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Summary

Motorcycles are vulnerable in traffic. In comparison with drivers of motorised four-wheeled vehicles, motorcyclists have a high risk of fatal or serious injury due to a crash. The main type of conflict in which a motorcyclist is injured or killed is a collision between a motorcycle and a car or van (circa 50% of the crashes). In many cases this crash is caused by the car driver failing to yield to the motorcyclist. In traffic literature these types of crashes have become known as “looked-but-failed-to-see” crashes, or “motorcycle conspicuity-related” crashes, because they are thought to be related to the low conspicuity of motorcycles.

Research questions
In order to develop measures to reduce conspicuity-related motorcycle crashes it is important to know the main cause of car drivers failing to notice them. Is it because motorcyclists are simply not visible? In this case measures should focus on improving conspicuity, for example by conspicuous clothing or (head)lights. But if drivers fail to notice motorcycles because they don’t expect them at junctions, measures should focus on increasing expectation and awareness among car drivers, for example in the standard car driver training. This report answers the following research questions:

RQ 1 Do car drivers indeed fail to yield to motorcyclists relatively often?
RQ 2 What is the role of motorcycle conspicuity (colour, size, brightness, etc) in motorcycle crashes?
RQ 3 What is the role of car drivers’ expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?
RQ 4 What is the role of motorcyclists’ behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?
RQ 5 On what problems should measures be focused to reduce conspicuity-related motorcycle crashes?

In order to answer these research questions, a literature review and an analysis of motorcycle crashes in the Netherlands were carried out.

Conclusions
The majority of motorcycle crashes are crashes with a car. In these crashes, the police register the car driver as first offender more often than the motorcyclist. So in absolute numbers, many motorcycle crashes seem to be caused by car drivers (research question 1). However, when adjusted for exposure, car drivers do not crash with motorcycles more often than motorcyclists with other motorcyclists. An analysis of different crash causes at intersections indicates that, relatively speaking, car drivers fail to give priority to a motorcycle as often as to a car.

In one situation motorcycles seem to be at a disadvantage compared to cars. This is when a car makes a left turn, and fails to give priority to an oncoming motorcycle. This specific type of crash occurs more often when the oncoming vehicle is a motorcycle than when it is a car. The literature

review provides some answers as to why this specific scenario (car driver making a left turn) is different for an oncoming car than for an oncoming motorcycle. From the side view a motorcycle is almost as large as some cars, and because the motorcycle is in motion the car driver receives relatively much information about movement and speed. From the front-view a motorcycle is narrower than a car and has only one front light instead of two, which gives less information about speed.

Regarding the second research question, there are several reasons why motorcycles are less conspicuous in traffic. Especially depth and speed perception of motorcycles are more difficult because of their small size (specifically from the front-view) compared to that of cars. In addition, studies that examined motorcycle conspicuity directly indicate that changing the appearance of a motorcycle and/or its rider does affect detection in traffic and even liability to crashes. However, research also suggests that the most important aspect of motorcycle conspicuity is contrast with the environment. Therefore, there is no clear indication of which appearance is best for conspicuity in all conditions.

Furthermore, this study indicates that the *expectation* of car drivers play an important role in the perception of motorcycles (research question 3). There seems to be less evidence for the role of motorcycle *awareness* in the perception of motorcycles. There are even indications that car drivers are more cautious when they interact with a motorcycle. The fact that dual drivers (car drivers who also ride a motorcycle) are less involved in motorcycle crashes than ‘regular’ car drivers, can probably be explained by their better knowledge about motorcycling and motorcyclists’ behaviour than that they care more about motorcyclists.

With respect to research question 4 we simply did not find many studies into the effect of motorcyclists’ behaviour on conspicuity. Only one in-depth analysis on motorcycle speed was found. This analysis of crashes at intersections involving a motorcyclist and another road user indicated that the initial speeds of motorcyclists involved in “looked-but-failed-to-see” crashes are significantly higher than in other types of crashes at intersections.

Overall we found evidence that the perception of motorcycles is affected by conspicuity of the motorcycle and its rider as well as by the expectancy and knowledge of car drivers. Measures could therefore be focused on both sides of the perception process.

Measures

This report discusses several measures and their potential effectiveness to reduce conspicuity-related motorcycle crashes (*Section 5.2*). There is evidence that physical appearance (bright and reflective clothing) has a positive effect on crash risk. However, in different conditions (a bright day in a rural environment), dark clothing and a dark motorcycle are better. In other words, it is difficult to recommend one type/colour of clothing to improve conspicuity in all conditions. Information to motorcyclists should focus on considering the conditions in which they will use their motorcycle. In addition, because study results differ, there is need to further study the effect of clothing in a Dutch setting.

The literature review and analysis of Dutch crash data both suggested that conspicuity of a motorcycle is especially difficult from the front-view. Therefore, improving frontal light configurations would seem a good way to improve motorcycle conspicuity. However, so far not much research has been done on the effect of different frontal light configurations on conspicuity. The study that we could find shows less positive results than was to be expected from the theory. Improving frontal light configurations seems promising to enhance motorcycle conspicuity, but should be further investigated.

It is evident that expectancy plays a role in the perception of motorcycles. However, it is less clear if and how expectancy of motorcycles in traffic can be increased long-term. It is probably not very effective to emphasize the presence of motorcycles in driver training. If this expectancy is not confirmed by what people experience in everyday traffic, expectancy of motorcycle in traffic would probably decrease rapidly. Therefore, to increase long-term expectancy of motorcycles, measures should focus on repeated reminders regarding the presence of motorcycles on the road. With respect to changes in driver training, it would probably be more effective to teach structural procedures aimed at the detection of other road users (e.g. always look over your right shoulder before making a right turn), rather than to focus on the occasional presence of a motorcycle.

Finally, it is important to realize that people, even when they are highly motivated, are limited by their capabilities; they commit errors. In this respect, measures should focus on improving the system and reducing the consequences of these errors and not on improving peoples capabilities (Wegman & Aarts, 2006). For example, ITS can be used to warn drivers that a motorcycle is approaching an intersection; or intersections can be redesigned in such a way that car drivers can make a left turn without the possibility of conflicts with oncoming traffic. Finally, motorcyclists should realize that they may not be expected or perceived by car drivers on the road. A defensive driving style could save lives.

Inhoud

1. Introduction

Motorcycles are vulnerable in traffic. In comparison with drivers of motorised four-wheeled vehicles, a motorcyclist has a relatively high risk of fatal or serious injury due to a crash. The main type of conflict in which a motorcyclist is injured or killed is a collision between a motorcycle and a car or van (circa 50% of the crashes). The second conflict type (almost 40% of motorcycle casualties) is a single vehicle crash (i.e. not involving another party). In many of the car-motorcycle crashes, the car driver failed to give priority to the motorcyclist. According to a European in depth study this is mainly because the car driver fails to notice the motorcyclist. In traffic literature these types of crashes have become known as “looked-but-failed-to-see” crashes, or “motorcycle conspicuity-related” crashes, because they are thought to be related to low conspicuity of motorcycles.

This report gives an overview of the available research on the different factors of influence on the perception of motorcycles. Analyses of Dutch motorcycle crashes provide a description of the relative occurrence of car-motorcycle crashes in the Netherlands. Finally, this report discusses possible measures that could help improve motorcycle conspicuity.

This chapter first presents some general figures on motorcycle use and risks in the Netherlands, before discussing the problem of conspicuity of motorcycles.

1.1. Background information

A motorcycle is a motorised, two-wheeled vehicle. Compared to other European countries, the Netherlands ranks about average in terms of motorcycle ownership with 33 motorcycles per 1,000 inhabitants in 2005 (SafetyNet, 2009). The number of motorcycles has increased considerably in recent decades, from 100,000 in 1980 to over 600.000 in 2010. The new owners are mainly men in the 35-54 age group (SWOV, 2010a). By contrast, the yearly distance travelled by motorcycle has declined in recent years. In 2009, 1.1 billion rider-kilometres in the Netherlands were travelled by motorcycle. In 1993, the top year, the figure was 1.8 billion kilometres. Considering that car use just continued to increase during this period, the proportion of kilometres travelled by motorcycle has declined from 1.7% in 1993 to 0.8% in 2009 (for more information see also SWOV, 2010a).

To ride a motorcycle in the Netherlands, one must be 18 or over and have a class ‘A’ driving licence. To obtain this licence, one must pass a theory exam and two practical exams: vehicle control and participation in traffic. In the Netherlands, a motorcycle driving licence can be obtained from the age of 18. Until the age of 21, a motorcyclist can only ride a ‘light’ motorcycle, that is, the motorcycle must have a power output of less than 35 kW but a cylinder capacity of more than 120 cc. After two years, the rider can switch to a bigger motorcycle without taking further exams. Motorcycles are subject to the same traffic rules as motorised four-wheeled vehicles. Since 1972, it has been mandatory for motorcyclists and their passengers to wear a (CE) approved helmet. Virtually 100% of motorcyclists in the Netherlands wear a helmet. Wearing protective clothing and eye protection is not mandatory.

1.2. Motorcycle safety

The number of fatalities among motorcyclists in the Netherlands fluctuates from year to year (see *Figure 1.1)*. Over the past 10 years, there has been an average of about 80 deaths per year. This amounts to about 10% of all road fatalities, a relatively high proportion considering the small share of road traffic accounted for by motorcyclists (0.8% of the total number of kilometres travelled). Each year there are also more than 1,100 serious road injuries among motorcyclists.

The vast majority of motorcycle casualties are men; as the riders are mostly male, this is to be expected. The age of motorcyclists involved in crashes has changed considerably over the years. Around 1980, most of the casualties were young (18-30). By approximately 1990, the age had shifted upward, a trend that has continued in subsequent years. We can see a similar trend (which is connected, of course, with a shift in motorcycle use from younger to older people) in most other European countries (SafetyNet, 2009). Virtually all the male casualties are the actual motorcycle riders. more than one third of the female casualties is a passenger.

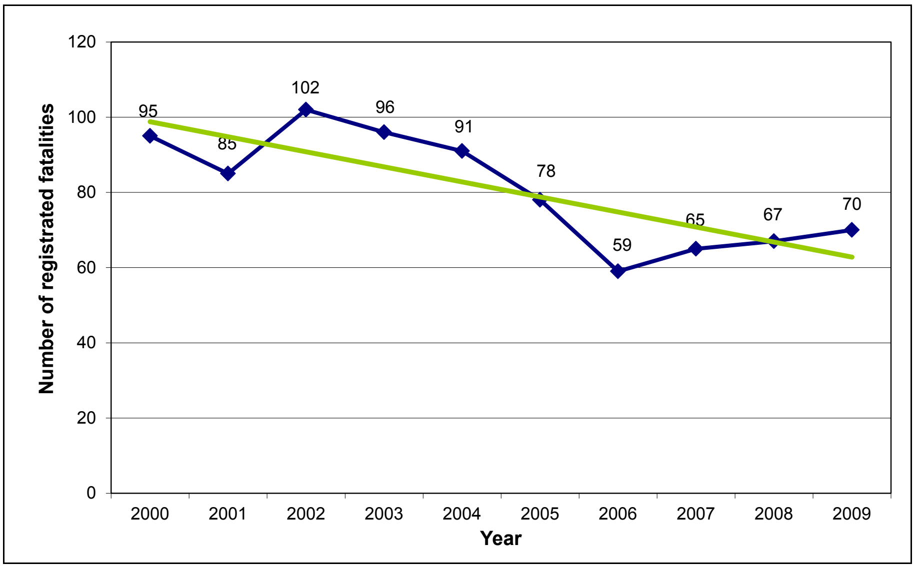

Figure 1.1. *Number of registered fatalities among motorcycle riders in the period 2000 to 2009. Source: Ministry of Transport, Public Works & Water Management, BRON (Road Crash Registration)*

Because of a lack of protection by the vehicle, the consequences of a motorcycle crash are relatively serious for riders and their passengers. In crashes involving a motorcyclist, it is usually the motorcyclist who is injured or killed. This was the case in 91% of serious crashes involving a motorcyclist in the period 2000-2007. Only in 11% of all motorcycle crashes did the other party in the crash sustain casualties.

The crash rate, i.e. the number of crashes per kilometre ridden, is relatively high for motorcyclists. In the period 2004-2008, the number of deaths per kilometre travelled was about 20 times higher for motorcyclists than for car occupants (SWOV, 2010a). The relative number of serious injuries per kilometre was even higher. In comparison with the situation at the end of the

1990s, the risk for motorcycle rider and passenger has declined somewhat, but it is still considerably greater than the risk for car occupants.

As was mentioned at the beginning of this chapter, the main type of conflict in which a motorcyclist is injured or killed is a collision between a motorcycle and a car or van (circa 50% of the crashes). Almost 40% of motorcycle casualties are incurred in single vehicle crashes (i.e. crashes not involving another party).These single vehicle crashes occur mostly on (bended) road sections (81%), rather than at junctions. Finally, in comparison with car drivers, more motorcycle riders are injured in urban areas and fewer on highways. These crash characteristics are not unique for the Netherlands: similar crash scenarios are reported in all western motorised countries (see e.g. SafetyNet, 2009).

1.3. Why do car drivers fail to yield to motorcyclists?

An important cause of the crashes between a motorcycle and a car is the car driver's failure to yield. According to the European MAIDS study (2004; 2009) the car driver's failure to yield can mainly be attributed to failing to notice the motorcyclist. In this study, over 900 crashes in five countries (France, Germany, Italy, Spain and the Netherlands) involving a motorised two-wheeled vehicle (motorcycle/moped) were analysed in depth. It was concluded that human error was the primary cause of 88% of the crashes. In these cases, the driver of the other vehicle was more often at fault (51%) than the rider of the motorised, two-wheeled vehicle (37%). In 37% of all MAIDS crashes, the reported primary contributing factor was a perception failure on the part of the other vehicle's driver; in 12% of the crashes, the primary contributing factor was a perception failure on the part of the two-wheeler rider. These results suggest that other road users (in the MAIDS cases primarily car drivers) have more problems perceiving a motorcycle than the other way around.

But why do car drivers fail to give way to motorcyclists? Without going into the matter too deeply, theories on information-processing (see e.g. Broadbent, 1958; Van Leyden Sr., 1993; Wickens & Hollands, 2000) can provide a stepping stone for the perception of motorcycles. Information processing is a general term used to emphasize all the processes that finally lead to identification and interpretation of stimuli (Coren, Ward & Enns, 1994). With respect to the perception of a motorcycle, there are several steps starting at the appearance of a motorcycle on the road to the correct decision of the car driver to give way (see middle column of *Figure 1.2)*. The left hand side of *Figure 1.2* shows the influence a motorcyclist has on the perception process, the right hand side of *Figure 1.2* shows the influence a car driver has on the perception process.

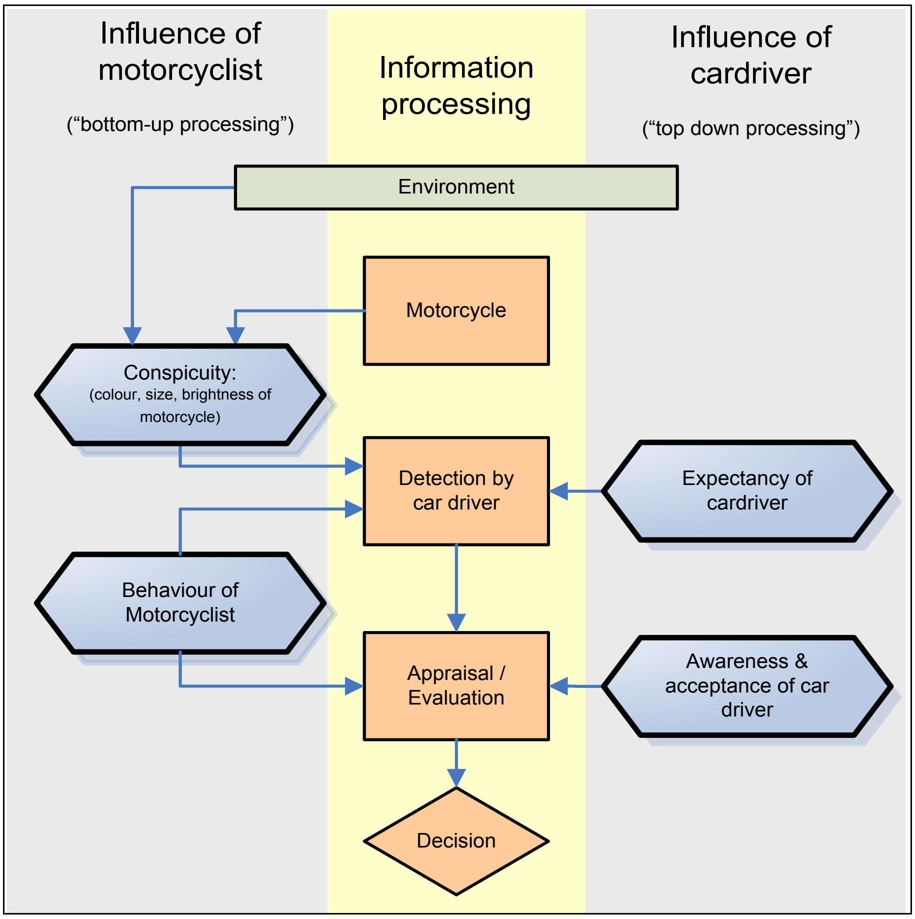

Figure 1.2. *Schematic process for perception of a motorcycle by a car driver.*

In words, *Figure 1.2* describes the following scenario: given a certain environment (road design, night/day, etc.) a motorcycle approaches an intersection. In order to give way a car driver first has to *detect* this motorcycle. The detection of a motorcycle is both affected by aspects of the motorcycle (size, colour, brightness), as by previous knowledge and expectancy by the car driver (e.g. does he/she look for a motorcycle?). In theories on information-processing this is often referred to as "bottom-up processing" (i.e. a passive system that receives a quantity of incoming information) and "top-down processing" (i.e. an active system that conditions the way in which information is gathered; Zimbardo et al., 1995).

Once a motorcycle has been detected, a car driver still has to *evaluate* the situation before he can make the correct decision. For example, when the car driver looks in the right direction and perceives and identifies a motorcycle, but still pulls out in front of the motorcycle, a collision might occur. What went wrong in this example is that the car driver may have misjudged the driving speed (or acceleration power) of the motorcycle and falsely decided that it was safe to move on to the road. On the one hand the process of evaluation (bottom part of *Figure 1.2*) is influenced by the characteristics of a motorcycle (acceleration power) and rider (e.g. speeding behaviour), and on the other hand by the awareness and acceptance of the car driver of these motorcycle characteristics.

1.4. Research questions

In order to develop measures to improve perception of motorcycles and their riders it is important to know the main cause why car drivers fail to notice them. Is it because motorcyclists are simply not visible? In this case measures should focus on improving conspicuity, for example by conspicuous clothing or lights. But if drivers fail to notice motorcycles because they don’t expect them at junctions, measures should focus on increasing expectation and awareness among car drivers, for example in the standard car driver training. This report answers the following research questions:

RQ 1 Do car drivers indeed fail to yield to motorcyclists relatively often?

RQ 2 What is the role of motorcycle conspicuity (colour, size, brightness, etc.) in motorcycle crashes?
RQ 3 What is the role of car drivers’ expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?
RQ 4 What is the role of motorcyclists’ behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?
RQ 5 On what problems should measures be focused to reduce conspicuity-related motorcycle crashes?

In order to answer these research questions this report presents a literature review and an analysis of motorcycle crashes in the Netherlands. The crash analysis, in itself, cannot conclusively answer research question 1 (due to limitations of available data, see Section 4.1) therefore the information obtained from the literature review will also be used to answer the first research question.

1.5. Structure of the report

This report first discusses the different factors that play a role in perception of motorcycles and their riders (*Figure 1.2*); *Chapter 2* discusses the conspicuity of the motorcycle (whether or not influenced by the environment), and the role of the motorcyclists’ behaviour; *Chapter 3* discusses the expectancy, awareness and acceptance of the car driver. Both chapters introduce general scientific theories on perception and information-processing which can be rather detailed and theoretical. Each chapter starts with these general theories and then proceeds to discuss the implications for motorcycle conspicuity and perception in traffic. Readers who are mostly interested in literature that specifically studied conspicuity are invited to read *Sections 2.3* and *2.4* on conspicuity of motorcycles and *Sections 3.2* and *3.3* on expectation, awareness and acceptance of car drivers.

Chapter 4 tries to link the theories on conspicuity to police records of motorcycle crashes in the Netherlands and attempts to answer the first research question: Do car drivers indeed fail to yield to motorcyclists relatively often?

Finally, *Chapter 5* summarizes the findings, lists some measures that are most promising to reduce conspicuity-related crashes and makes suggestions for further research.

2. Motorcycle conspicuity

This chapter reviews existing literature on conspicuity in general and of motorcycle conspicuity specifically. This literature review primarily aims to answer the following research questions:

RQ 2 What is the role of motorcycle conspicuity (colour, size, brightness, etc.) in motorcycle crashes?
RQ 4 What is the role of motorcyclists' behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?

In this chapter the main focus is on the features of the motorcycle and the motorcyclist and how they influence the detection by other road users, and in particular by car drivers. The chapter starts with a few theories on saliency[1] of stimuli and its contribution to the detection of objects (*Section 2.1*). Second, the relevance of these theories to the conspicuity of motorcycles in the traffic situation is discussed (*Section 2.2*). These sections can be rather detailed and theoretical. Readers who are mostly interested in research that specifically studied motorcycle conspicuity are invited to read *Section 2.3* which discusses literature on: the motorcyclist (helmet, clothing), the motorcycle (colour and coating), and the use of daytime running lights (DRL). *Section 2.4* describes studies on the influence of motorcyclists themselves on conspicuity.

As was indicated in the introduction, the perception process does not only involve bottom-up processes, but is highly influenced by expectations and attention of the observer (top-down processes; see *Figure 1.2*). Although this chapter primarily deals with the bottom-up aspect (i.e. stimulus-features), it is often difficult to separate this completely from top-down processes which are crucial for orientation towards the stimuli. A more detailed description of the role of expectancy, awareness and acceptance in the detection of motorcycles can be found in *Chapter 3*.

2.1. Theories on the saliency of objects

In the psychological literature much information can be found on the saliency of objects in a visual scene. The saliency of objects can be investigated in a variety of ways. Much work has been done on visual search, the identification of orientations, or modelling information processing for static images. For studies on perception of dynamic scenes different approaches were used, such as estimating time of arrival. First, we will discuss some work on static images; next we will discuss the studies on depth cues and dynamic scenes.

[1] In literature on traffic safety, the word 'conspicuity' is used to refer to the degree to which an object is visible, stands out. In the psychological literature the word 'saliency' is used to address the degree to which an object sticks out, or is visible. In this chapter, we will use these words as synonyms.

2.1.1. *Visual saliency and visual search in static images*

Most of the experiments on visual search conclude that the effectiveness of the search, measured in time needed to find a target, is dependent on the visual saliency of the target (Noordzij, Hagenzieker & Theeuwes, 1993; Estes & Taylor, 1965 as cited in Pasher & Johnston, 1998). This is especially true if the task is a free search task, in which the target is not specified beforehand. If the task is directed towards a specified target or target location, the search is influenced by the context via top-down processes. Underwood and Foulsham (2006) studied visual search with realistic pictures. They concluded that visual search in a free search task is dependent on saliency of the objects in the image. The most salient objects will be focussed on prior to the less salient objects. If the search task is directed (e.g. “search for object x”), top-down processes influence the search pattern dependent on the task itself. For example, if the task involves searching for a small not salient object, the more salient objects in a scene can be neglected or ignored.

Oliva and Torralba (2006) concluded that humans can obtain the gist of the scene within a glance. This gist is based on local features of the visual scene, which are not necessarily the features with a low spatial resolution since these global features can also be derived from high spatial resolution properties of the scene. In earlier work, Torralba (2003) mentioned that attention is directed on the base of bottom-up saliency, object-centred features based on top-down knowledge of the features of the object, and contextual modulation (the context determines the most logical class of objects, scale and location). Thus the gist of a scene is assessed in a glance, and this information can be used to guide a more detailed perception of the scene. Objects are perceived more quickly when they appear in an expected location in the visual field. Therefore, both bottom-up and top-down processes are involved in visual information processing of static images. The relative contribution of these processes is dependent on the task that is given to the observer.

Experiments on visual search mainly used static images. The stimuli used in these studies are often rather simple: finding a different oriented line in between a pattern of lines, Gabor patches in different orientations, etcetera. Although these stimuli are very basic, effects of orientation of objects on detectability are relevant for this report, because the car is a mainly horizontal oriented object whereas a motorcycle is vertically oriented. The literature on effects of orientation of stimuli focuses mainly on oblique orientations (circular) versus cardinal orientations (horizontal and vertical). For example, many studies describe ‘the oblique effect’ which refers to the phenomenon that both horizontal and vertical orientations are easier identified than oblique orientations (see e.g. Furmanski & Engel, 2000).

However, in a study on the detection of objects in more natural pictures Hansen and Essock (2004) found that oblique orientations were easier identified than cardinal orientations. Furthermore, vertical orientations were identified more easily than horizontal orientations. This result seems to contradict with the large body of research on ‘the oblique effect’ under reduced conditions. Hansen and Essock explained these findings by claiming that horizontal lines occur more often in a natural environment than vertical or oblique orientations and are therefore less attention captive than the other orientations. They hypothesize that the introduction of the natural pattern will probably change the task at hand considerably, which may explain the difference between this study and the research under more restricted conditions. And therefore we can only conclude from this work, that the task given to observers, the stimuli and the conditions in which the stimuli are presented will influence the results considerably.

2.1.2. *Depth perception and dynamic scenes*

Traffic is per definition not static, as it is characterized by motion in depth. One aspect of dynamic scenes is the three-dimensionality of the scene. An observer has to determine the locations of objects in the scene based on two-dimensional information (the image on the two retinas). Numerous depth cues are being used to process these two-dimensional images into a three-dimensional one. These depth cues are traditionally divided into three groups: physiological, pictorial and motion-based depth cues. Physiological depth cues, binocular disparity, accommodation and convergence, are not of interest for traffic psychology since they only contribute to depth perception in a range of 1 to 4 meters from the observer. Pictorial depth cues (for example relative size, occlusion and height in the visual field) and motion-based cues are very relevant for perception during participation in traffic. To estimate relative positions of objects (for example motorcycles) in depth, pictorial depth cues are combined with motion-based depth cues (DeLucia, 1991). It is generally accepted that the exent to which different sources of information about depth are used depends on their reliability in the past. This experience can differ between people, so people can differ in the extent to which they make use of certain depth cues (Doumen, 2006).

Itti (2005) investigated the influence of saliency on eye movements in dynamic scenes. He concluded that eye movements of humans tend to be directed to salient stimuli in a video-clip. Motion energy and temporal change are also strong attractors of attention, besides colour, intensity and orientation. Thus various sources of information can be combined to direct attention in a dynamic scene.

2.1.3. *Conclusions conspicuity of objects*

From the literature on the static image, we can conclude that a combination of bottom-up and top-down effects modulates the perception of objects in the visual scene. The gist of a scene determines which objects can be expected. These objects are perceived more quickly when they appear in an expected location in the visual field. Therefore, top-down processes involve expectations about the events happening in a scene and thus long-term memory. Bottom-up processes involve mainly the saliency of objects i.e. the extent to which it stands out in between the other objects in the scene. The degree to which top-down or bottom-up processes influence perception are dependent on the task at hand. In the literature a distinction is made between free search and directed search. Visual search in a traffic situation is a combination of a free search task and a directed search task. Expectancy of events to happen in a scene will inflict top-down processes and directed search, unexpected events will trigger bottom-up processes. The literature on dynamic scenes suggests that the stimulus features motion energy and temporal change are features that capture the attention of an observer.

2.2. From visual perception in general to the perception of motorcycles

How do we translate the theories discussed in *Section 2.1* to the daily practice of perceiving traffic situations and to the perception of motorcycles in particular? To answer this question, we will first discuss the preceding overview in the light of traffic psychology and the perception of motorcycles. In the subsequent section, *Section 2.3*, we will describe studies that studied motorcycle conspicuity directly.

The literature on dynamic scenes suggests that the stimulus motion energy and temporal change are features that capture the attention of an observer. From this point of view, you would expect a quickly accelerating motorcycle to capture a lot of attention. Here the direction of movement is an interesting issue which influences both motion energy and temporal change. If a vehicle moves in a front parallel plane in the visual field, the temporal change will be larger than when it moves along with the observer. If, for example, a motorcycle moves along with a car, the temporal change is small. If the motorcycle moves in the same line, but in the opposite direction of the car, the change in size of the motorcycle is the only cue to movement for the observer. Because the front view of a motorcycle is relatively small, the change in size of the motorcycle provides relatively little information about its movement. If, however, the motorcycle moves in a direction perpendicular to the direction of the car, the change in the visual field of the car driver is quite large. Thus the direction of an approaching motorcycle may be of interest here: a motorcycle approaching on a perpendicular road will inflict the greatest temporal change and motion energy when arriving at the intersection together with another road user (assuming the paths cross each other).

We pointed out in *Section 2.1.2* that because traffic concerns motion, pictorial depth cues and motion based depth cues are important. A car, which has a predefined, consistent shape, provides a reliable source of information on depth perception. However, the shape of motorcyclist on a motor is not well defined; it is dependent on the type of motorcycle and the movement of the motorcycle and the motorcyclist himself. Therefore, the motorcyclist provides a less reliable source of information on depth perception. It could be that depth is not as easily derived from a moving motorcycle as from a moving car. Furthermore, a motorcycle is smaller than a car, especially its front view. Horswill et al. (2005) found that car drivers accept smaller gaps when crossing a road in front of a motorcycle than when crossing in front of a car. They explain this result by the size-arrival effect that was described by DeLucia (1991). This size-arrival effect states that smaller objects are perceived to arrive later than larger objects. This effect could therefore be disadvantageous for motorcycles.

To conclude, when applying the theories on saliency and depth and motion perception to the motorcycle situation, there are many situations where the motorcycle is theoretically at a disadvantage compared to a car. Mostly this is because of its relatively small size (especially from the front view) compared to a car.

2.3. Conspicuity of the motorcycle and its driver

In the previous section we extrapolated the general theories on visual search, saliency of stimuli and depth cues to the perception of motorcycles. In this section, we will discuss the literature that studied conspicuity of motorcycles or motorcyclists directly. Traditionally, three kinds of studies have been conducted to test the effect of conspicuity of motorcyclists: 1) studies that compare the conspicuity of motorcyclists that were involved in crashes with the conspicuity of general population of motorcyclists; 2) studies of the reaction time of drivers when confronted with pictures or video-footage of traffic situations with motorcycles; and 3) gap-acceptance studies.

Results from these studies were used to describe three conspicuity-related topics. First we will discuss studies that were conducted to test the effects of the conspicuity of the motorcyclist. Second, we will discuss the research about conspicuity of the motorcycle and the coating of the vehicle. And, finally, we will review the literature on the effects of Daytime Running Lights (DRL).

2.3.1. *Conspicuity of the motorcyclist: clothing and helmet*

The conspicuity of motorcyclists can be altered by adapting the clothing and helmet of the rider. Traditionally, the use of fluorescent or bright clothing is studied in day-time experiments. Night-time experiments more often study reflective clothing. Several studies have been carried out on the clothing and helmet of motorcyclists. However, the literature shows ambiguous results concerning the effects of clothing on the safety of motorcyclists.

Wells et al. (2004) conducted a large-scale case-control study on the effect of the conspicuity on crash risk of New-Zealand motorcycle riders. Fluorescent or reflective clothing and wearing a white or light helmet were associated with a reduced risk of motorcycle crashes. Olson and colleagues (1981) conducted a gap-acceptance experiment in which they varied, among others, the clothing of the motorcyclists. They found that during daytime car drivers accept smaller gaps when the motorcyclist is not wearing fluorescent clothing. In the dark, the same was the case for reflective clothing. Acceptance of a small gap was interpreted as the driver being unaware of a dangerous situation.

In contrast, studies based on reaction time or detection rate measures do not indicate a general trend towards a better or quicker detection of motorcyclists when the motorcyclist wears bright clothing. These studies conclude that it is the contrast with the environment that is important (Hole, Tyrrell & Langham, 1996; Rogé, Ferretti & Devreux, 2010; Gershon, Ben-Asher & Shinar, 2012). For instance, Hole and colleagues found that in urban environments observers responded quicker to motorcyclists with bright coloured or fluorescent clothing than to motorcyclists with dark clothing. The reverse effect was found in rural settings, there the observers responded quicker to motorcyclists wearing dark clothing. They concluded that this was due to the brightness of the environment: the environment in the rural setting was dominated by a clear blue sky.

2.3.2. *Conspicuity of the motorcycle: coating*

Most studies concerned with the conspicuity of the motorcycle itself have focused on the use of DRL; this will be discussed in the next section. Only a few studies have, in addition to other features, examined the colour of the motorcycle itself, and found no clear effect of the coating of a motorcycle. Olson, Halstead-Nussloch and Sivak (1981), for example, found no effect of the coating of the motorcycle in a gap acceptance study. And the New Zealand case-control study (Wells et al., 2004), which was discussed in de preceding section, also did not find a relationship between the colour of the motorcycle and crash risk. The absence of a relationship between the colour of the motorcycle and crash risk or gap acceptance is somewhat unexpected, and in contrast with the effect of the colour of motorcycle clothing. No explanation has been given to indicate why the colour of the motorcycle does not seem to matter, whereas the colour of the clothing does seem to make a difference.

2.3.3. *Conspicuity of the motorcycle: Daytime Running Lights (DRL)*

Many studies have been conducted on the detection of motorcycles with or without DRL. In general, DRL enhances the conspicuity of motorcycles during daytime (e.g. Thomson, 1980; Torrez, 2008). However, most studies report this effect to be dependent on the specific situation, e.g. on the characteristics of the environment (Hole, Tyrrell & Langham, 1996), the motorcycle's speed (Howells et al., 1980 as cited in Pai, 2011), or the weather conditions (Pai, 2011). Hole and Tyrrell (1995) concluded that DRL is most effective at large distances between motorcycle and observer and that in urban environments DRL is not as effective as in rural environments. In 1996, Hole, Tyrrell and Langham concluded that the effectiveness of DRL is dependent on the amount of clutter in the background. This could explain the smaller effect of DRL in urban environments found in the 1995 study.

Some studies report that the use of DRL decreases the risk of fatal or serious injury crashes of motorcyclists. However, these studies have some methodological problems that were not properly addressed. Therefore, the changes in motorcycle crashes could be minor.

Nowadays, many drivers have grown accustomed to using DRL on their cars. The question arises whether this influences the conspicuity-enhancing effects of motorcyclists using DRL. Al-Awar Smither and Torrez (2010) concluded from a simulator study that DRL used by motorcyclists maintained its enhancing effects. However, reaction times for detecting a motorcycle with DRL which was followed by a car with DRL (in the same scene) was slower than when the motorcycle with DRL was followed by a car without DRL. However, detection of a motorcycle without DRL that was followed by a car with DRL was even slower than detecting a motorcycle with DRL that was followed by a car with DRL.

Related to DRL, some studies have looked into motorcyclists using other types of lights to enhance conspicuity. For example, Olson and colleagues (1981) studied the use of *running lights*, when the turn signal lights were on fulltime (not flashing). They found a positive effect of the use of running lights in a gap-acceptance experiment (the gap increased). Rößger and colleagues (2012) studied the effect of different frontal light configurations on the recognition of motorcycles (see *Figure 2.1*).

Figure 2.1. *Three different frontal light configurations: (a) Conventional frontal view headlight ON, (b) T configuration, and (c) T configuration plus helmet lights (from: Rößger et al., 2012).*

Rößger and colleagues (2012) report positive results for the T-shaped light configurations: “Results of a laboratory experiment have shown that motorcycles with a T-shaped light configuration are more quickly identified, particularly when the motorcycles are in visual competition with other motorised road users (p.82)”. However, based on the results of their study we come to a slightly different conclusion. The motorcycles with T-shaped lighting configuration were not detected earlier. Rather, after the first pictures were shown, the fixation time decreased for the experimental conditions (T-shaped lighting configuration). It seemed like the observers in the experimental conditions were first surprised by the lighting configuration (they fixated longer on the motorcyclists) and after a few pictures the fixation time decreased again. This decrease in fixation time did not coincide with detection time. Thus, in our opinion, this study does not provide conclusive evidence of an enhancing effect of a T-shaped lighting-configuration for motorcycles.

2.3.4. *Conclusions on the conspicuity of the motorcycle and its driver*

Many studies focus on the improvement of motorcycle conspicuity with, for example, colour of the clothing, helmet, (configuration of) lights, et cetera. The main conclusion that can be drawn from these studies is that contrast with the environment is a major factor to improve conspicuity. For instance, at night bright coloured and reflective clothing is most effective to improve conspicuity. During a bright day in a rural environment, dark clothing and a dark motorcycle provide better conspicuity. Even in the studies on DRL which reported an overall positive effect on conspicuity, the magnitude of the effect depended on the surroundings.

2.4. Influence of motorcyclists' behaviour on conspicuity

The previous sections have all focused on the appearance of a motorcycle and its rider. This section focuses on studies on behavioural aspects concerning the motorcyclists to improve conspicuity. Theoretically a motorcyclist has a large influence on his conspicuity, for example by choice of location on the road, or of speed when approaching an intersection. However, we did not find many studies on the motorcyclists' behaviour in relation with improving conspicuity.

Only a few studies discuss the role of motorcyclist's speed on conspicuity. Brenac and colleagues (2006) conducted an in-depth analysis of 22 crashes involving a motorcyclist and a car where visibility-problems were involved. They compared crashes in which conspicuity of the motorcyclist was a factor with crashes in which the visibility problem was due to another cause (obstruction of view for example). They concluded that in the conspicuity-related crashes the motorcycles travelled at higher speeds than in the control group. However, the study was quite small, and the authors suggest further research on the topic. The same research group recently repeated their in-depth study (Clabaux et al., article in press); this time with an analysis of 44 crashes at intersections involving a motorcyclist and another road user. In their reconstruction of these crashes they found that the initial speeds of motorcyclists involved in "looked-but-failed-to-see" crashes are significantly higher than in other crashes at intersections. In contrast, the larger MAIDS in-depth study which included more than 900 motorcycle crashes (MAIDS, 2004; 2009), found relatively few cases in which excess speed was an issue related to crash causation. However, the MAIDS study did not specifically focus on "looked-but-failed-to-see" crashes.

2.5. Conclusions

This chapter dealt with theories on conspicuity that can explain why car drivers fail to give priority to motorcyclists. More specifically, this chapter tried to answer the following research questions:

RQ 2 What is the role of motorcycle conspicuity (colour, size, brightness, etc.) in motorcycle crashes?
RQ 4 What is the role of motorcyclists' behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?

Concerning research question 2, we conclude that there are many indications that motorcycles are simply less visible in traffic. Especially depth and speed perception are more difficult with motorcycles because of their small size (especially from the front view) compared to a car. On the other hand, literature that studied the conspicuity of motorcycles in practice reports less straightforward effects of inferior conspicuity than was to be expected from the theory. In the following two sections we sum up the conclusions on clothing, helmet and motorcycle (*Section 2.5.1*) and daytime running lights (*Section 2.5.2*) in terms of measures.

With respect to research question 4 we simply did not find many studies on the effect of motorcyclists' behaviour on conspicuity. It is possible that the effect of motorcyclists' behaviour was studied but that no effects were found;

but it is also possible that the role of motorcyclists' behaviour has not been studied very often.

2.5.1. *Clothing, helmet and motorcycle*

Theories on visual saliency and depth perception indicate that conspicuity is a major contributor to the perception problem. In addition, research indicates that conspicuity of motorcycles can be improved with clothing, at least to some extent. However, research also suggests that the most important aspect of motorcycle conspicuity is contrast with the environment. That is, a motorcyclist benefits from wearing reflective clothing at night, but during the day it depends on the environment whether motorcycle and rider are easily detected. This implies that it is not always that simple to let motorcycles 'stand out' more in traffic, and that it is difficult to give one general advice for motorcyclists that applies in all traffic situations. Information to motorcyclists should be focused on making them aware of the circumstances in which they are using their motorcycle. For example, when riding through very dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night reflective clothing could be most effective.

2.5.2. *Daytime running lights and frontal light configurations*

Research suggests that using DRL is beneficiary for motorcycle riders. In general motorcyclists with DRL are perceived better than motorcyclists without DRL. However, most motorcyclists already use DRL. So it is the question how much more can be gained by, for example, making it compulsory for motorcyclists to ride with DRL. Another development in this area is that more and more car drivers are also driving with DRL. In theory this could be detrimental to the conspicuity of motorcycles with DRL. However, research differs on the negative effect for motorcycles. In any case, DRL for motorcycles is always better than no DRL at all.

In theory different frontal light configurations could improve motorcycle conspicuity, especially from the front view. By extending the light from only the front light to other parts of the motorcycle (helmet, throttles, etc.), the surface of the front view is enlarged. This could not only be beneficiary to the perception of the motorcycle itself, but would also improve the perception of speed of a motorcycle approaching from the front. The first studies that compared different frontal light configurations in an experimental setting did not report very convincing results so far.

3. Expectancy, awareness and acceptance of car drivers

This chapter discusses the role of the car driver in the process of perceiving and appraising a motorcycle. These factors in the perception of motorcycles have also been called ‘cognitive conspicuity’ (Hancock et al., 1990). This includes the theory on expectancy which was already briefly mentioned in the previous chapter: when you consciously look for certain items the chances are better that you will locate them. Awareness[2] and acceptance of motorcycles (e.g. Crundall et al., 2008b) relate to the notion that car drivers tend to view the traffic situation from the perspective of a car driver and are not familiar with the characteristics of a motorcycle and its rider. This notion also has a sort of ‘motivational’ aspect: Car drivers don’t *care* about motorcycles and are therefore less inclined to look out for them on the road.

More specifically this chapter answers the third research question:

RQ 3 What is the role of car drivers’ expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?

Similar to the previous chapter, this chapter starts with some detailed theories on expectancy and attention (*Section 3.1*). Readers most interested in practical studies on the expectancy of motorcycles can skip the first section and start with *Section 3.2*. *Section 3.3* presents studies on awareness and acceptance of motorcycles and their riders.

3.1. Theories on expectancy and attention

3.1.1. *Scripts and schemata*

The concept of expectancy is related to Norman’s (1981) Activation-Trigger-Schema theory. According to this theory, every task performed by humans is represented by hierarchical, ordered schemas. For example: a visit to the doctor (“Parent Scheme”) contains a number of “Child Schemas” for dressing, leaving the house, driving my car, etc. Driving the car, in itself, contains the schemas: starting the car, accelerate, obeying traffic rules, navigating, etc. According to Norman each schema is ‘triggered’ for activation. For example, accelerate only happens after the car is started, not before. The completion of a task by using schemas is dependent on triggers provided by the situation, motivation, the presence of other competing schemas and strength of a schema as a result of frequent successful use.

The term *script* was introduced as a particular type of schema that describes the kind of knowledge that people can derive from a common, frequently occurring event (Searleman & Herrmann, 1994). Scripts are not composed of memories for any one particular event, instead, they contain generic knowledge or memory about what usually happens. The benefit of having a script is that it allows a person to fill in missing details.

[2] The term ‘awareness’ in this context should not be confused with the Endsley’s (1995) theory on Situation Awareness (SA; introduced in *Section 3.1.2*).

In order to activate the correct schema or script, a driver has to know what to expect in a certain situation. As a driver gains experience he develops expectancies on what can happen in traffic, which in turn increases anticipation (Van Elslande & Faucher-Alberton, 1997; Martens, 2000). However, improved anticipation due to experience does not always have a positive effect on traffic safety (Houtenbos, 2008). Unjustified expectancy can have a major negative impact on traffic safety. Especially with looked-but-failed-to-see-errors, it appears that experienced road users are more likely to miss road users due to unjustified expectations (Herslund & Jørgensen, 2003).

3.1.2. *Attention*

The human capacity for information processing is limited; humans cannot process all information they are presented with (O'Donnell & Eggemeier, 1986). Attention helps people to selectively filter which information they process and which information they do not process. An example of selective attention is when people are conversing at a noisy crowded party. They are quite capable to hear and understand the person they are talking to, while ignoring all other surrounding noises. This phenomenon is called the ‘cocktail party phenomenon’ (Cherry, 1953; as cited in Zimbardo et al., 1995).

Roughly speaking, two kinds of theories about attention exist. The first category is the bottleneck theory of attention. The theory states that not all information can be attended to and thus a bottleneck is present. In which stage of information processing this bottleneck is located has been under debate since the introduction of the theory (Zimbardo et al., 1995). Some theories describe an ‘early selection’ of information, indicating that there is little processing of the ignored information (Broadbent, 1958). With ‘late selection’ the information has already been given some meaning, so at least some information-processing has occurred (e.g. Duncan, 1980; Norman, 1968; as cited in Pasher, 1998). The second theory describing attention is the theory of attentional resources. This theory states that human observers have a maximum amount of resources that can be used to process information. Thus, the amount of information is limited by the capacity of these resources. The bottleneck theory and the attentional resources theory do not necessarily have to contradict each other (Coren, Ward & Enns, 1994).

According to the (holistic) theory of Situation Awareness (Endsley, 1995), both attention and expectation are important for efficient information-processing. Situation Awareness (SA) is defined as “The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (Endsley, 1988, p. 789, as cited in Endsley, 2000). The theory of Situation Awareness also describes that expectancy is developed during practise and with experience (Mundutéguy & Ragot-Court, 2011).

In presenting the literature on attention, the next sections will be restricted to visual attention, since vision is the dominant mode of perception in traffic situations.

3.1.3. *Attention & Visual search*

Attention in a visual context is often described as a spotlight, or attentional gaze, that 'highlights' a part of the visual field (Coren, Ward & Enns, 1994; Wolfe, 1998). The attentional gaze can be attracted by stimulus features like a rapid onset of movement or conspicuous differences in movement, shape or colour of an object. These stimulus features were already discussed in more detail in the previous chapter (*Section 2.1*). Three aspects of attentional gaze have been identified: the locus (position of the spotlight), extent (size of the area in the spotlight) and detail set (level of detail; Coren, Ward & Enns, 1994; Yantis, 1998). The extent and detail set are dependent on each other: the larger the area that is attended, the less detailed the information that is being perceived.

The attentional gaze is independent of the visual gaze. It is possible to focus attention on a stimulus without focusing the eyes on it (covert attention). The human observer is capable of filtering information that is of special interest to the observer. For example, when we are looking for a familiar face in a crowd, we can focus on the faces of the people instead of the often colourful clothing people are wearing. This is also an example of the, abovementioned, cocktail party phenomenon.

Under most circumstances, driving a car is similar to the example of the cocktail party phenomenon. Drivers have strong expectations of what to expect based on years of experience. Even in unfamiliar environments there are clear expectations on what can be expected on a certain road type. From this point of view, expectation is used to direct attention and to shift between the enormous amount of information that approaches a driver at high speed (Martens, 2000).

3.1.4. *Change blindness and attentional capture*

So, expectation and attention can help a driver to selectively filter information that is important for the driving task. However, selective attention can be at the expense of something else that demands attention. Two concepts that describe suboptimal results for the detection of objects in traffic are change blindness and attentional capture.

Change blindness refers to the fact that observers are often blind to changes in the visual field that are irrelevant for them at that moment (Simons & Chabris, 1999). Martens (2011) describes an experiment on change blindness in a traffic situation. Observers had to detect a change in road sign in a video recording of a drive through a city. Martens concluded that glance duration influences the detection of changes. Thus, the longer observers fixated on an item, the larger the chance was that the change was detected. In this experiment, using video recordings, the change was an artificial one (erasing the presence of road signs) which is different from naturally occurring changes. An example of a naturally occurring change is when a motorcycle is temporarily blocked from view; this change can be missed by an observer when the motorcycle is not of interest to him/her at that moment. The observer could be surprised by the motorcycle when it is visible again.

Attentional capture is the notion that if an object has ‘captured’ the attention of an observer, other objects in the visual field are not perceived (Mortier, Donk & Theeuwes, 2003). For example, if a car driver is judging the speed and position of an oncoming car, it could easily interfere with the detection of a motorcycle. As mentioned in the previous section the attentional gaze is independent of the visual gaze. So, in some instances a driver can overlook a motorcyclist, because his attentional gaze is focused elsewhere, even though he is looking straight at this motorcyclist. This could be at the origin of the ‘looked-but-failed-to-see’ crashes.

3.1.5. *Conclusions on the theories on expectancy*

Human observers are masters in filtering information. If this were not the case, we would be flooded by information all day long, and would not be able to function at all. Attention and expectancy help drivers to select which information is most relevant and important for the performance of their driving task at that specific moment in time. In addition, expectancy helps to select the correct script in time to deal with the situation. However, selective attention for part of the driving task or visual field can be at the expense of other parts. Especially when something unexpected happens, a driver can respond sub-optimally, or in some cases completely miss important information (or a motorcyclist).

3.2. **Expectancy of motorcycles**

The previous section indicated that expectancy plays an important role in how people direct their attention, what they perceive, and the selection of the correct script for action. What do these theories mean for the perception of motorcycles in traffic?

As early as 1981, Åberg conducted an experiment in a real driving environment, in which drivers (and passengers) were measured on their ability to perceive moose (dummies). When driver and passengers were specifically instructed that moose were the search targets about 80% of the moose were detected. When no specific target was specified the detection rate was 20% (Åberg, 1981). Gershon, Ben-Asher and Shinar (2012) studied the effect of expectancy on the perception of powered two-wheelersin two experiments. In the first experiment, participants watched a series of pictures, half with and half without a powered two-wheelerin different settings (urban, rural, powered two-wheeler at far distance or close by, etc.). After each picture, the participant had to report which motor vehicles they had seen in the picture. In the second experiment, the same pictures were shown to a different group of observers. This time, the observers were instructed to press a button as soon as they observed a powered two-wheeler. The combined results of these experiments showed that, at the farthest distance, powered two-wheelers detection rates were three times higher when the observers were instructed to look for powered two-wheelers. In fact, in this second experiment, an average of 97% of the powered two-wheelers were identified. Without instruction to search for powered two-wheelers, the correct detection of powered two-wheelers was only 65%.

These experiments indicate that expectation of objects (or motorcycles) enhances detection. In the Netherlands there are only few motorcycles on the road compared to the number of cars. From the perspective of a car driver it is conceivable that they do not expect a motorcycle on the road or at an intersection as most of the time there will not be one. In addition, there are many ‘seasonal’ riders in the Netherlands, that is, they only ride their motorcycles in the summer. So, in winter there are even fewer motorcycles on the road. Although the crash records do not show an increased risk for motorcyclists during the winter and spring time (when they are least expected) in the Netherlands (De Craen et al., 2012), in theory, seasonal riding will diminish the car drivers’ expectation of motorcycles on the road even further.

3.3. Awareness and acceptance of motorcycles

3.3.1. *Awareness and acceptance as influence on motorcycle-car crashes*

In addition to expectation, it is sometimes mentioned that car drivers lack in “awareness and acceptance” of motorcycles (e.g. Crundall et al., 2008b). The term ‘awareness’ in this context should not be confused with the Endsley’s (1995) theory on Situation Awareness which was introduced in *Section 3.1.2*. Awareness and acceptance of motorcycles in the present section refers to the idea that car drivers travel through traffic from the perspective of a car driver and fail to recognise that riding a motorcycle is a different and more challenging mode of transportation. In contrast with expectancy from the previous sections this statement has a sort of ‘motivational’ aspect. Car drivers don’t *care* about motorcycles and their riders and therefore miss them at an intersection. Some studies indicate that car drivers do not regard motorcycles as a potential danger for collisions (e.g. Mannering & Grodsky, 1995). Other studies report that car drivers have negative attitudes towards motorcyclists (e.g. Crundall, Clarke & Shahar, 2010). Recently, Musselwhite and colleagues (article in press) examined the attitudes of road users towards motorcycle riders and found that motorcyclists are viewed as a high risk group and are viewed as ‘thrill seekers’. The motorcyclists themselves tended to agree that motorcycle riding is a risky activity. However, they were also inclined to state that they had acquired skills to be able to deal with the risk.

An important element in the discussion of awareness and acceptance of motorcycles is: does this affect car drivers’ behaviour? Is the occurrence of motorcycle crashes (partly) influenced by these subjective (negative) feelings of car drivers? A research result often refered to is that of Brooks and Guppy (1990), who found that drivers with family members or close friends who ride motorcycles are less likely to cause a crash with a motorcyclist. They are also reported to show better observation of motorcycles than other car drivers. These findings would imply that drivers who have more awareness (or empathy) for motorcyclists do indeed behave differently (safer) in their interaction with motorcyclists. Although many studies report these findings by Brooks and Guppy (e.g. Huang & Preston, 2004; Crundall et al., 2008a; Torrez, 2008; Crundall, Clarke & Shahar, 2010; Shahar, Clarke & Crundall, 2011; Musselwhite et al., article in press; Ragot-Court, Mundutéguy & Fournier, article in press), the original study did not actually find the reported effect. Brooks and Guppy compared groups of drivers who differed only in whether or not they had a close acquaintance who was a motorcyclist (none of these drivers had powered two-wheeler riding experience); and found *no* difference in crash-involvement between these groups. Brooks and Guppy conclude that having ‘Social Awareness’ does not reliably reduce a driver's risk of crash involvement with a powered two-wheeler if this driver does not also have ‘Technical Awareness’ (i.e. motorcycling experience).

There are, to our knowledge, no studies that report a direct link between car drivers’ awareness and acceptance of motorcyclists and involvement in motorcycle crashes.

3.3.2. *Studies with dual drivers*

Although awareness and acceptance do not seem to affect car drivers’ likelihood to crash with motorcycles, there is evidence that car drivers who also have their motorcycle licence (so-called dual drivers) are less likely to collide with motorcycles than car drivers without a motorcycle licence. This was the conclusion in the abovementioned Brooks and Guppy (1990) study, but also a result of the in-depth analysis of the MAIDS data (MAIDS, 2004; 2009) by Magazzù, Cornelli and Marinoni (2006). However, this study does not explain the decreased risk for dual drivers with the suggestion that dual drivers have more awareness or acceptance of motorcycles. According to Magazzù et al. these findings can be explained because dual riders have more knowledge. They know, from their own experience, what behaviour can be expected from their fellow motorcyclists.

In a questionnaire study Crundall et al. (2008a) found that dual drivers have more empathic attitudes and greater understanding of the need to search for motorcyclists, compared to car drivers. They found that drivers with two to ten years of driving experience were less positive about motorcycles than drivers with either less than two years or more than ten years of driving experience, or dual drivers. However, this result does not necessarily imply that car drivers have less empathy for motorcyclists than they have for other car drivers. It is also possible that the drivers with two to ten years of driving experience are more negative in general, perhaps also regarding cars. Crundall and colleagues tried to relate a negative attitude towards motorcyclists with self-reported near-crashes, but could not find a relation.

Although most studies conclude that dual drivers have more awareness for motorcycles than ‘regular’ car drivers, there are also indications that car drivers are more cautious and considerate with motorcycles than with other cars. Crundall and colleagues (2012) found that novice, experienced *and* dual drivers gave greater caution to conflicting motorcycles than to conflicting cars in the videos that they were asked to watch. Both the percentage of safe responses as well as the response time (to pull out onto the intersection after the conflicting vehicle had reached the safe point) reflected a greater safety margin in response to motorcycles. Of the three groups, the dual drivers made the safest responses and the novice drivers made the most unsafe responses. In any case, the results do indicate that drivers do take the vulnerability of the motorcycle (compared to a car) into account.

Another study by the same group of researchers (Shahar et al., 2012) also indicated that drivers pay more attention to motorcyclists than to car drivers. In this study, lane changing was studied using video clips from a moving car including footage from the rear view mirror and right-side mirror[3]. Participants had to notice whether there was traffic from behind that was about to overtake; this could either be a car or a motorcycle. The results indicated that conflicting motorcycles received more attention than conflicting cars. According to the authors this was to be expected because motorcycles are less salient, therefore harder to process and require longer processing. The results could, however, also indicate that, once a motorcycle is perceived, a car driver takes the vulnerability and movability into account. Furthermore, this study found that dual drivers paid more attention to motorcycles than experienced or novice drivers (without a motorcycle licence).

3.3.3. *Conclusions awareness and acceptance*

In summary, these studies on awareness and acceptance suggest that car drivers are aware of the vulnerability of motorcyclists. However, car drivers who also own a motorcycle licence (dual drivers) respond even better to other motorcycles. This is probably not because they have more awareness (or empathy) for motorcycles, but simply because they have more knowledge. They know better than 'regular' car drivers which behaviours or manoeuvres can be expected from motorcycles; or which difficulties and challenges motorcyclists are faced with when riding their bicycle. It is also possible that the differences between dual drivers and 'regular' car drivers can be explained by a difference in general riding/driving experience or by a different interest in motorized vehicles. The fact that dual drivers hold more than one type of licence could imply that they simply drive and/or ride more, and enjoy doing so.

3.4. **Conclusions**

This chapter dealt with the role of the car driver in crashes with motorcycles, and specifically tried to answer the third research question:

RQ 3 What is the role of car drivers' expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?

The theory of visual attention and expectation provides evidence that the perception of motorcycles is not only dependent on conspicuity of motorcycles, but that car drivers also play an important role in perception and information processing. Perception is influenced by what people expect or even anticipate in situations. It is not hard to imagine that car drivers do not expect motorcycles on the road; most of the time there isn't one. This effect is even greater in winter because there are even fewer motorcycles on the road. There are, however, no indications that this increases the relative risk for motorcycles; there is no increased risk in the winter or springtime when motorcycles are least expected by car drivers.

There is little evidence that awareness and acceptance have an effect on the risks of car drivers to collide with motorcycles. The often referred to research finding that car drivers, who have family members or friends who ride a

[3] Because this study was conducted in Britain, where drivers drive on the left side of the road, this footage would be comparable to the left-side mirror in a Dutch driving scene.

motorcycle (and therefore have a greater awareness), have fewer crashes with motorcycles can actually not be found in the referenced article. However, there are some difference between so-called dual drivers and ‘regular’ car drivers. Dual drivers are less often involved in crashes with motorcycles. This can, however, also be explained by their increased knowledge of motorcycles rather than by increased awareness. Dual drivers know, from their own experience, what behaviour can be expected from ‘their fellow’ motorcyclists. It is even possible that the difference between dual drivers and 'regular' car drivers is caused by a difference in general riding/driving experience. The fact that dual drivers hold more than one type of licence could imply that this group is far more experienced in traffic (regardless of mode of transportation). In addition, dual drivers could have different motives for transportation. Where car drivers are predominantly people who use the car to commute, motorcycle and dual drivers are probably more motivated by the pleasure of riding.

Finally, there is evidence that car drivers do acknowledge the vulnerable, specific characteristics of motorcycles. Simulation studies indicate that drivers are more careful towards conflicting motorcycles than towards conflicting cars in the videos that they were asked to watch. Dual drivers give the safest response and the novice drivers the most unsafe. But the results do indicate that drivers do take the vulnerability of the motorcycle into account.

When discussing expectation and awareness, and possibly also ways to increase expectation and awareness of motorcycles, it is important to realize that people (car drivers) have selective attention for a reason. It is the only way we can function in an ever changing environment. If we were to have equal attention for everything that is coming at us during a trip, we wouldn’t be able to drive a car or ride a motorcycle at all. The focus of our attention is influenced by experience; what works best or what was most efficient or important in the past will determine what we will look for in the future. Therefore, it is extremely difficult to change expectation or increase awareness for motorcycles if the environment in which drivers use their cars remains the same.

4. Crash analysis

The literature review has found many theories on how and why the perception of motorcycles by car drivers can fail. From the literature review it seems plausible that car drivers indeed fail to yield to motorcyclists relatively often. But is this also apparent in the crash records? To answer this question Dutch crash data was analysed; more specifically those crashes were studied in which motorcycles were not given priority when they had right-of-way. Analysis of crash data does not allow reconstruction of why a driver failed to yield, nor can it indicate that this was because of lacking conspicuity of the motorcycle. However, we assume that the majority of the road users want to give priority to other road users; and when they fail to do so this is involuntary. Therefore we assume that the difference between priority given to cars and motorcycles is predominantly caused by differences in appearance of these vehicles.

This chapter attempts to answer this first research question using Dutch crash data:

RQ 1 Do car drivers indeed fail to yield to motorcyclists relatively often?

As discussed in Chapter 1, from the motorcycle perspective this seems to be the case: the most common type of conflict in which a motorcycle is involved is a collision between a motorcycle and a car. However, this is not entirely unexpected. The motorcyclist shares the road primarily with car drivers, and there simply are so many cars on the road. To put it bluntly, if a motorcyclist crashes, the risk is a higher that he/she will collide with a car rather than, for example, a tractor.

This chapter tries to unravel if – adjusted for traffic participation - motorcyclists indeed have more conflicts with cars than with other road users. Two approaches were used. First, *Section 4.2* describes how the number of crashes per conflict type was adjusted for exposure. Two different measures of exposure are used for this purpose: distance travelled and the number of registered vehicles. In the second approach (*Section 4.3*) we compare the causes of crashes (e.g. failing to give priority, speeding, etc.) between different crash types (motorcycle-motorcycle or car-motorcycle). The chapter will sum up the findings from the crash records with the conclusions in *Section 4.4*. Before we explain and discuss the results of the crash analyses it is important to discuss the limitations of the crash data that is available (*Section 4.1*).

4.1. Considerations about the crash and mobility data

4.1.1. *Casualty registration rate*

The analyses in this chapter are based on the *police registered* crashes with at least one serious injury[4] during the period 2000-2009. It is important to realise that the number of reported crashes, and thus the number of

[4]With the exception of *Table 4.2* where more data was needed and crashes with slight injuries or property damage only were included.

casualties in these crashes, are not the same as the actual number of crashes or casualties. The number of road fatalities in the Netherlands is determined by Statistics Netherlands (CBS) in cooperation with the Ministry of Infrastructure and the Environment (IenM). This is done on the basis of three sources: 1) the so called B-forms (cause of death records reported in the case of any death), 2) files of the district prosecutor's office, and 3) the Road Crash Registration (BRON). The number of serious road injuries is estimated by linking two data files: BRON and the National Medical Registration (LMR). The injury severity according to the Maximum Abbreviated Injury Scale (MAIS), as given in the corresponding medical record is used to identify serious injuries. A serious injury is defined as an injury with a minimum score of MAIS 2. By linking these data sources CBS and IenM estimate the 'real' number of serious road injuries.

The severity of a crash is defined by the most serious injury of one of the persons involved, so a serious injury crash is a crash with at least one casualty being seriously injured, but without a fatality. The BRON-registration rate is defined as the number of casualties with a MAIS score between 2 and 6 registered in BRON, divided by the estimated ('real') number of serious road injuries[5]. The registration rates in BRON strongly differ for different injury severities but also for the involvement of a motor vehicle and even for the different traffic modes of the casualty. *Figure 4.1* shows the registration rate in BRON for all fatalities and serious road injuries (all casualties in crashes with at least one motor vehicle), and for motorcycle and car casualties separately. The registration rate in BRON has been decreasing over the years, especially for serious road injuries. For fatalities, the registration rate in BRON is still over 90% whereas for serious road injuries among motorcyclists, the registration rate in BRON dropped from about 60% in 2000 to 35 % in 2009. In other words, in 2009 the majority of seriously injured motorcyclists are not registered in BRON.

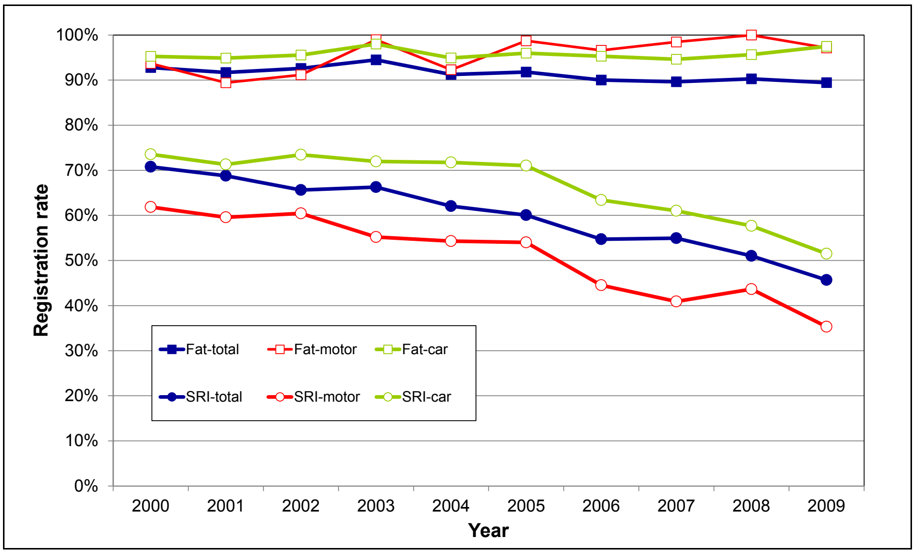

Figure 4.1. *Registration rate in BRON for fatalities and serious road injuries in the period 2000-2009 (Fat=fatalities, SRI=serious road injuries, involving at least one motor vehicle). Sources: CBS, IenM and DHD.*

[5] Note that the method used to estimate the 'real' number of fatalities and serious road injuries only results in a registration rate of the number of *casualties*. For the number of crashes, which are analysed in this chapter, no registration rate is available.

For the crash analyses in this report it was not possible to use the estimated ('real') number of serious road injuries, because we needed information on the first and second collider and on the primary crash cause. Therefore we had to resort to the BRON database, with its imperfect registration.

The registration rate may have a major influence on the results, especially in the first approach (*Section 4.2*) where we compare different conflict types in which motorcycles are involved. It is known that the registration rate in BRON for single vehicle crashes is lower than for multiple vehicle crashes. As a result, the proportion of single vehicle crashes is underestimated. In the second approach (*Section 4.3*), the relative occurrences of different crash types at intersections are compared. This analysis is probably less influenced by a lower registration rate.

4.1.2. *First and second collider*

The analyses in this chapter use information about the first and second collider in a crash as available from the BRON registration. The first collider is the one who, *according to the police* is probably the one who caused the crash. It is extremely important to realise that this is the opinion of the policeman who dealt with the crash and recorded it. This is not always the person who indeed caused the crash. It is possible that, after more research the (legal) responsibility is changed to the other crash partner. This is not changed in the record containing the first and second collider in the police records though. In addition, we know, for example, that there is a tendency to report a motorized vehicle as the first collider rather than a non-motorized vehicle, because of its vulnerability. In 2001, a law was abolished that slow traffic (i.e. bicycles and mopeds) should give way to motorized traffic at junctions without any designated priorities.

Keeping in mind that the assignment of first and second collider is purely the opinion of the policeman on the scene, we still find that this information can be used for the purpose of these analyses.

4.1.3. *Crash causes*

Similar to the first and second collider issue, is the issue of the recorded crash cause, which is also the opinion of the policeman recording the crash. Although we know that most crashes have more than one cause, the cause registered in BRON is the cause that is reported for the first collider. There is a tendency to report certain crash causes more than others, especially those that are more judicially oriented and can be proven more easily. For example: car driver A is speeding, and because of this car driver B does not expect car driver A at an intersection and fails to give priority. One could argue that the speeding actually caused the crash; nonetheless 'failing to give priority' will probably be recorded in the police records because this conclusion is more straightforward and easy to establish.

The issue of multiple causes was recognised and implemented into the BRON registration in 2004 and records from earlier years were converted. Up to 3 causes from a predefined list are scored. The ordering of the causes in this list determines which one will become the primary cause. As a second or third cause is only recorded in 6% of the crashes, this does not have a large effect on the distribution of causes. Although the number of crashes with speeding being one of the causes increases with 50% by taking the second cause into account, this still is a small fraction of all crashes (1.2% increased to 1.9%[6]).

In the analyses we only study *relative* occurrence of crash causes for certain conflict types, i.e. we compare the relative occurrence of failing to give way within motorcycle-car crashes with the occurrence of the cause within car-car crashes. We therefore assume that the preference for a certain causation type does not influence the conclusions of our analysis.

4.1.4. *Mileage*

In order to adjust for traffic participation we use estimations of the annual mileage. Data on the mobility of individuals is collected with a survey of Dutch households, see for more information (SWOV, 2010b). Unfortunately, due to the lower number of motorcyclists in the survey, many more car trips are reported than motorcycle trips. For example, in 2009 over 40,000 car trips were reported compared to less than 300 motorcycle trips. As a result the estimation of the distance travelled by car drivers is much more reliable than the mobility estimate for motorcycle riders. This is important to realize when interpreting the results.

4.2. **Analysis of crash opponents of motorcyclists**

Almost half of the registered crashes in which motorcyclists are involved are crashes with cars. But cars are also the most common road user. Are motorcyclists often involved in crashes with cars, simply because there are so many of them? This section presents a method that could answer this question. To analyse whether motorcycles are relatively more often involved in crashes with cars we needed to correct the number of crashes with some kind of exposure measure. In this way, instead of the absolute number of crashes, the 'risk' of getting involved in a crash, when meeting a certain opponent is calculated. Unfortunately, the limitations of the data (see previous section) restrain us from drawing firm conclusions.

Figure 4.2 shows all crashes (registered in BRON) in the Netherlands with fatal or serious injury in the period 2000-2009 in which at least one motorcycle was involved[7]. In this period over 6,500 crashes involving at least one motorcycle were registered in BRON. About one third of these crashes were single vehicle crashes. However, the registration rate in BRON of single vehicle crashes is expected to be lower than the rate for multiple vehicle crashes. Since on average the registration rate in BRON for seriously injured motorcyclists is only about 50%, this proportion of single vehicle crashes will probably be an underestimation. The crashes involving more than one vehicle are divided in subgroups according to the motorcycle being the first or second collider of the crash according to the police registration in BRON. This information gives an indication of which crash partner was (primarily) responsible for the crash. In about one third of the crashes with multiple colliders, the motorcycle was registered as the first

[6] Based on BRON registered crashes with killed or seriously injured in the Netherlands in the period 2000-2009
[7] In these crashes at least one person is killed or seriously injured, but this is not necessarily the motorcyclist

collider, in about two third of the crashes as the second collider. In the majority of the multiple vehicle crashes, a motorcyclist crashed with a car, the motorcycle being the first or second collider.

In order to calculate the 'risk' of involvement with certain crash partners, for each subgroup the number of casualties was adjusted for the exposure measure of the opponent of the motorcyclists. Two kinds of exposure measures were used: the distance travelled and the fleet size. The bottom boxes show the adjusted numbers of registered crashes with the motorcycle indicated *as first collider*. These boxes show that when the motorcyclist (MC) is registered as first collider, there are more crashes with a car (CD) as second collider (MC→CD: n=967) than other motorcycles (MC→MC: n =145). However, when adjusted for exposure, this difference between a car and motorcycle as second collider seems to shift towards relatively more MC→MC crashes than MC→CD crashes.

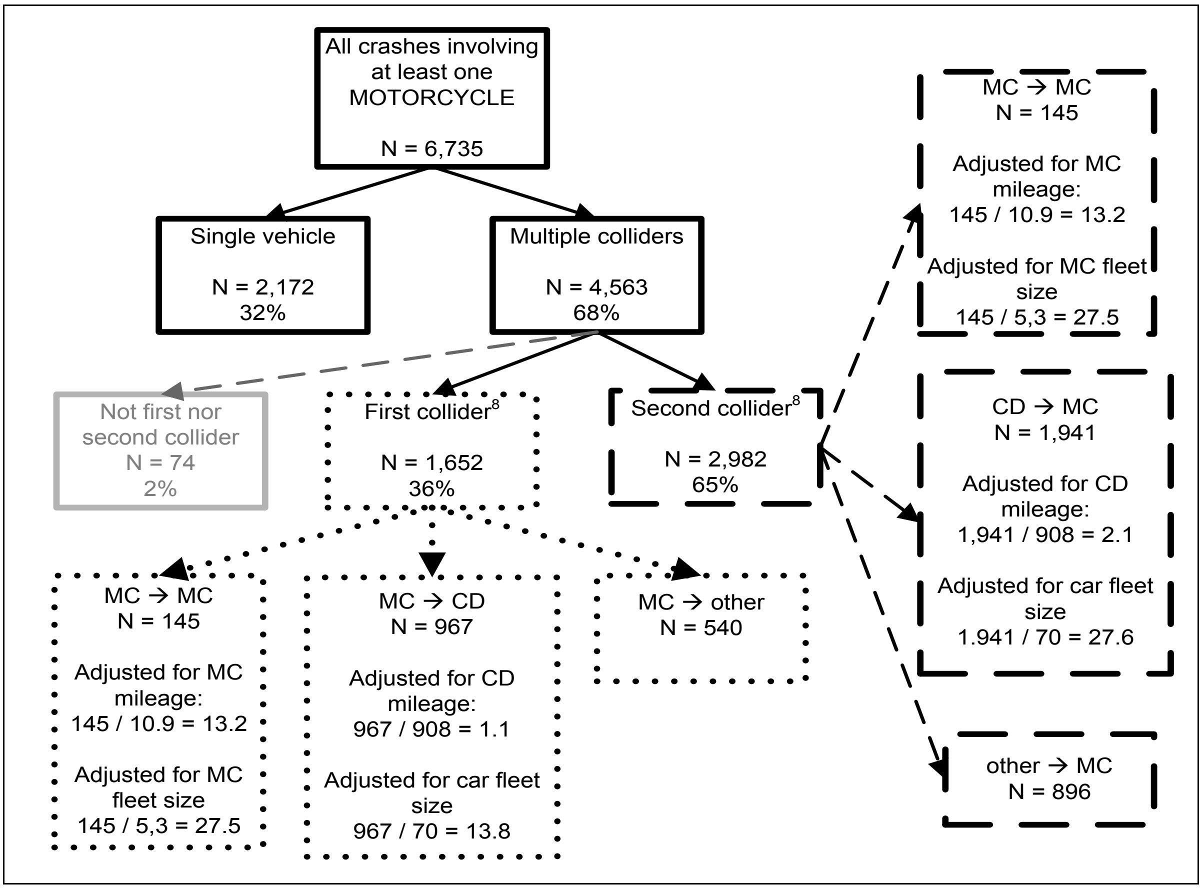

Figure 4.2. *Number of crashes in which at least one motorcycle is involved in the period 2000-2009, including distribution over type of crash (i.e, reported first and second collider)*[8]. *NB: mileage in billion km, fleet size in millions, totals over the period 2000-2009, Source: BRON.*

The boxes on the right-hand side show the adjusted numbers of registered crashes where the motorcycle was indicated *as second collider*. Within these crashes, the number of car drivers being the first collider is much higher

[8] *the motorcycle-motorcycle crashes (MC - MC crashes) are included in the "first collider" crashes as well as the "second collider" crashes; this explains why these percentages do not add up*

(CD→MC: n =1,914) than the number of other motorcyclists (MC→MC: n =145). However, when adjusted for exposure, there is no evidence that *car drivers* are involved in crashes with motorcycles more frequently than other *motorcyclists*.

Assuming that the registered crashes are representative for all crashes, this would indicate that – when adjusted for exposure - car drivers do not crash more often with motorcyclists than motorcyclists do with other motorcyclists. However, there are some issues that make it impossible to draw such strong conclusions from *Figure 4.2*. The most prominent expected influence on the results is the registration rate in BRON. The registration rate in BRON for fatalities is above 90%, so the non-registered fatalities will not make a big difference to the analysis presented above. However, because there are more seriously injured casualties than fatalities, the analysis is probably dominated by the number of serious road injuries. The registration rate of serious road injuries is much lower. For motorcyclists the registration rate in BRON of serious road injuries in 2009 is only 35%. This means that for about two thirds of the serious road injuries among motorcyclists in 2009, no information is available in BRON. It is possible that for the non-registered casualties (and/or for crashes) the distribution over conflict types is quite different than for the registered cases. This can have a large effect on the results presented in *Figure 4.2*.

In BRON there is a large difference in the registration rates of fatalities and serious road injuries. So, if the ratio of fatalities and serious road injuries is different for the different conflict types, this can have an impact on the number of crashes and relative crash rates and therefore on the comparison of the types of conflict. Also, the registration rate of serious road injuries has decreased with about 25% in the last decade. This results in a higher impact of crashes in the first part of the analysed period.

To calculate the relative crash risk, we used the number of crashes adjusted for the distance travelled as well as for the fleet size. Both versions have their own shortcomings as exposure measure for the number of possible collisions, some of which have already been discussed in *Section 4.1*. The data on the distance travelled, for example, is from a survey which annually reports a much smaller number of trips for motorcyclists than for car drivers. These figures are therefore less reliable. The disadvantage of using fleet size information is the difference in distance travelled per vehicle for cars and motorcycles. On average, cars travel a greater annual distance than motorcycles. Therefore the relative risk for cars is underestimated compared to motorcycles. However, motorcyclists may ride in groups relatively[9] often. Hence, they have a relative higher chance to 'encounter' another motorcycle, which could account for an effect in the opposite direction.

To conclude, although there are many limitations on the data used in our analysis, these are all *possible* biases that create uncertainty, but not necessarily false results. We believe that, despite all limitations, this crash analysis indicates that car drivers do not crash more often with motorcyclists than motorcyclists do with other motorcyclists.

[9] As understood from personal communication with motorcycle interest groups

4.3. **Analysis of primary crash cause at intersections**

In the second approach we analysed crashes at *intersections* in which someone was killed or seriously injured in the period 2000-2009. This is a sub-sample of all crashes in *Figure 4.2*, supplemented with car-car crashes at intersections. The police records describe several different crash causes, such as red light running, speeding, cutting off, etcetera. There are two types of priority crash causes: these are 1) failing to give *priority*, and 2) failing to give *way*. The first crash cause describes the situation where the motorcycle approaches an intersection and has priority (because he/she approaches from the right, or drives on a priority road), but the driver fails to give priority (see *Figure 4.3* for an example of this Scenario 1). Failing to give way describes a situation where a car driver is making a manoeuvre (taking a left turn) and fails to give way to traffic approaching on the same road (see *Figure 4.3,* Scenario 2). The scenarios depicted in *Figure 4.3* are examples of the most common occurrence of these two crash causes; in reality there are many different scenarios in which a driver can fail to give priority (for example, the motorcycle could also be approaching from the left on a priority road) or fail to give way. It is important to remember that in all situations the motorcycle had priority or right of way.

This analysis focuses on a comparison of the relative occurrence of failing to give priority and failing to give way within car-motorcycle crashes and within car-car crashes.

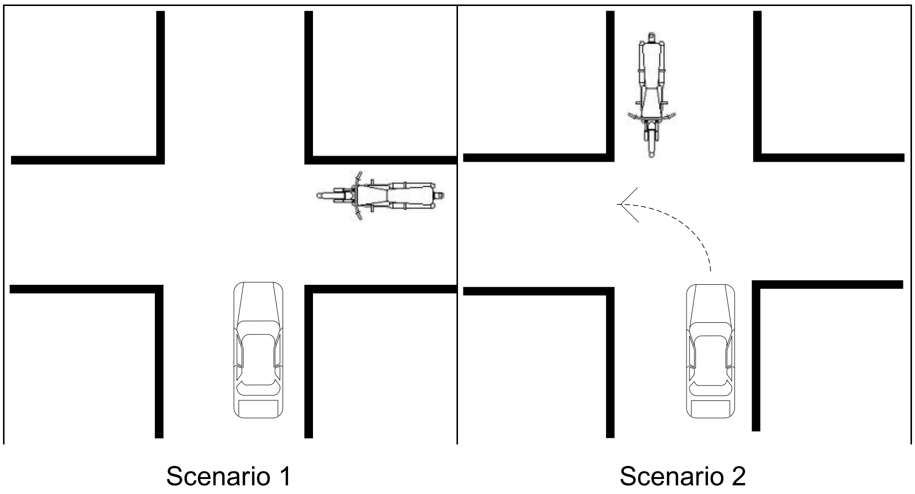

Figure 4.3. *Typical crash scenarios where the car driver fails to give priority (Scenario 1) or to give way (Scenario 2) to a motorcycle.*

Because there are many more cars in traffic, *Table 4.1* shows the absolute number as well as the *proportion* of each registered crash cause. So, for example, the first column indicates that in 9% of the crashes with two motorcycles (MC → MC) registered in BRON the motorcycle failed to give priority (Scenario 1), in 9% the motorcycle failed to give way (Scenario 2), in 67% the motorcycle kept insufficient distance, etcetera. So, the majority of motorcycle-motorcycle crashes reported in BRON are registered by the police as being caused by insufficient distance.

Primary crash cause	MC → MC		MC → CD		CD → MC		CD → CD	
	N	%	N	%	N	%	N	%
Failed to give priority (Scenario 1)	4	9%	89	24%	657	**56%**	1,898	**56%**
Failed to give way (Scenario 2)	4	9%	17	5%	372	**32%**	439	**13%**
Insufficient distance	31	67%	63	17%	18	2%	321	9%
Cutting off	2	4%	69	19%	16	1%	47	1%
Red light running	0	0%	28	8%	56	5%	406	12%
Speeding	0	0%	8	2%	0	0%	13	0%
Other	5	11%	98	26%	51	4%	277	8%
Total number of crashes	46	100%	359	100%	1,259	100%	7,412	100%

Table 4.1. *Number and proportion of primary crash causes in crashes with fatalities and/or serious road injuries registered in BRON over the period 2000-2009.*

Before going into what *Table 4.1* can tell us about motorcycle conspicuity, we first need to make some more general remarks on the results. First, it is remarkable that speeding is recorded as a cause in so little of the crashes. Especially since we know that speed is one of the basic risk factors in traffic (Wegman & Aarts, 2006; SWOV, 2009). This can be explained by what was already mentioned in *Section 4.1.3*: not all crash causes are equally likely to be recorded as the main crash cause. Speeding is difficult to prove and often coincides with another offence (e.g. red light running, failure to yield, etc.), which is easier to prove. This would explain why speeding is relatively rarely recorded as the main crash cause. A second important crash cause is insufficient distance in crashes with two or more motorcycles (67% of the motorcycle-motorcycle crashes). These are probably crashes in which motorcyclists were riding in groups[10]. Because motorcyclists relatively often ride in groups, these types of crashes also occur relatively often.

For this analysis the last columns of *Table 4.1*, and the percentages in bold, are the most interesting. When the car driver is registered as the first collider (i.e. according to a police officer caused the crash), in 56% of the cases failure to give priority (Scenario 1) is the cause of a crash with a motorcycle. The proportion is similar in car-car crashes. This similarity indicates that for car drivers giving priority (Scenario 1) is not more difficult when the opponent is a motorcycle than when the opponent is a car. However, for Scenario 2 there is a difference between car-motorcycle crashes and crashes with two cars. When the oncoming vehicle is another car this was the primary cause in 13% of the crashes, whereas it is 32% when the oncoming vehicle was a motorcycle. This suggests that car drivers have relatively more problems with giving way to a motorcycle than to another car in Scenario 2.

Could this difference be explained by a difference in conspicuity? The difference between Scenarios 1 and 2 is the view on the motorcyclist as the

[10] As understood from personal communication with motorcycle interest groups.

car driver and motorcycle approach the intersection. In the first scenario, when approaching an intersection, the car driver views the (also approaching) motorcycle from a perpendicular angle. In Scenario 2 the car driver only sees the front-view of the motorcycle. From the side the conspicuity of a motorcycle and a car is more comparable than the front-view of these vehicles. In addition, in Scenario 1, the car driver has more information of the speed of the approaching motorcycle. In this scenario the motorcycle moves in the view field (and the image moves on the retina) to provide information about speed. In Scenario 2, the only information about the speed of the motorcycle can be obtained from the increasing size of the image (an object far away is seen as a small dot, as it approaches this dot increases slightly in size).

One of the aims of this report is to assess whether the failure to give priority (or to give way) is caused by lack of conspicuity and/or by a lack of awareness by the car driver. Unfortunately, the police records (*Table 4.1*) cannot tell us anything about *why* the road users failed to give way. To get an idea if there is a difference we analysed if car drivers who also have their motorcycle licence (so called dual drivers) have less problems to give way than car drivers who never ride a motorcycle. As was already concluded in the previous chapter, we assume that dual drivers have more knowledge about and better expectancy for motorcycles. *Table 4.2* shows the percentage of failing to give way and failing to give priority for dual drivers and car drivers. In contrast with the previous analyses in this chapter, *Table 4.2.* includes crashes with slight injury or property damage only. This was necessary since information on the driving licence is available only for the period 2006-2009; and without slight injury or property damage there would not be enough crashes for meaningful comparisons. We should, however, keep in mind that the registration rate in BRON decreases when the seriousness of the crash decreases, and this increases the uncertainty of the results.

Primary crash cause	Dual CD – MC		CD – MC		Driving licence unknown		Total
	N	%	N	%	N	%	N
Fail to give priority (Scenario 1)	40	47%	1,168	50%	68		1,276
Fail to give way (Scenario 2)	14	16%	613	26%	28		655
Other	31	36%	549	24%	70		650
Total	85	100%	2,330	100%	166		2,581

Table 4.2*. Driving licence category of the car drivers in CD – MC crashes over the period 2006 – 2009 (including crashes with property damage only). Source: BRON.*

Table 4.2 shows a trend which is in line with the conclusions from *Table 4.1*; there seems to be a “motorcycle-specific” problem for failures to give way (Scenario 2); and not so much for failing to give priority. Dual drivers have relatively the same amount of failures to give priority as regular car drivers (resp. 47% and 50% of the crash causes). However, dual drivers do cause fewer crashes (16%) due to failure to give way on the same road, compared to regular drivers (26%). An explanation of these results could be that dual riders have less difficulty perceiving an oncoming motorcycle than regular car drivers. These results seem to indicate that awareness, or at least knowledge about motorcycles and motorcyclists' behaviour play a role in conspicuity-related crashes.

4.4. Conclusion

In this chapter two types of analysis of motorcycle crashes were presented using Dutch crash data. The first method focuses on the conflict type and the question whether the car is the opponent in a motorcycle crash relatively more often than other road users. The second method studies the cause of crashes at intersections to analyse if conspicuity may play a role.

The results of both analyses have their shortcomings because of data limitations (see *Section 4.1*). All analyses could only be performed on the registered crashes. However, the information in the BRON database is less than perfect. The registration rate as well as the quality of the data is limited. For example, the registration rate of serious road injuries among motorcyclists in 2009 is only about 35%. This means that for almost two thirds of the motorcycle casualties no information is available. We do not know if the distribution of the conflict type of the registered cases is sufficiently similar to the true distribution. The registration rate for fatalities is much higher than for serious road injuries. Therefore, a different ratio in type of casualties in different conflict types can influence the results. Furthermore, all data is based on the opinions of individual police officers. This is especially important in the second analysis, but also in the registration of first and second collider. In theory, the first collider is the one who caused the crash. This, however, is not always easy to determine which may introduce arbitrariness. In all, the results of both analyses have to be interpreted very carefully and no firm conclusions can be drawn.

The first analysis tries to answer the question whether cars are overrepresented as the opponent in motorcycle crashes (*Section 4.2*). In the majority of motorcycle crashes, a car is registered as crash opponent. However, cars also dominate traffic. Therefore, we adjusted the number of casualties by traffic exposure. Two types of exposure were used, the distance travelled and the fleet size. These relative risks show no evidence of overrepresentation of cars in crashes with motorcyclists.

In addition to the limitations of the casualty data described above, both measures of exposure have their limitations as being representative in the "exposure to crashes" of motorcyclists. Data on the distance travelled is based on a survey, in which the reported number of motorcyclists' trips is relatively small. Therefore the uncertainty of the distance travelled by motorcyclists is large compared to that travelled by car drivers. Since it is possible that motorcyclists relatively often ride in groups, the probability of meeting other motorcyclists might be greater than the number of casualties adjusted for the distance travelled indicates. In general, the annual distance per car is larger than the annual distance per motorcycle. This must be taken into account when comparing the relative risk in motorcycle-motorcycle crashes and motorcycle-car crashes.

The analyses of crash *causes* at intersections (*Section 2.3*) indicate that there is a difference between two priority situations. When the opponent, car or motorcycle, of a car driver approaches the intersection from a perpendicular angle (Scenario 1 in *Figure 4.3*), failure to give priority is the cause in about 56% of the cases. This indicates that when car drivers fail to give priority, there does not seems to be much difference whether the other collider is a car or a motorcycle. However, there is a difference for failing to give way (Scenario 2 in *Figure 4.3*) between car-motorcycle and car-car crashes. When the oncoming vehicle is another car (car-car crash), “failing to give way” was registered as the primary crash cause relatively less often than when the oncoming vehicle was a motorcycle (car-motorcycle crash).

From the data we cannot determine if this is due to the motorcycle being less conspicuous. However, it does make sense to assume a conspicuity-related explanation because of the difference between priority Scenario 1 and 2. Especially when a vehicle is approaching on the same road, a motorcycle (with a relatively small front view) is more easily overlooked than a car. Furthermore, when a vehicle is approaching an intersection from a perpendicular angle, the car driver has more information about the speed of the approaching vehicle. The vehicle moves in the view field (and the image moves on the retina) to provide information about speed. In priority Scenario 2, the only information available regarding the speed of an oncoming vehicle is the increasing size of the image (an object far away is seen as a small dot, as it approaches this dot increases in size). Because the front view of a motorcycle is smaller than that of a car, there is relatively less information about the speed of the approaching motorcycle. In addition, the manoeuvre of making a left turn and having to give priority to oncoming traffic is in itself a difficult manoeuvre. For example, older drivers experience relatively more difficulty with this manoeuvre than with other manoeuvres (Davidse, 2007).

It is difficult to indisputably determine whether lack of conspicuity of the motorcycle explains these results; this kind of information is not directly available in the police records. It is even more difficult to conclude whether motorcycles do not get priority because they are simply less visible or because car drivers have no awareness or expectancy of motorcycles. However, by subdividing the car drivers into a group of car drivers with also a motorcycle licence (i.e. dual drivers) and a group of regular car drivers (without motorcycle licence), we attempted to learn more about the role of awareness and expectancy. For this analysis, we had to use data on all crashes including crashes with property damage only. The results of this division showed that dual drivers have relatively the same amount of failures to give priority as regular car drivers (resp. 47% and 50% of the crash causes). However, dual drivers do cause considerably fewer crashes (16%) due to failure to give way on the same road than regular drivers (26%). An explanation of these results could be that dual riders have less difficulty perceiving an oncoming motorcycle than regular car drivers. These results suggest that awareness of, or at least knowledge about motorcycles and motorcyclists’ behaviour play a role in crashes where the motorcycle approaches the intersection from the opposite direction. When the motorcycle approaches from a perpendicular angle there is no difference in perception between dual drivers and regular car drivers.

5. Conclusions and measures

An important cause of crashes involving motorcyclists is a car driver failing to give priority. According to the European MAIDS study (2004; 2009) this is mainly due to the car driver failing to notice the motorcyclist.

In order to develop measures to improve conspicuity of motorcycles and their riders it is important to know the main cause why car drivers fail to notice them. The introduction in *Chapter 1* presented an information processing model for the perception of motorcycles. Based on this model, the following research questions were formulated:

RQ 1 Do car drivers indeed fail to yield to motorcyclists relatively often?
RQ 2 What is the role of motorcycle conspicuity (colour, size, brightness, etc.) in motorcycle crashes?
RQ 3 What is the role of car drivers' expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?
RQ 4 What is the role of motorcyclists' behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?
RQ 5 On what problems should measures be focussed to reduce conspicuity-related motorcycle crashes?

This chapter will first sum up the conclusions for research question 1 to 4. After this, a separate section will discuss some measures (research question 5). Finally, this chapter will conclude with some suggestions for future research necessary to answer remaining questions on the conspicuity of motorcycles.

5.1. Research questions

5.1.1. *RQ 1. Do car drivers indeed fail to yield to motorcyclists relatively often?*

It is clear that, from the point of view of the motorcycle, many crashes are caused because car drivers fail to give them priority. However, there are relatively many cars on the road. Therefore, to determine if this was still the case – relatively speaking – the number of crashes was adjusted with two measures for exposure to provide a more valid estimation of car-motorcycle crashes. Assuming that the registered crashes are representative for all crashes, our analysis indicates that – when adjusted for exposure - car drivers do not crash more often with motorcycles than motorcyclists do with other motorcyclists (*Section 4.2*). There is, in other words, no indication that specifically car drivers have conflicts with motorcyclists.

The analysis of crash causes at intersections (*Section 4.3*) indicates that motorcycles were not given priority (Scenario 1 in *Figure 4.3*) just as often as cars, when looking at the *proportion* of crash causes. In these situations, when the opponent of a car driver is approaching the intersection from a perpendicular angle, it does not seem to make much difference whether the opponent is a car or a motorcycle. However, there is a difference between car-motorcycle and car-car crashes for failing to give way (Scenario 2 in *Figure 4.3*). When the oncoming vehicle is another car, failing to give way was registered as the primary cause less often than when the oncoming vehicle was a motorcycle. This result indicates a “motorcycle-specific” problem when a car driver wants to make a left turn and a motorcycle approaches the intersection. The information on driving licence categories implies that failing to give way to a motorcycle is less often registered for car drivers who also have a motorcycle licence (dual drivers) than for ‘regular’ car drivers.

To conclude, in absolute numbers, the majority of motorcycle crashes are crashes in which a car is involved (*Figure 4.2*). In these crashes the car driver is more often recorded as first offender by the police officer than the motorcyclist. However, when adjusted for exposure, car drivers do not crash more often with motorcycles than motorcyclists do with other motorcyclists. And relatively, considering the different crash causes, car drivers do not fail to give priority to a motorcycle more often than to a car (*Table 4.1*). Only when the motorcycle is approaching the intersection from the opposite direction when a car driver wants to make a left turn, this motorcycle is not given priority more often than a car is given under the same circumstances.

5.1.2. *RQ 2. What is the role of motorcycle conspicuity (colour, size, brightness, etc.) in conspicuity-related motorcycle crashes?*

From the theories on perception, saliency and conspicuity there are many indications that motorcycles are less visible in traffic (*Sections 2.1* and *2.2*). Especially depth and speed perception are more difficult in relation with motorcycles because of their small size (specifically from the front view) compared to that of a car. In this respect, the direction of movement is an interesting issue. If the motorcycle moves along the same line, but in the opposite direction of the car, the change in size of the motorcycle is the only cue to movement for the observer. Because the front view of a motorcycle is relatively small the change in size of the motorcycle provides relatively little information about movement. If, however, the motorcycle moves in a direction perpendicular to the direction of the car, the change in the visual field of the car driver is quite large. This effect is consistent with the crash analysis, which indicated that car drivers fail to give way relatively more often when a motorcycle approaches them from the front than when the motorcycle approaches from a perpendicular direction.

Literature that studied conspicuity of motorcycles directly, report less straightforward effects of inferior conspicuity than expected (*Section 2.3*). Research indicates that conspicuity of motorcycles can be improved with clothing and the colour of a helmet, at least to some extent. However, research also suggests that the most important aspect of motorcycle conspicuity is contrast with the environment. In some situations (e.g. very dense traffic) light coloured clothing improves conspicuity. In other situations (rural, open-space area) dark clothing seems to be better, while at night reflective clothing improves conspicuity.

To conclude, theoretically there are many reasons for motorcycles being less conspicuous in traffic. In addition, studies that examined motorcycle conspicuity directly indicate that changing the appearance of a motorcycle and/or its rider does affect detection in traffic and even crash liability. However, there is no clear indication of which appearance is best for conspicuity in all circumstances.

5.1.3. *RQ 3. What is the role of car drivers' expectancy, awareness and acceptance of motorcyclists in conspicuity-related motorcycle crashes?*

The theory of visual attention and expectancy provides evidence that car drivers play an important role in the perception of motorcycles (*Sections 3.1* and *3.2*). Perception is influenced by what people expect or even anticipate in situations. In the Netherlands there are relatively few motorcycles on the road compared to cars. So it is understandable that car drivers do not always expect a motorcycle on the road or at an intersection; most of the time there will not be one. Furthermore, there are many 'seasonal' riders in the Netherlands who only ride their motorcycles in the summer. This decreases the expectation of car drivers to encounter motorcycles in traffic. Although there are no indications that this increases the relative risk for motorcycles; there is no increased risk in the winter or springtime when motorcycles should be least expected by car drivers.

There is less evidence that car drivers' awareness and acceptance have an effect on motorcycle conspicuity (*Section 3.3*). The often referred to research finding that car drivers who have family members or friends who ride a motorcycle (and who therefore have more awareness) have fewer crashes with motorcycles was not found in the cited reference. There is even evidence that car drivers do acknowledge the vulnerable, specific characteristics of motorcycles. Simulation studies indicate that drivers gave greater caution to conflicting motorcycles than to conflicting cars in the videos that they were asked to watch; dual drivers (car drivers who also hold a motorcycle licence) display the safest response and novice drivers gave the most unsafe response (but still safer than with conflicting cars). However, the results indicate that car drivers take the greater vulnerability of the motorcycle (compared to a car) into account when interacting with a motorcycle in a simulated traffic environment.

There are some indications that dual drivers are less frequently involved in crashes with other motorcycles. This can, however, also be explained by their increased *knowledge* of motorcycles rather than by increased *awareness*. Dual drivers know, from their own experience, what behaviour can be expected from 'their fellow' motorcyclists. It is even possible that the difference between dual drivers and 'regular' car drivers is caused by a difference in general riding/driving experience. The fact that dual drivers hold more than one type of licence could imply that this group is far more experienced on the road (regardless of mode of transportation).

To conclude, there are indications that low expectancy for motorcycles plays a role in conspicuity-related crashes. The theory suggests that when car drivers expect motorcycles on the road they will perceive them more easily. There are, however, no indications that car drivers have less 'awareness' for motorcycles, in the sense that they don't care much for motorcycles. There are even indications that car drivers are more cautious when interacting with a motorcycle than with a car. Studies with dual drivers suggest that having more knowledge about motorcycle and motorcyclists' behaviour improves safe interaction with motorcycles in traffic.

5.1.4. *RQ 4. What is the role of motorcyclists' behaviour (e.g. speeding) in conspicuity-related motorcycle crashes?*

With respect to research question 4 we simply did not find many studies on the effect of motorcyclists' behaviour on conspicuity. Only information on the motorcyclist's speed was found (*Section 2.4*). In-depth analysis of 44 crashes at intersections involving a motorcyclist and another road user indicated that the initial speeds of motorcyclists involved in "looked-but-failed-to-see" crashes are significantly higher than in other crashes at intersections.

It is possible that the effect of motorcyclist behaviour was studied but that no effects were found; it is, however, more likely that the role of motorcyclists' behaviour has not been studied very often. The crash analysis could not provide information on the role of speed in relation with the occurrence of crashes, because speeding is rarely indicated as the primary crash cause in the crash records.

5.1.5. *Overall conclusions*

Motorcycles are vulnerable in traffic. In comparison with drivers of motorised four-wheeled vehicles, a motorcyclist runs a relatively high risk of sustaining fatal or serious injury in a crash. There are indications that motorcycles are less visible in traffic and that especially depth and speed perception of motorcycles are more difficult because of their small size (specifically of the front-view). Research further indicates that the *expectation* of car drivers plays a role in the perception of motorcycles. There seems to be less evidence for the role of motorcycle *awareness* in the perception of motorcycles. There are even indications that car drivers are more cautious when they interact with a motorcycle. The fact that dual drivers are less involved in motorcycle crashes than 'regular' car drivers, is more likely caused by their better *knowledge* about motorcycling and motorcyclists' behaviour than that they care more about motorcyclists. Finally, there is one specific situation in which motorcycles seem to be at a disadvantage compared to cars. This is when a car makes a left turn, and fails to give priority to an oncoming motorcycle. This specific scenario occurs relatively more often when the oncoming vehicle is a motorcycle than when it is a car. The literature review provides some answers as to why specifically this scenario (car driver making a left turn) is different for an oncoming car versus an oncoming motorcycle. From the side-view a motorcycle is more similar in size to (some) cars, and because the motorcycle is moving the observer receives relatively much information about movement and speed. From the front a motorcycle is smaller than a car and has only one front light instead of two, which provides less information about speed.

As a final note: although we found evidence that motorcycles are less visible in traffic and that they are not always expected by other road users, it was not possible to determine the size of this contributing factor. That is, we do not know how often a perception failure contributed to the occurrence of a motorcycle crash, compared to for instance speeding, alcohol abuse, poor road maintenance etc. For example, from the police records we only have information that a car driver failed to yield, there is no information that this is due to a *perception* problem. Moreover, the analysis of crashes at intersections even suggests that when a motorcycle approaches the intersection from a perpendicular angle this motorcycle is given priority just as often as cars. However, although we do not have information about the magnitude of the problem with perception of motorcycles, from the international literature we know that it is *a* contributing factor. The next section will describe potential measures to reduce conspicuity-related motorcycle crashes.

5.2. Measures

Overall, we found evidence that the perception of motorcycles is affected by conspicuity of the motorcycles as well as by expectancy and knowledge of car drivers. Measures could therefore be focused on both sides of the perception process. The literature review in this report occasionally provided some information on the effectiveness of certain measures for increasing perception of motorcycles. For example, studies on reflective clothing were discussed in *Chapter 2* to show that the appearance of a motorcycle could affect conspicuity. In the present section knowledge about the perception of motorcycles is approached specifically focused on potential measures. The section discusses the potential effectiveness of seven measures to improve perception of motorcycles in traffic, and answers the final research question:

RQ 5 On what problems should measures be focused to reduce conspicuity-related motorcycle crashes?

5.2.1. *Vehicle, clothing and helmet*

Intuitively it seems to make sense to increase conspicuity of motorcycles by increasing their physical appearance. There are indications that physical appearance has an effect on crash risk. A large population based case-control study in New Zealand found that increased conspicuity of motorcycle and rider reduced the risk of motorcycle crashes with severe or fatal injury (Wells et al., 2004a). Drivers wearing reflective or fluorescent clothing had a 37% lower risk of crash-related injury, wearing a white helmet was associated with a 24% lower risk (compared to a black helmet), and voluntary use of DRL was associated with a 27% lower risk of crash-related injury. Of course, with a case-control study there is a risk of confounding factors, e.g. riders wearing highly visible clothing and/or helmet are likely to be more safety conscious than other riders. Therefore, it is not clear if the same crash reduction could be achieved for every motorcycle rider who, for example, is obliged to wear a white helmet.

In contrast, there are also studies indicating that in some environments wearing fluorescent clothing did not improve conspicuity. Research indicates that the most important aspect of motorcycle conspicuity is contrast with the environment. For instance, at night, light-coloured and reflective clothing are most effective to improve conspicuity. During a bright day in a rural environment, dark clothing and a dark motorcycle are better. It is, in other words, difficult to recommend one type/colour of clothing to improve conspicuity in many situations. Information for motorcyclists should be focused on realising in which circumstances they are using their motorcycle. For example, when riding through very dense traffic, a rider should wear light clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night, reflective clothing could be beneficial.

5.2.2. *Daytime running lights*

All studies on daytime running lights show an improved effect on conspicuity. However, most motorcyclists already use DRL. So it is the question how much more can be gained by, for example, making it compulsory for motorcyclists to ride with DRL. Another development in this area is that more and more car drivers also drive with DRL. In theory, and substantiated by some research results, this could decrease the positive effect for conspicuity of motorcycles with DRL. In any case, although the conspicuity benefit could be reduced because of cars also driving with DRL, motorcycle conspicuity is always better for motorcycles with DRL than for motorcycles without.

5.2.3. *Frontal light configurations*

The literature and analysis of Dutch crash data both suggest that conspicuity of a motorcycle is especially a problem from the front-view. From the side-view a motorcycle does not differ that much in size from a small car. From the front a motorcycle and a car differ much more, especially because the motorcycle has only one headlight. The crash analysis indicates that only when a motorcycle approaches an intersection as an oncoming vehicle, car drivers have more problems with a motorcycle than with a car.

Reviewing these results, altering the front view of a motorcycle, for example with different frontal light configurations should, in theory, improve conspicuity of a motorcycle. However, the available studies on frontal light configurations (e.g. Rößger et al., 2012) did not report the promising results that were expected from theory. It must be said that, as of yet, not much research has been done on the effect of different frontal light configurations on conspicuity. In addition, the experiment by Rößger and colleagues indicated that observers were surprised and at first did not recognize the different frontal light configurations as motorcycles. It is possible that when drivers are more familiar with these types of figurations, this will indeed help the perception of motorcycles. So, considering the theoretical advantages of altering the frontal light configurations, developments in this field remain interesting and promising.

5.2.4. *What can a motorcyclist do?*

Instinctively, a first strategy would be to make car drivers realize that they share the road with motorcyclists. But if car drivers fail to improve or are not capable of improving, it is the motorcyclist who is vulnerable and pays the price in terms of a crash (possibly even death). Research (Brenac et al., 2006; Clabaux et al., article in press) indicated that motorcyclists who speed, are more involved in crashes at locations where they should have been given priority. This raises the interesting question what a can motorcyclist do to avoid these types of crashes. Obviously, he/she can respect the speed limits, but are there other things a motorcyclist can do to be seen? In theory, a motorcyclist could anticipate on the fact that car drivers do not expect him/her on the road, and be cautious when taking priority (i.e. defensive driving). Unfortunately, no research has been done into the effect of a motorcyclists' level of defensive driving on the occurrence of conspicuity-related car-motorcycle crashes; neither is it known whether defensive driving can be improved with education. Possibly the scheduled evaluation of an advanced motorcycle training in the Netherlands in 2012-2013 will show if improving motorcyclists defensive driving skills could reduce conspicuity-related crashes.

5.2.5. *Raising car drivers' expectancy*

The literature review indicates that expectation of objects (or motorcycles) enhances detection. In the Netherlands there are relatively few motorcycles on the road compared to cars. From the perspective of a car driver it is conceivable that they do not expect a motorcycle on the road or at an intersection; most of the time there will not be one. It would seem a good idea to increase car drivers' expectancy of the presence of motorcycles on the road.

However, increasing expectancy may be harder to achieve than it seems. It is an illusion that emphasizing – for example during driver training – the existence of motorcyclist on the road, will make a car driver alert to motorcycles for the rest of his driving career. It must be stressed, that humans have selective attention for a reason. This system has developed through evolution to increase our survival chances. If we were to spend large amounts of time and attention on everything we see on the road we could not be able to drive at all. The most important part of information processing (in traffic and elsewhere) lies in *neglecting* what is not relevant or important. Therefore, in order to increase the long-term expectation of motorcycles, measures should focus on repeated reminders regarding the presence of motorcycles on the road. With respect to changes in driver education, it would probably be more effective to educate structural procedures aimed at detection of other road users in general (e.g. always look over your right shoulder before making a right turn), than to educate car drivers about the occasional presence of a motorcycle.

5.2.6. *Raising car driver's awareness and acceptance of motorcycles*

In *Section 3.3* we came to the conclusion that lack of awareness of motorcycles probably does not affect perception of motorcycles by car drivers. The fact that dual drivers are less often involved in crashes with motorcycles than 'regular' car drivers is probably due to the fact that they have better *knowledge* about motorcycle riding than that they *care* more.

Yet, some studies report interventions aimed at raising awareness in car drivers of motorcycle riders. For example, Crundall, Clarke and Shahar (2010) found that attitudes towards motorcycles can be improved with an intervention (same results also reported in: Shahar, Clarke & Crundall, 2011). This intervention was aimed at improving negative attitudes in car drivers and to increase their empathy for the demands that motorcyclists face by exposing them to the motorcyclist's perspective. For this purpose hazard perception clips filmed from a motorcycle were used, as well as simulated hazards in a motorcycle simulator. A car simulator and car hazard clips were used as control conditions. The authors are very positive in their conclusions about the intervention. However, they also report some limitations, which suggest that the results should be interpreted more cautiously. The first limitation is that there was no clear advantage for the motorcycle simulator and hazard clips, as compared with the car-based conditions which were used as controls. This suggests that the specific intervention aimed at motorcycle safety, did not have to be so specific. Any hazard perception/anticipation intervention would probably reach the same results. The second limitation is that the level of improvement was relatively minor. In addition, it was also noted that positively influencing attitudes towards one minority sub-group of road users could have a potentially negative effect on attitudes to other road-user sub-groups. As yet, it is unclear what underlying reason may lead to this effect. These results indicate that we should at least be careful with interventions to improve attitudes towards motorcyclists; the results may be minor and could even have negative effects for other road users.

5.2.7. *Intelligent Transport Systems (ITS)*

It was mentioned earlier: the fact that car drivers do not expect and therefore do not perceive motorcycles on the road, is probably difficult to improve by simply educating car drivers. When the possibility to encounter a motorcycle on the road is not confirmed often, the expectation of a motorcycle will probably decrease quickly. Therefore, it would be better to accept that car drivers do not expect motorcycles on the road, and help them in situations where this is necessary. For example with the help of Intelligent Transport Systems (ITS) it is possible to alert drivers that a motorcycle is approaching an intersection. Especially in the situation where car drivers are relatively most likely not to give right of way (Scenario 2 in *Figure 4.3*), a warning sign could improve perception of motorcycles.

5.2.8. *Conclusions on measures*

Section 5.2 discussed seven measures and their potential effectiveness to reduce conspicuity-related motorcycle crashes. Some measures focus on increasing conspicuity of the motorcycles, others on increasing expectancy and knowledge of car drivers. This section reflects on the most promising measures.

There is evidence that physical appearance (bright and reflective clothing) has a positive effect on crash risk. However, under different circumstances (a bright day in a rural environment), dark clothing and a dark motorcycle are better visible. It is, in other words, difficult to recommend one type/colour of clothing to improve conspicuity in all conditions. Information to motorcyclists should be focused on considering the circumstances in which they will use their motorcycle. Furthermore, because study results differ, the effect of clothing in a Dutch setting needs to be studied further (see also next *Section 5.3*).

The literature review and analysis of Dutch crash data both suggest that conspicuity of a motorcycle is especially a problem from the front-view. Therefore improving frontal light configurations would seem a good way to improve motorcycle conspicuity. However, as of yet, not much research has been done on the effect of different frontal light configurations on conspicuity. This measure seems promising, but should be further investigated (see *Section 5.3*).

It is clear that expectancy plays a role in the perception of motorcycles. However, it is less clear if and how expectancy of motorcycles can be increased for the long-term. It is probably not very effective to emphasize the motorcycles in driver training. If this expectancy is not confirmed by what people experience in everyday traffic, expectancy of motorcycles would probably soon decrease. Therefore, in order to increase long-term expectancy of motorcycles, measures should focus on repeated reminders regarding the presence of motorcycles on the road. With respect to changes in driver education, it would probably be more effective to educate structural procedures aimed at detection of other road users (e.g. always look over your right shoulder before making a right turn), than to educate drivers on the occasional presence of a motorcycle.

Finally, it is important to realize that people, even when they are highly motivated to drive safely, are limited by their capacities; they commit errors. In this respect, measures should focus on improving the system and reducing the consequences of these errors and not on improving human's capabilities (Wegman & Aarts, 2006). For example by using ITS to warn drivers that a motorcycle is approaching an intersection; or reorganizing intersections in such a way that car drivers can make a left turn without the possibility of conflicting with oncoming traffic. Furthermore, motorcyclists should realize that they may not be expected or perceived by car drivers on the road. A defensive driving style could save lives.

5.3. Future research

5.3.1. *Crash and mobility data*

The data limitations that were mentioned in discussing the crash analyses (*Section 4.1*), reveal an important need for more knowledge and information. In order to calculate a *risk* of motorcycling, we need to adjust for traffic participation (i.e. we need estimations of the annual mileage). Data on mobility of individuals is collected by means of a survey of Dutch households. Unfortunately, the number of motorcyclists responding to this survey is far lower than the number of car drivers. As a result, the estimation of the distance travelled by motorcycles is much less reliable than the mobility estimate for car drivers.

In addition, the registration rate in BRON has been decreasing over the years, especially for serious road injuries. For fatalities, the registration rate in BRON is still over 90%, whereas for serious road injuries among motorcyclists, the registration rate in BRON dropped from about 60% in 2000 to 35 % in 2009. In other words, in 2009 the majority of serious injured motorcyclists were not registered in BRON. Furthermore, the registration rate in BRON of single vehicle crashes is expected to be lower than for multiple vehicle crashes. As was mentioned in *Chapter 1*, almost 40% of motorcycle casualties occur in single-vehicle crashes (which make this the second most important crash type after a car-motorcycle crash). Most of the single-vehicle motorcycle crashes resulting in a serious injury are not even registered in the crash database.

5.3.2. *Perception of motorcyclists in traffic*

There has been much (international) debate about the effectiveness of fluorescent clothing on motorcycle conspicuity. From the international research we learn that contrast with the background is most important for improving conspicuity. It would therefore seem useful to study the influence of fluorescent clothing on motorcycle conspicuity in a Dutch setting. This could be achieved by a fairly simple experiment in which participants view video recordings of Dutch traffic and have to find (or count) the number of motorcycles (and/or vulnerable road users). The motorcyclists in the videos can be portrayed with and without fluorescent clothing.

Furthermore, it would be interesting to study the effect of expectation on the detection of motorcycles and if expectation of motorcycles can be influenced by education. This can be studied in the same experiment as described above by dividing the observers into two groups. One group receiving information on motorcycle riding while the other group receiving some general road safety information.

Finally, it would be interesting to further investigate the different priority scenarios that were found to differ in the crash analyses. These analyses indicated that conspicuity of motorcycles is only a factor when the motorcycle approaches a left-turning car, and not when the motorcycle is approaching an intersection at an perpendicular angle. It would be very interesting to study this in an experimental setting. The type of priority scenario could be entered as a variable in the experiment described above. However, it would probably be more informative to study the effect of different priority scenarios in a driving simulator. In this experiment the possible benefits of ITS warning the driver of an approaching motorcycle can also be studied.

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