RISK AWARENESS ANALYSIS: A COMPARISON BETWEEN CAR DRIVERS AND MOTORCYCLISTS

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ABSTRACT: The general framework of this research is about risk awareness through the aspect of cognitive abilities - to perceive and assess the criticality of the driving situation - among motorcyclists versus car drivers. In order to study risk awareness, we have developed some tools based on video films. The experimental task consists in assessing the criticality of dynamic driving situations, via a Likert scale, and qualifying these situations using Osgood's semantic differential. The results show that riders globally consider our sample of driving situations as less critical than car drivers do. This paper presents the main differences observed between the two populations.

1 Introduction and objectives

This paper deals with drivers *versus* riders' awareness of risk while driving. Risk is widely studied in scientific literature as it helps explaining a high proportion of traffic accidents. Risk is then studied from different angles, such as risky driving behaviour through the study of motivations and attitudes towards risk. First of all, risk is more or less linked to human errors problems [1]. Driver Behaviour Questionnaire (DBQ) is one of the tools designed to study this aspect through verbal methods [2]. Risk taking is defined as either a socially unacceptable volitional behaviour with a potentially negative outcome in which precautions are not taken or a socially accepted behaviour in which the danger is recognized [3]. Risk sensation tries to determine the connection between a risky driving behaviour and the driver's personality factors. Sensation Seeking Scale is one of the tools used to evaluate this aspect of risk [4]. Risk perception refers to the subjective experience of risk in potential traffic hazards or is considered as a precursor of present driving behaviour [5]. Far from tackling every aspect of this concept of risk, our research particularly sets out to understand how a driver becomes aware of risk, and how he / she assesses the criticality of a situation when this situation is likely to turn into an accident. [6].

This work is in line with the research carried out at INRETS (*The French national institute for transport and safety research)* concerning drivers' mental activities modelling and simulation [7]. From a methodological point of view, this study continues the experimental protocols developed and validated at the LESCOT (*Laboratory of Ergonomics and Cognitive Sciences applied to Transport*) for scientific purposes investigating drivers' mental representations [8], [9]. Indeed, the awareness of risk and the assessment of criticality are two particular aspects of the Situation Awareness [10], mainly focusing on driving situations presenting a risk of collision. Lastly, this research continues the ARCOS project [11] dedicated to the design of "adaptive collision avoidance devices". Part of the ARCOS project has been devoted to analysing driving activity when approaching fixed or dynamic obstacles. Within this framework, this naturalistic experiment gathers data collected for twenty-two hours during which 1200 kilometres were covered and over 110 situations with a risk of collision were encountered [12]. All the situations presenting a risk have been analysed. Then, a Driving Activity Model (DAM) in critical driving condition was developed according to these data. When approaching a slow vehicle, the DAM model distinguishes 6 main cognitivo-behavioral phases implemented by the driver in order to avoid an accident [11]:

1. The *normal driving situation* phase, preceding the occurrence of the obstacle.
2. The *realization* or *risk awareness* phase (i.e. the moment when the driver detects the occurrence of an obstacle / the risk of collision and realizes that the situation is critical).
3. The *recovery* phase (i.e. the driver acts on the situation to avoid collision with the obstacle).
4. The *stabilized driving* phase, once the driver recovers the situation and controls risks of collision with the obstacle but this does not necessarily mean that the risks incurred are definitively eliminated.
5. The *resolution* phase, generally amounting to overtaking a slow vehicle when approaching it.
6. Finally, the situation becomes *normal* again once the obstacle is really out of view.

The focus point of this new research deals with the in-depth analysis of cognitive mechanisms involved during the second phase of this DAM Model: the *risk awareness* stage. We will thoroughly study the cognitive phase during which the driver realizes that the driving situation, that was normal until then, is suddenly becoming critical. The research aims are the human errors analysis and the cognitive modelling of abilities implemented by the driver/rider to detect or not the critical nature of a driving situation. To study risk awareness, we established a protocol based on 21 ARCOS video sequences (filmed on board a car) and presenting a risk of collision. These sequences are accompanied with a Likert Scale, and with an Attitude Scale in the form of a semantic differential based on Osgood's work (e.g. [13]) in order to refine the quality of the participants' subjective assessments. On the base of this methods, it is then possible to study and compare risk assessment performances of different populations of drivers. In this paper, we will present the main results obtained for two categories of drivers: one group of car drivers *versus* one group of motorcyclists.

The reason why we selected a population of motorcyclists is that over the last 5 years, there has been a significant increase in the number of accidents involving motorcycles on the European roads (+41%). According to the European Road Safety Action Programme [14] 14% of motorcyclists were killed in 2003 although the number of people killed on the road decreased by 12% over this period. Thus, motorcyclists are particularly vulnerable and sensible of risk wherever they are in Europe [15], [16]. In France, 807 motorcyclists were killed and 17 390 were seriously injured on the road in 2006. Therefore, motorcycle has rapidly become the most dangerous vehicle compared to all the means of transport used on the road [17]. Besides, for each kilometre covered, motorcyclists' risk of being killed is 20 times higher compared to drivers of standard four-door cars. This leads us to suggest that motorcyclists are forced to show a greater vigilance as they are perfectly aware of their own vulnerability among the other road-users. Although they comply to the same highway code and they resort to the same cognitive processes as car drivers, their vehicle remains more sensitive to weather conditions (rain, black ice…) and infrastructures (slippery road surfaces marking on rainy days, holes or uneven road surface, crash barriers that are dangerous when falling off a motorbike). Moreover, they are more severely injured when they fall off their motorcycle as they have no shell to protect them. The other drivers have more difficulty to perceive them because their vehicle is smaller and faster. They are more fragile within the road network. Nevertheless, according to a study carried out at the French national institute for transport and safety research – INRETS [18] dealing with two-wheelers crashes, motorcyclists have generally more weaknesses during the prognostics and execution phases at the level of cognitive functions while errors made by car drivers rather occur on perceiving and diagnosing situations.

When considering the vulnerability of motorcyclists, they should be more sensitive of risk and should anticipate the evolution of the traffic situation earlier to start a regulation action if the situation worsens. From this fact, it is possible that they do not perceive risks in the same way as car drivers. Certain situations that are considered as not critical by car drivers may be considered as dangerous by motorcyclists owing to a feeling of vulnerability. Conversely, it is also possible that other situations may appear as critical by car drivers, whereas they will be considered as not risky by motorcyclists. In some cases, these last differences could explain the higher level of risk of accident for motorcyclists. This research tries to examine these alternative hypotheses.

2 Methods

The methodology implemented is based on the presentation of 21 ARCOS video sequences (filmed on board a car) of driving situations presenting a risk of collision. These video sequences are divided into 6 categories of situations: approaching fixed obstacles, approaching intersections, changing lanes, following a vehicle, approaching slow vehicles, presence of vulnerable obstacles (pedestrians and cyclists). The participants are asked to stop the sequence when they feel that the situation becomes critical. Moreover, at the end of the sequence, two measurement scales are then submitted to the participants (see figure 1):

- A Likert-type scale [18]: The participants assess the level of risk by moving a cursor sliding along a scale with no graduation. The situation can thus be quantified in terms of criticality on this scale, ranging from 0 % (not critical) to 100 % (high level of criticality).
- Attitude Scale in the form of a semantic differential based on Osgood's work [13], in order to refine the quality of the participants' subjective

assessments. This differential is made of 16 antonyms defined for the specific context of driving under critical situation. The use of a semantic differential is complementary to an intensity scale as it helps us investigate the different cognitive dimensions underlying the notion of criticality while driving. This semantic differential is made of 4 dimensions: feelings, predictability, description and implication. Each dimension has respectively 4 antonyms.

Fig.1. Synthetic view of the Risk Awareness Measurement Tool, including a Likert Scale (on the left, below the road scene view) and an Osgood Semantic Differential (on the right)

3 POPULATIONS

We recruited 21 participants altogether. We chose two population samples of drivers in order to check if there were significant differences or not, in terms of risk awareness, between car-drivers and motorcyclists. Owing to the exploratory nature of this study, the size of our samples is limited. We should be cautious about generalizing the results in terms of representativeness of all the French motorcyclists *versus* car drivers. Nevertheless, we have built two homogenous groups of riders / drivers, regarding their driving experience and age, to increase the interest of the comparison.

Car-driver population: 11 experienced car-drivers (having a category B licence for over 4 years and covering 5000 kilometres per year) participated to the experiment. They have never driven a motorcycle before. They were all about the same age, between 22 and 30 years old (mean age: 28).

Motorcyclist population: 10 motorcyclists participated to the experiment. They all have a Motorcyclist “A” Licence and they rode their bike regularly, in terms of frequency and distance (over 2000 kilometres/year by motorbike). They are between 21 and 52 years old (mean age: 32). Some of them also had a car, but their main means of transport was their motorcycle.

4 Main Results

The first experimental task of the participants was to quantify the level of criticality by means of a Likert scale. This scale had no graduation, but the results were subsequently reported in percentage (from 0 to 100 %). At this stage, we then collected several results:

Overall criticality values (via the Likert scale)**:** the criticality average value assessed by all the "car drivers" participants for all the sequences is 57%, against 34% for "motorcyclists" participants. This difference is statistically significant (p< 0,001; T of student test). If we look into the detailed answers given by the participants for each type of sequences, we notice that the category considered as most critical (74%) by the car drivers corresponds to vulnerable obstacles but the motorcyclists considered the same category almost half as critical (38.5%). Moreover, the category considered as most critical by the motorcyclists corresponds to intersections (45%). The car drivers also considered these situations as critical (63%). For this category of situations, the criticality differential for both populations is the smallest (18%). Finally, the categories linked with the presence of an obstacle or depending on an interaction with another vehicle (car, lorry or tractor) are on the whole considered to be not very or not critical at all by motorcyclists (of the order of 20 %). On the other hand, the criticality level of each of these categories assessed by car drivers remains around 50% (from 48% to 56%).

Table 1. Average value of criticality, according to categories of situations

Car drivers	Crit. %	Motorcyclists	Crit %
category 1 : approaching fixed obstacles	56	category 1 : approaching fixed obstacles	27
category 2 : approaching intersections	63	category 2 : approaching intersections	45
category 3 : changing lanes	59	category 3 : changing lanes	52
category 4 : following vehicles	48	category 4 : following vehicles	23
category 5 : approaching slow vehicles	48	category 5 : approaching slow vehicles	21
category 6 : presence of vulnerable obstacles	74	category 6 : presence of vulnerable obstacles	38
Average value of criticality	**58%**	**Average value of criticality**	**34%**

Criticality values, according to categories of driving situations: We classified our 21 video sequences in categories according to the type of situations that may cause accidents such as approaching fixed obstacles, approaching intersections, changing lanes, following vehicles, approaching slow vehicles, presence of vulnerable obstacles (pedestrians and cyclists). Table 1 present results showing that, by and large, car drivers judged the situations as more critical than motorcyclists. The main significant differences observed between Motorcyclists and Car drivers concern categories 1, 4 and 6.

Categories of situations according to the averages of criticality assessment given by the participants: If we classify the 21 video sequences according the criticality assessments obtained by the two populations, we can see four categories of situations (figure 2). The car drivers and the motorcyclists feel that 7 sequences out of 21 are critical. They more particularly concern approaches to vulnerable obstacles and one case of failure to give way. On the other hand, 4 sequences are considered as not very or not critical at all by all the participants. Moreover, 8 situations are assessed as critical by the car driver but less critical by the motorcyclist. They more particularly concern approaches to fixed obstacles. Finally, there remain two sequences that the motorcyclists considered more critical in comparison with the car drivers proportionally to their average. Indeed, these two sequences show situations involving a fixed obstacle detected with difficulty and rather belatedly (a lorry parked at the end of a curve) then a sequence filmed in bad weather showing a bus that rapidly enters a roundabout.

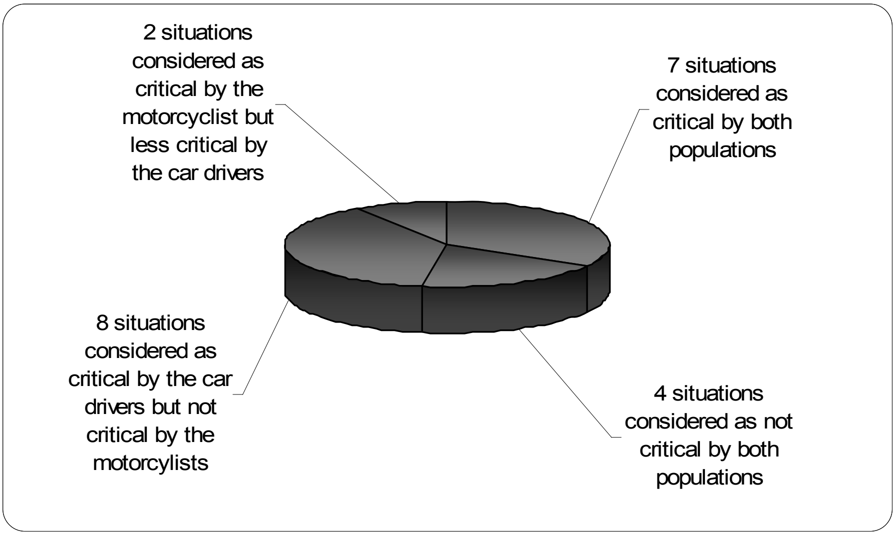

Fig.2. Groups of situations, according to criticality averages among the two populations

Early detection: The car drivers stopped the video sequences from 0.01 to 9.69 seconds earlier than motorcyclists did. However, the motorcyclists stopped 4 sequences out of 21 earlier (from 0.26 seconds to 2.86 seconds).

Number of sequence-stops: The car drivers tend to stop the sequences several times (they stop the sequence on risk detection under driving situation). Here is the total number of sequence-stops by all the subjects and of all the sequences: 58 sequence-stops for the car drivers and 21 stops for motorcyclists.

Results concerning the Osgood semantic differential: The participants also had to complete the grid of the semantic differential based on Osgood's approach (table 2) and made of 16 antonyms classified according to 4 dimensions: (1) Predictability (e.g. probability to occur), (2) Feelings (e.g. to be afraid or not), (3) Implication (e.g. to feel responsible or not of the criticality) and (4) Driving situation characteristics (e.g. complexity level of the driving situation). We noticed that all the participants - car drivers as well as motorcyclists - considered the major part of our 21 sequences as *Dangerous*, *Fast* and *Abnormal*. However, the car drivers judged these 3 antonyms significantly far more strongly than riders (p< 0.05, T Student test). For instance, the car drivers gave 67% to the antonym *Fast*, against 52% for the motorcyclists. More interesting, we also noticed that the two groups clearly disagree about two antonyms. Indeed, the motorcyclists generally considered the sequences as *Controllable*, and they felt more *Responsible* for the situation. Conversely, the car drivers considered more frequently the sequences as *Uncontrollable*, and they felt less *Responsible* of the criticality of the driving situation.

Table 2. Answers given by the participants to the Osgood semantic differential*

(Shaded items show a significant difference via Student Test: p<0.05)

Antonyms	Drivers (%)	Motorcyclists (%)
Safe / Dangerous	71.80	57.69
Stressful / Calm	33.08	42.59
Disturbing / Reassuring	31.69	40.36
Difficult / Funny	67.52	65.74
Soliciting / Ordinary	44.12	49.56
Irresponsible / Responsible	39.25	58.42
Brought about / Suffered	57.44	68.75
Uncontrollable/Controllable	45.21	64.92
Probable / Improbable	56.65	51.21
Rare/ Frequent	73.62	67.10
Abnormal / Normal	35.35	46.96
Unpredictable / Predictable	56.72	59.43
Slow / Fast	67.47	52.67
Complex / Simple	51.51	57.15
Dynamic / Static	38.52	36.60
Forced / Open	64.74	70.55

(*NB: note that for this Osgood's scale, a value of 50% is the "origin" and means that not any of the 2 antonyms is chosen. If % value is < 50%, the situation is then defined by first antonym (like "Safe"). If % value is > 50%, it means that the 2nd antonym (like "Dangerous") is assessed as more relevant to describe the driving situation

Typical example of diverging answers between the car drivers and the motorcyclists: To conclude this part dedicated to the results presentation, we would like to present detailed data collected concerning a typical case of diverging answers between the two populations (see Figure 3). The case (Sequence n°21) corresponds to a situation assessed as very critical by the car drivers (69%), but not critical at all by motorcyclists (18%).

Diverging answers between drivers and riders for this sequence could be explained like that. During this situation, after having passed a bend in a roadwork zone, the participants see a pedestrian finishing crossing the road (20 meters in front of our vehicle). For the car drivers, this situation is critical due to the combining effect of the pedestrian presence on the left (after he crossed the road) and the car incoming in the opposite direction. Consequently, they must reduce their speed to avoid an accident. Conversely, it is easier for motorcyclists to manage risk in this case: only the pedestrian's crossing behaviour could be potentially critical, but as he is now walking on the left side along the road, the criticality is low for riders and it is possible to bypass him without any interference with the incoming car on the opposite way. Semantic differential results show that this situation is assessed as *highly Dangerous* (83.91%), *Fast* (89.09 %), *Stressful* (29.45%), *Uncontrollable* (33.09 %), *Disturbing* (21.27%), *Abnormal* (26.82%) and *Irresponsible* (17.27%) by car drivers. On the contrary, this situation is identified as *not Dangerous* (54.5 %; reminder: the "0" value for Osgood scales are 50%), but very *Frequent* (70%), *Predictable* (70.70%), *Simple* (61.80%) and *Controllable* (59.30%) by motorcyclists. These results clearly confirm the interest and the validity of our "Risk Awareness Measurement" methods for studying and understanding the nature of divergences between different populations of road users, concerning risk assessment.

SEQUENCE n° 21:

Last view of the video sequence

ANTONYMS	Driver	Rider
Safe / Dangerous	83.91	54.50
Stressful / Calm	29.45	46.70
Disturbing / Reassuring	21.27	42.10
Difficult / Funny	66.82	57.10
Soliciting / Ordinary	36.00	43.90
Irresponsible/Responsible	17.27	53.00
Brought about / Suffered	38.82	48.80
Uncontrollable/Controllable	33.09	59.30
Probable / Improbable	54.82	54.70
Rare / Frequent	62.64	70.60
Abnormal / Normal	26.82	56.70
Unpredictable / Predictable	59.00	70.70
Slow / Fast	89.09	67.30
Complex / Simple	48.36	61.80
Dynamic / Static	36.64	35.20
Forced / Open	49.27	47.00

Osgood semantic differential results for the each population (Shaded items show a significant difference: $p<0.05$)

CAR DRIVERS

Criticality score for Car Drivers (Likert Scale): 69%

MOTORCYCLISTS

Criticality score for Motorcyclists (Likert Scale): 18%

Fig.3. detailed results collected for sequence n° 21

5 Discussion

The purpose of this research was to elaborate a methodology allowing us to collect assessments of risk and to evaluate traffic situations presenting a risk of collision among two populations of experienced drivers (11 car drivers and 10 motorcyclists). Motorcyclists are supposed to be more aware of risk as they are very vulnerable on the road in case of accident. From this point of view, they should judge “risky” situations as more critical and be aware of risks earlier.

As far as criticality assessment is concerned (grade given in percentage between 0 and 100), the results show that, on average, the car drivers consider the situations presented as more critical than the motorcyclists (reminder: 53% for the car drivers and 34% for the motorcyclists). Moreover, the car drivers stop the sequences more often and earlier on average. Nevertheless, we may say that some of our driving situations represent a minimal risk for a motorcyclist while they are perceived as risky by a car driver. For instance, we had 4 video sequences showing approaches to fixed obstacles which are very easy to manage for a motorcyclist but more difficult for a car driver. Consequently, the average value of criticality for all the sequences is not the main relevant result in this experiment. The most interesting results concern in-depth analysis according to the type of traffic condition and driving context.

Indeed, a thorough analysis of our results shows that the risk assessments of our video sequences between the two populations are not homogenous according to our different categories of situations. There were 6 different categories of situations. Approaching fixed obstacles or approaching slow vehicles are not considered as critical by motorcyclists since it is easier for a motorbike to bypass these obstacles when a car driver should slow down or stop. On the other hand, approaching vulnerable obstacles (pedestrians, bicycle, etc.), and more especially crossing intersections is on the whole assessed as far more critical by the motorcyclists in comparison with their overall criticality value of all the situations in so far as they fear that the car drivers may not adapt their speed correctly. More simply, they fear that car drivers may not spot them in time. Besides, accidentology data show that half of the accidents involving a PTW and a car on an intersection are due to the car’s failure to give way in 55% of the cases [19]. It is interesting to notice that motorcyclists often considered our situations as critical when they took place in unfavourable weather conditions. But generally, what is often considered dangerous for motorcyclists is the quality of road surface, holes, gravels, rain which is normal since the security of the motorbike is mostly ensured by the grip of the machine on the road.

Concerning the semantic differential, it is interesting to mention that the situations are judged as “controlled” and “responsible” (i.e. involving the rider / driver’s responsibility) by motorcyclists, while it is the contrary for car drivers. These 2 antonyms refer to the notion of involvement: the fact of feeling “responsible” for what is happening and the fact of feeling able to “control” the situation. Those last results are interesting. Indeed, being perfectly aware that they are very vulnerable in case of accidents, this awareness tends to make motorcyclists more aware of risks. That is what the differences observed for these two antonyms seem to reveal.

6 Conclusion and perspectives

The general framework of this research was to analyse the cognitive mechanisms involved in the assessment of collision risks when approaching fixed or dynamic obstacles. We compared two populations of road users, one of which being particularly exposed to risk (motorcyclists).

As the size of our driver samples is limited, we should be cautious about generalizing the results in terms of representativeness of all the French motorcyclists *versus* car drivers. Nevertheless, the protocol developed during this experiment appeared to be very discriminating since it enabled us to collect very different data between the two populations. We can also notice that criticality assessment differences, observed between car drivers and motorcyclists, differ or not according to the various categories of driving situations.

Within the framework of a current research, we will question more car drivers and motorcyclists. Concerning riders, more specifically, a new research is in progress at LESCOT with the aim to compare risk awareness abilities for different profiles of motorcyclists (e.g. novice *versus* experienced riders, motorcyclists who like sport motorbikes, versus Harley Davidson or Scooters). In this work, the characteristics of the riders' personality are also assessed by studying Zuckerman Sensation-Seeking Scale [20].

We will also draw a parallel between our video methods and other more classic verbal methods implemented for Driver's attitudes towards risk study and/or human errors analysis (like the DBQ questionnaire; e.g. [2, 16]), with the aim to evaluate correlations between social cognition on one hand, and risk awareness abilities, on the other.

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