) than did the non–motorcyclist motorists (average = 143.3 ms, \( SD = 64.3 \)).

These results are consistent with the hypothesis that car drivers who also have a motorcycle license and who ride regularly may use specific visual strategies if we consider that these strategies include a high number of
saccades and a fast capture of information (on the rearview mirrors and on the vehicles seen on the screens).

**DISCUSSION**

Theoretical models relating to visual attention (Itti & Koch, 2001; Theeuwes, 1991a, 2004, 2010; Treisman & Gelade, 1980; Treisman & Gormican, 1988) are used to interpret the results obtained in this study and to put forward reasons why certain motorcycles might not be detected on the road.

**Visual Attention Theories**

According to Treisman’s feature integration theory, the content of the visual field is broken down into elementary dimensions (such as color, intensity, contrast, and orientation) to make feature maps during the first phase of processing visual information, which is rapid, preattentive, and involuntary (Treisman & Gelade, 1980; Treisman & Gormican, 1988). In each map, only locations that stand out locally from their surroundings can persist. These feature maps are then combined into a single map: the master “saliency map” that topographically encodes the salience of items in their visual environment (Itti & Koch, 2001; Itti, Koch, & Niebur, 1998). This is a map of locations whose local visual attributes differ significantly from the surrounding image attributes along some dimension or combination of dimensions. Attention is then oriented toward the item (or location) that is the most salient in the saliency map, the visual salience of this item causing an attention capture qualified as bottom-up selection (Itti & Koch, 2001; Theeuwes, 1991a, 2004). Once attention has shifted to the location of the salient item, its identity becomes available. In a target search task, if the selected item is different from (or does not belong to) the target, this location is inhibited (by inhibition of the return mechanism) and the attention shifts to the element that is next in line with respect to salience (i.e., the second most salient, etc.). These last stages (comparison of the item with the target being sought and potential disengagement of attention at a specific location) are carried out at an attentive level of processing (i.e., under the control of top-down knowledge).

**Motorcycle Sensory Conspicuity and Visual Attention Theories**

The significant interaction of color contrast and the arrival position of the motorcycle on the visibility distance on one hand and the nonsignificant interaction of color contrast and the groups of car drivers on the same data on the other hand led to the conclusion that color contrast has an effect for oncoming motorcyclists and that this effect does not depend on whether drivers have experience on a motorcycle. These results therefore illustrate a true bottom-up effect. According to the theories outlined earlier, the car driver works out a saliency map at a preattentive level that takes into account, inter alia, the color and shape (elementary dimensions) of the elements present in the road scene. When the contrast in color between the motorcycle and the road background is high, the car driver’s attention is captured and directed automatically toward locating the salient elements (which may in fact be parts of the motorcycle and/or the motorcyclist) in the road environment by means of a bottom-up mechanism. The car drivers then identify the motorcycle by top-down mechanisms, and the motorcycle is detected from farther away (88.27 m). When the color contrast between the motorcycle and the road background is low, attention capture is thought to occur on salient items that are not, in these cases, elements of the motorcycle.

Attention search continues and attention passes to the next most salient item (by inhibition of the return mechanism) to compare the new item with the target sought. It is thought that a new saliency map is created in case the road image changes (because either the participant or the other vehicles have moved) or if the car driver glances at another location. The search for a motorcycle with low color contrast may therefore take more time; hence, the motorcycle is detected at a shorter visibility distance (78.62 m). Another explanation for this result may be that it takes more time to detect a low-contrast motorcycle because it has to be larger than a high-contrast motorcycle to be detected. As far as we know, this result is innovative since the effect of color contrast was observed during a dynamic car-driving task carried out in a controlled experimental setting (in which the char-
acteristics of the color and luminance of the road environment and those of the vehicles were totally controlled; the motorcycles were presented at the same points in time and at the same speed for all participants).

The effect of color contrast in the current study is in keeping with the results obtained by Hole et al. (1996). That study led to the conclusion that a high color contrast between the road scene and the motorcyclist’s clothing affects visibility in static scenes. Similarly, the effect of the color contrast in the current study is also in agreement with the improvement of motorcycle visibility with a high color contrast between the traffic and the motorcycle when the latter is being ridden between lanes of light vehicles (Rogé et al., 2010). We should recall that the motorcycle detection task used in this previous study begs the question of the relationship between improvement in motorcycle sensory conspicuity through color contrast and the possibility of anticipating from where and in what circumstances the motorcycle may appear in the road environment (see the introduction). It can be concluded that this improvement is possible since the color contrast has a significant effect on performance in the motorcycle detection task whereas anticipation is limited in the current study.

Motorcycle Cognitive Conspicuity and Visual Attention Theories

The result concerning a higher visibility distance of motorcycles (39.55 m) for motorcyclist motorists when they appeared from behind the participants (compared to 27.45 m for non-motorcyclist motorists) matches a specific ability to detect, assess, and cope with potential hazards (Horswill & Helman, 2003; Underwood & Chapman, 1998), such as an oncoming motorcycle appearing behind the participant. It can therefore be concluded that the visibility of motorcycles is also related to their cognitive conspicuity for car drivers and that top-down control is involved in the detection of motorcycles on the road. Note that the significant interaction of the groups of car drivers and the arrival position of the motorcycle on the visibility distance and the nonsignificant interaction of these factors with the color contrast on this distance led to the conclusion that top-down control may be independent from the sensory conspicuity of the motorcycles.

According to some researchers, the saliency calculations for drawing up the saliency map are thought to be more or less restricted to the attentional window (or “spotlight”) of the observers (Theeuwes, 2004, 2010; Van der Stigchel et al., 2009). The corollary is that salient information outside this window might be ignored. The size of the window may be adjusted according to the intentions, expectations, and goals (i.e., under top-down control) of the observer, and consequently, this mechanism is thought to influence the processing of the first feed-forward sweep of information (Theeuwes, 2010; Van der Stigchel et al., 2009).

In the current study, a top-down mechanism could lead the motorcyclist motorists to reduce their attentional window to examine sequentially small parts of the road scene because, as a motorcyclist, they know that motorcycles ride in specific parts of the road (because of prototypical representations of the scene). In contrast, the non–motorcyclist motorists presumably set their attentional window so that it encompasses a larger part of the road scene. The reduction of the attentional window could lead to a low probability that irrelevant salient elements will capture attention and its location on specific parts of the environment (such as behind the car) may explain why motorcyclist motorists detect motorcycles approaching from the rear at a greater distance than non–motorcyclist motorists. An alternative interpretation of this result could be that motorcyclist motorists may process the contents of the mirrors in parallel with greater efficiency than the non–motorcyclist motorists, with the consequence that motorcycles approaching the participant would be detected with a greater visibility distance (or when they are smaller).

Analyses of the participants’ ocular indices led to the conclusion that the ocular behavior of the two groups of car drivers is different. Indeed, our results indicate that motorcyclist motorists capture information faster than non–motorcyclist motorists since the duration of their glances or fixations is shorter. Moreover, they also capture information related to the vehicles displayed in
front of them more quickly. It is suggested that they probably need less time to collect information to identify the motorcycle since they limit spatial selection in advance of the motorcycle’s appearance to the location of specific parts of the road where they expect to see a motorcycle. These shorter durations of glances at vehicles and at the rearview mirrors observed for the motorcyclist motorists are consistent with the shorter duration of eye fixations of motorcyclists recorded by Nagayama et al. (1980). Motorcyclist motorists carried out more saccades than the non-motorcyclist motorists. In the event that the hypothesis of the restriction of the attentional window was correct, the results concerning the ocular behavior of the motorcyclist motorists could be easily interpreted as a consequence of their restricted attentional window. Indeed, they need to move their eyes more frequently to cover the road environment if they examine small parts of the road scene sequentially.

CONCLUSION

The attentional selection of a motorcycle in the road environment is believed to depend on bottom-up and top-down processing, processes described in the theoretical models relating to visual attention. Improvement in the visibility of motorcyclists by increasing color contrast may indicate bottom-up processing. The finding that color contrast between the motorcycle and the road surface is a significant factor for capturing attention when the motorcycle appears in front of car drivers has a practical implication. Motorcycles, motorcyclists’ clothes, and motorcycle helmets should be colored to contrast with the roadway to enhance their visual conspicuity. In addition, the effect of characteristics specific to car drivers (such as the fact of having a motorcycle license and using this mode of transport regularly) on the motorcycle visibility distance may be a sign of top-down processing since the detection of motorcyclists seems to depend on knowledge, experience in riding a motorcycle, and/or skill in detecting dangers.

Top-down processing is accompanied by specific ocular behavior (more saccades, shorter mean fixation durations, shorter glances at the mirrors and shorter fixation duration on vehicles) observed in motorcyclist motorists. These drivers may collect and/or process visual information from the environment faster compared with non-motorcyclist motorists. It would be interesting to compare the characteristics of the useful visual field of these two groups while driving (Rogé, Pébayle, Kiehn, & Muzet, 2002). Actually, a larger field, or a field with a higher resolution and/or an ability to detect and analyze visual information faster (whatever the information is) while driving, may also explain the better performance of the motorcyclist motorists in detecting motorcycles appearing from behind.

Future research could be undertaken to counter possible limits, specific to the car driver, in the cognitive processing of information related to motorcycles. It would, for example, be worthwhile to propose training that would make it possible to improve the estimation of the position, speed, and behavior of motorcycles and adopt specific ocular strategies used by motorcyclist motorists, as highlighted in this study. The objective could be to examine whether this training helps car drivers to increase their ability to detect motorcycles.

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KEY POINTS

- The low conspicuity of motorcycles might be related to their physical characteristics and/or to the car drivers’ cognitive processing of information regarding motorcycles.
- Two groups of car drivers (motorcyclists vs. non-motorcyclists) carried out a motorcycle detection task in a car-driving simulator.
- A high level of color contrast between the motorcycles and the road surface enhanced the visibility of motorcycles.
- Motorcyclist motorists detected motorcycles sooner and carried out more saccades than non-motorcyclist motorists.
• Bottom-up and top-down processing involved in motorcycle detection and applications of these results are discussed.

REFERENCES


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