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Conceptual and methodological tools for analyzing situations of vulnerability on the road.

Examples from a motorcycle riding study.

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ABSTRACT

Motivation – This paper presents some theoretical and methodological tools that help to identify and analyze “situations of vulnerability” for drivers.

Research approach – This study refers to “Course-of-Action Centred Design” that highly considers the situational aspects of activity to improve situations.

Findings – Examples have been drawn from a field study of the “situations of vulnerability” of novice motorcyclists in real world with a view to improving initial training in France.

Research limitations – The main limitation of the proposed methodology is the limited number of subjects due to the complexity of the data collection.

Take away message – The concept of “situation of vulnerability” provides an alternative to the concepts of “vulnerable road user” and “accident situation” which are conventionally used in transport research, and which have limitations for ergonomics research.

Keywords

Situations of vulnerability on the road, Course-of-Action Centred Design, Road safety, Motorcycling, Self-confrontation interview

INTRODUCTION

The risks associated with motorcycling are a major public health issue in Europe (CARE, 2007). In France, motorcycles account for 1% of motorized traffic but 40% of injured road users and almost 20% of fatalities at a time when the size of the fleet is increasing considerably (ONISR, 2009). In spite of this high accident rate, the body of research on motorcyclists is very small (2BESAFE, 2009-2011) and mainly relates to accident data. The principal weakness of this approach is that a number of events that are significant for drivers are omitted from accident registers (Haworth and Mulvihill, 2005). First, they involve all those incidents that do not require police action, i.e. where no medical treatment is required. Second, they also involve all the accidents which the rider manages to avoid just before the collision. However, these situations appear to be important parts of motorcyclists' driving history as they result in radical and permanent changes in driving

habits (Aupetit, 2011), and to be frequent in relation to the number of accidents that involve motorcyclists. For these reasons, we propose to use the concept of “situations of vulnerability”.

The aims of this methodological paper are (1) to present this concept and to show how it can help us understand the driving behaviour, (2) to present a rich theoretical framework and methodological tools which can be applied when studying situations of vulnerability and (3) to describe the kind of results we can hope for from this approach.

Throughout this paper, we shall present examples obtained from a study of the activity of beginner motorcyclists¹. The goal of this study was to identify the “situations of vulnerability” for novice motorcyclists who have just passed their test, in order to improve initial training in France given in motorcycle schools.

SITUATIONS OF VULNERABILITY ON THE ROAD

We consider that an individual, or a group consisting of a variable number of individuals, is in a situation of vulnerability when one or more of the dimensions that are given importance in ergonomics is hindered or impaired (i.e. performance, health, comfort, development, pleasure). The vulnerability in question may thus lead to an objective and/or subjective reduction in performance, a risk to health or safety, an inadequate level of comfort or impede the driver's development or pleasure (Theureau and Jeffroy, 1994).

In the context of driving, vulnerability mainly impinges on safety and comfort. The concept of “situation of vulnerability” differs from that of “vulnerable users” as it takes account of the fact that the individual is vulnerable in a given situation, for example a pedestrian when crossing a road, a motorcyclist trying out a new machine in a built-up area or a young driver joining a traffic stream on a motorway. The concept underscores the transient or non-permanent nature of vulnerability, which is not a stable characteristic of individuals but

¹ This study is conducted as part of the French SIM2CO project (Design of motorcycle training modules including simulation to the development of hazard perception skills, 2011-2013).

one which may be expressed only in certain situations. This “situated” aspect of vulnerability is expressed in specific situations which we need to understand. It is not just the driver who is vulnerable, it is the driver in a situation which has specific social, technical and cultural dimensions. The “situation of vulnerability” concept includes and goes beyond that of “accident situations”, which are situations in which vulnerability is evident. However, we also consider all the situations which the actor sees as problematical but which do not actually result in an accident.

THE SITUATIONS OF VULNERABILITY IN THE “COURSE-OF-ACTION CENTRED DESIGN”

This study refers to “Course-of-Action Centred Design” (CACD) (Theureau, 2003) that presents conceptual and methodological tools for data collection and analysis, and the design process². This approach is at the crossroads between several disciplines (cognitive anthropology, psychology and microsociology). Its origin lies in “French cognitive ergonomics” (Ombredane and Faverge, 1955) and it draws on advances in the areas of “situated cognition” (Suchman, 1987) and “distributed cognition” (Hutchins, 1994).

The aim of the activity analysis is to explore the links between context, cognition and action in real world. This approach is perceived as an alternative to the computational approach, on the grounds that that computing-based models of human cognition can be enriched by taking into account the influence of the context but also the cultural, situated and embodied dimensions of activity (Dreyfus, 1972). According to Ranney (1994), none of the available models on human activity (Rasmussen, 1987; Wickens, 1992) or on driving (Michon, 1985; Keskinen, 1996; Groeger, 2000) can adequately explore the role of situational factors to study the complexity of driving. The study of the “situations of vulnerability” must be linked with a framework that highly considers the situational aspects of activity.

The CACD framework has already been applied in a number of studies dealing with driving situations (Villame, 2004; Ciaccabue and Saad, 2008) and motorcycle riding situations (Aupetit, Riff, Espié and Buttelli, 2011; Aupetit, Espié, Larnaudie, Riff and Buttelli, 2011). In this approach, the goal of optimizing existing situations necessarily involves considering human activity comprehensively and dynamically, by an analysis of the natural context and by taking account of the subjective experience of the actors. The methodological implications of each of the postulates for the study of novice riders are presented.

Considering the activity in a holistic manner

The central concept in this approach is that of “activity”. Instead of reducing human activity to a task made up of a number of variables, the aim is to analyze it as a total

entity that includes emotions, attention, perception, actions and communication (Theureau, 2003). This use of the concept of activity makes it possible to avoid distorting natural behaviour. Here, it means taking account of the complexity of the driving activity and not focusing on a single aspect of the activity of drivers (Saad and Villame, 1996), not reducing driving to information processing nor the activity of the driver to the driver’s behaviour.

In practical terms, this meant that we decided to study all the dimensions of the novice riders’ activity in the situations of vulnerability. The methodological tools we used meant that it was possible to describe their emotions, attention, perceptions, actions and communication, and demonstrate the links between them.

Modelling the dynamic aspect of the activity

In CACD, human activities are seen as belonging to “stories” which are fundamentally dynamic in nature as they are modified by the experience of the actors and the perpetual changes in the situations they encounter (Lave and Wenger, 1991). The driving activity, for example, requires the driver to adapt constantly to changes in traffic situations (Van der Molen and Botticher, 1988). Even if most studies of driving behaviour have adopted a prescriptive approach involving isolated measurements of behaviour rather than long-term studies, the extent to which the activity is changes over time is striking. This means that the activity of drivers must be analyzed over periods that are long enough to describe their dynamic and studied sufficiently systematically to reconstruct the disturbances that affect the activity (Goldenfeld, Twisk and de Craen, 2004).

The approach that has applied for novice riders was thus to carry out systematic monitoring of all the trips made by the eight motorcyclists for more than two months after passing the test (a total of 82 weeks of monitoring, involving a distance of more than 20,000 km).

Studying the activity in the natural context

As in this approach human activity is considered to be intimately linked to the context in which it takes place (Suchman, 1987), it is necessary to study it in real situations. Conducting a study under real conditions means investigating the activity of individuals in the natural environment. The behaviours, intentions and emotions of the actors which are analyzed could have occurred naturally. The situation that is observed is not controlled by the observer in terms of, for example, the goals to be achieved and the task to be performed are concerned.

The literature survey which was conducted as part of the 2BESAFE project (2009-2011) highlighted that no research into motorcycle riding behaviour has ever been conducted under natural conditions. However, if we wish to consider the intentions of riders in contexts with dynamic environments (AIDE, 2004-2006) and develop valid recommendations for design (Rajaonah, Anceaux

² This article deals especially with the data collection and analysis part of this approach.

and Vienne, 2006), the study of human activity must absolutely be conducted in a real situation (Haradji and Faveaux, 2006).

At the methodological level, this means first of all that the experimental set-up had to be capable of collecting the required data without causing excessive disturbance, as this would adversely affect both the development of the drivers' activity and the research. The novice riders' study is thus affected in a number of ways: the observation devices were very discrete, the participation contracts made precise guarantees regarding anonymity and confidentiality, and the motorcyclists were studied while riding their own machine. We therefore decided to design instrumentation that could be fitted to a Kawasaki ER6n motorcycle which is popular among novice drivers who have just passed their test. This instrumentation required no major alterations to the motorcycles (their type approval and insurance terms were unaffected). It was also reversible (the machine could be returned to its original state after the experiment) and autonomous (the recording devices were automatically turned on and off when the motorcycle started and stopped).

Taking the actors' subjectivity into account

In CACD, taking account of the point of view of the actors with regard to their activity is considered to be essential in order to study what has meaning for them (Bannon, 1991). It is the participant who is in the best position to describe the difficulties he encounters (Grize, 1995). With this goes the idea that the motorcyclist acquires significant experience when riding which can be "reactivated" and may provide useful research material. A partial understanding of participants' activity can be gained when they describe, show and comment on what is significant for them in a particular situation.

At a methodological level, while the production of objective data on participants' behaviour is of value, the idea that lies behind this approach is that we can only successfully study the activity of these participants if we link the objective data with the participant's subjective opinions. In concrete terms, the data on the driving context was "filtered" by the beginners' point of view in the interviews. It was the motorcyclists themselves who decided whether a situation was problematic or not. In CACD, this is known as the "primacy of the intrinsic" (Theureau, 2003).

DATA COLLECTION

In the sections that follow, the main elements of the study of the "situations of vulnerability" faced by the motorcyclists will be presented and illustrated with examples taken from the novice riders study.

Population

The decision to study the driving activity in such a systematic manner and the complexity of the data collection device meant that the number of subjects had to be smaller than in traditional experimental studies. In

addition, the benefits of studying more individuals in a superficial manner rather than a single individual in depth depends on the context of the study (Clot, 1999). If the aim is to carry out a very detailed investigation of the subjective experience of an actor in a given situation, then an individual may be a valid object of study.

Among the eight novice motorcyclists, four travel on the roads of the Paris region and the other four remain in the provinces. Four of them had had no previous experience of riding a motorized two-wheeler while two of them had ridden scooters with an engine capacity of under 50cc, and two had ridden 125cc motorcycles.

Data collected and equipment

An articulated set of data collection methods has been developed for CACD. These make it possible to collect data at various levels in order to obtain a comprehensive description of the studied activity. Data on the context (audiovisual recordings, direct observation...) are collected and linked to data on the internal dynamic of the participants, obtained, for example, from interviews, questionnaires and diaries (for a detailed presentation of the combination of these methods in the data collection and analysis, see Aupetit et al., 2011).

Three methods were applied to have a comprehensive view of the situations of vulnerability of the novice riders: diaries (to identify their situations of vulnerability), camera instrumentation (to observe the riders' behaviour in the identified situation and allows conducting interviews) and interviews (to describe the subjective part of the riders' activity and identify their problems). These tools were chosen because they permit to fill the questions of research of the present study and they are referred by Baldanzini et al. (2009) as fruitful method to conduct a naturalistic riding study.

The diaries

Throughout the experiment, the novice motorcyclists filled in a diary which was specifically designed for this study. In it they were asked to note down the situations they had experienced during their journeys which were or could have been problematic from the motorcyclist's point of view.

A considerable amount of work was done with the motorcyclists beforehand in order to explain the type of situations to be included in the diary (i.e. not just accident or near-accident situations but all the riding situations where they think that their performance, health, comfort, development or pleasure is or could be impaired) and reach agreement about the amount of detail in which these situations should be described.

The participants were asked to record when these situations occurred (date, time, journey) and describe them briefly in words and if possible with a diagram (see Figure 1). Each participant was also asked to make a diary entry every day describing the situations encountered in as much detail as possible. Each motorcyclist was provided with a diary for each week the experiment ran.

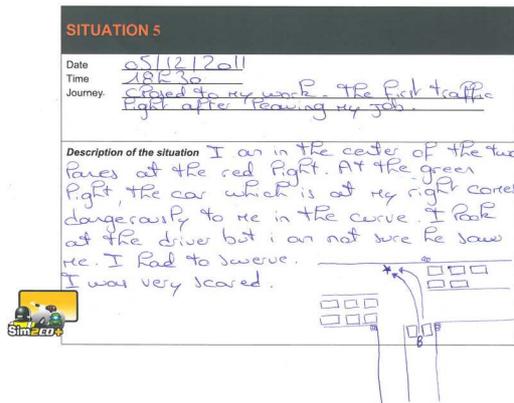


Figure 1: Extract from participant 6's diary for the 3rd week of the study (translated from the French)

The main purpose of the diary was to reveal the situations of vulnerability encountered by the motorcyclists during the study period. The situations that were described provided a basis for the interviews that were conducted at the end of each week of monitoring.

The camera instrumentation

Audiovisual recordings were made with four cameras that were mounted on each motorcycle³. Two cameras were mounted on each side of the motorcycle's rear top case, covering about 160 degrees of the front visual field (Figure 2). In order to mount the other two cameras, a wind deflector was specially developed for the study which was 10cm wider than the standard models. On this were mounted one camera pointing towards the scene to the front and another pointing towards the driver's face. The data was stored on SD memory cards. The recorder was housed in the top case of each motorcycle (Figure 3).

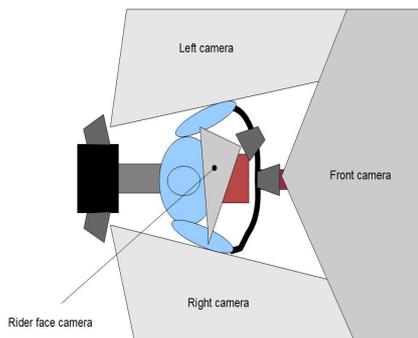


Figure 2: Positioning of the four cameras on the motorcycle and the possible views

³ This type of method has been used many times for studying work environments (Laws and Barber, 1989), sport situations (Omodei and McLennan, 1994) and car driving (NHTSA, 2006). Only Motoki and Yamazaki (1990) have tested this method for the study of motorcyclists. We inspired by these authors for the positioning of the cameras. This positioning also depends on the insurance requirements for the experimental devices and our ambition to maintain the motorbike manufacturer certificate.



Figure 3: Camera instrumentation mounted on one of the participant's motorcycle

The a posteriori interviews

At the end of each week of the experiment, a face-to-face interview that lasted between 20 and 30 minutes depending on the motorcyclist's availability was conducted at the participant's home or place of work. This interview was in two parts: (1) an interview that focused on the description and accuracy of the situations of vulnerability reported in the diary, and (2) a self-confrontation interview based on the video footage of the identified situations. The interview also provided an opportunity to recover the data storage cards and replace them with empty ones.

The term "self-confrontation" is used to describe a very wide variety of practices. The technique presented here was developed for CACD. This method provides a way of documenting in detail the subjective part of the participants' experience and their immediate understanding of their behaviour when shown audio, video or other types of recordings of their actions. In our study, this technique provided a way of obtaining a step-by-step description of the motorcyclist's actions while driving. The interview consisted of asking the motorcyclists to express their emotions and sensations, share their main concerns and interpretations, and explain their statements and actions during the driving situation when faced with the audiovisual recording of it. The interviewer's questions focused on action in order for the motorcyclists to be able to put themselves back in the dynamic context of the experienced situation.

The researcher's input is systematically related to what the participant has just said or done during the interview or the situation on the screen and playback of the video footage is interrupted from time to time to give the participant time to speak. The researcher tried to intervene as little as possible so as to avoid triggering thought processes among the participants, so that the only focus was what was significant for the motorcyclist in the situation when the events occurred (Theureau, 2003). The interview was recorded with the same audiovisual device that was installed on the participant's motorcycle, but only three cameras were used for the interview (Figure 4).

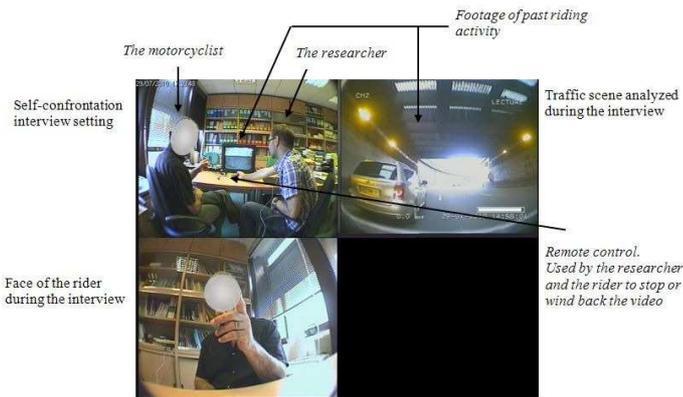


Figure 4: A self-confrontation interview situation showing the equipment and the positions of the motorcyclist and the researcher

DATA PROCESSING

The collected data was then loaded into processing tables that were based on the verbal protocols developed by Theureau (2003). The aim was to combine the different levels of data in order to obtain the most detailed description possible of the situation of vulnerability described by the motorcyclists.

For the novice rider's study, the tables consisted of three sections (Figure 5). The first contained a full retranscription of the data collected using the diaries (texts and diagrams). The second listed the remarks made by the researchers based on the video data that showed the context of the situation (behaviour of participants, infrastructure, traffic...). The third section contained verbatim retranscriptions of the participant's verbalizations during the face-to-face interview that included the interview based on the diary and the self-confrontation interview).

Diary	Observations		Interview		
	Time	Videos	Time	Speaker	Verbal data
Date: 10/28/2011 Time: 10h30 Journey: Home to Paris. I have the priority and I see a car approaching from the right at a stop mark. Suddenly he restarts and stops in the center of the road I avoid him.	10h28	The situation takes place in urban areas in an intersection in "X". The rider avoided the vehicle by the left side of his lane. Cars were present in the opposite direction.	1'12	Rider 2	I saw the driver turned his head in my direction at the stop line. I thought I had detected me. And suddenly I was surprised to see the car ahead. The driver notices me and brakes suddenly
			1'35	Researcher	What are you doing at this time?
			1'42	Rider 2	I think I started to slow down but I realized that this will not be enough to stop, so I released the brakes and decided to avoid the car by the left. Fortunately there was a little place in the lane. I was relieved to be out without falling!

Figure 5: Extract of a table for processing the collected data for week 2 of the participant 7

DATA ANALYSIS

Data analysis consists in a macro-analysis to characterize the identified situations of vulnerability, and a micro-analysis to make an in-depth analysis of the driver's activity in each situation.

The macro-analysis

The analysis categories for a corpus of data of this type may be determined by applying a "top-down" model

(deductive reasoning) and a "bottom-up" model (inductive reasoning). The categories are the outcome of a combination of research questions and a preliminary analysis of the collected data. Immersion in the empirical data provides a starting point for the development of analysis categories and a way of conserving an evidential link with the field data (Glaser and Strauss, 1967).

The identification of the analysis categories and the corpus analysis for the novices involved a six-stage process that was conducted by two researchers:

1. Construction of a first version of the analysis categories based on an initial examination of the data and the research issues (4 major categories, 18 sub-categories).
2. Further work in order to develop a practical definition for each category and sub-category after a rigorous examination of a series of extracts from the corpus of data and identify a prototypical example drawn from the data.
3. Discussion and decisions about the validity of several of the categories.
4. Drawing up of the final version of the classification which contained three main categories ("the journey as a whole", "the context of the situation", "the motorcyclist's internal dynamic") and 15 sub-categories (for example in the case of the "context of the situation": "Infrastructure", "Types of interaction with another road users", "State of the pavement", "Meteorological conditions", "Driving alone or with a passenger", "Driving in a group").
5. Coding of the corpus of data using the analysis categories by the two researchers working independently of each other.
6. Comparison of the results of the two coding operations and taking of a joint decision where there were differences of opinion.

The micro-analysis

The goal is to analyze each of the identified situations of vulnerability accurately in "activity graphs" using the various types of data collected in order to have a comprehensive view of the activity of the riders in these situations. These "activity graph" present the motorcyclist's actions during the observed situation on the basis of his verbalizations during the interviews, the rider's actions observed on the videos ("Slows down" and "Takes bend"), photographs of the context and the time. The aim is to reconstruct the "film" of the situation on a step-by-step basis using all the different types of data that was collected. This way of presenting the data has the advantage of retaining the fundamental aspects of human activity: dynamic aspects (displaying the change in the situation over time, the sequence of actions performed by the motorcyclist, etc.) and integrated aspects (links between the different dimensions of the activity by combining different levels

of data). This presentation highlights the constant links between observation of the context and actions, as well as between the driver's actions and emotions. In addition, the "activity graphs" provide a comprehensive summary of the participant's actions in the studied situation. With this kind of time-based modelling, we are able to understand the dynamics of activity and the difficulties experienced by the drivers without omitting the situational aspects.

The first example we shall examine, involves a situation that occurred on 2 October 2011 at 18:22 during a home-to-work journey made by the novice riders number 3. This situation was identified from the following diary extract:

"I was approaching a junction and a car travelling fast arrived from the left, forcing me to brake on a bend and nearly fall off" (Diary, Participant 3)

The data given in Figure 6 gives us a better understanding of this situation.

The second example involves a situation experienced by participant number 2 on 18 October 2011 at 18:57 during a leisure journey:

"I was riding between two streams of vehicles on the Paris orbital motorway when a vehicle changed lane just in front of me forcing me to brake urgently" (Diary, Participant 2)

The motorcyclist's activity graph for this situation is shown in Figure 7.



Figure 6: Activity graph of participant 3 during an identified situation of vulnerability

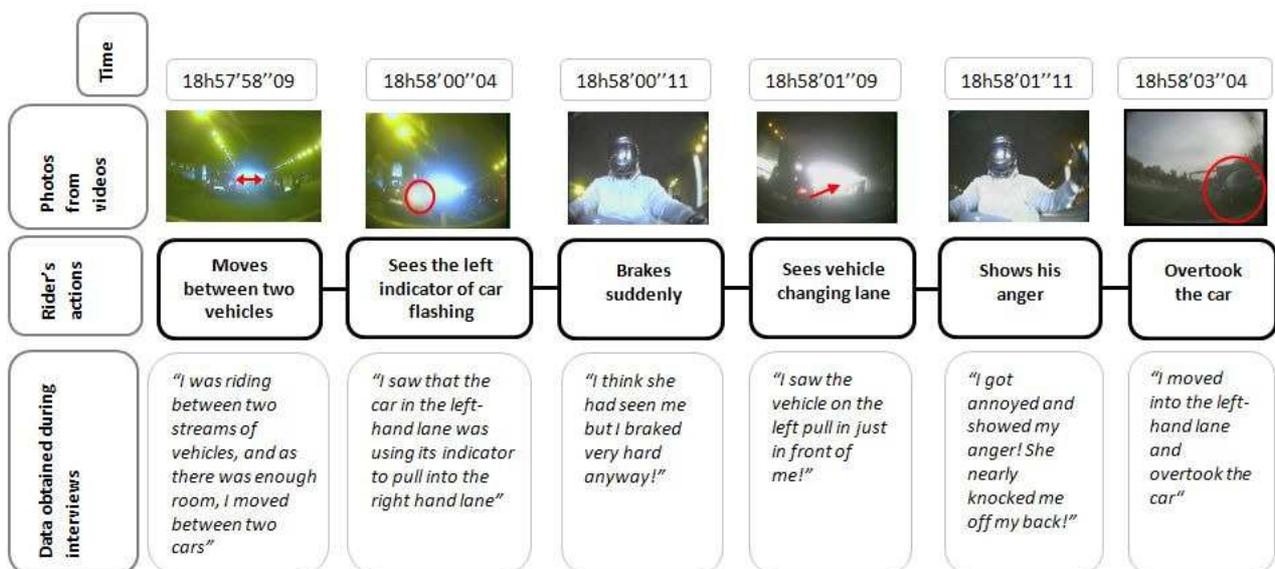


Figure 7: Activity graph of participant 2 during an identified situation of vulnerability

TYPES OF RESULTS THAT CAN BE ANTICIPATED FROM THIS APPROACH

The approach described in this paper provides a way of (1) characterizing the situations of vulnerability encountered by drivers – especially by the macro-analysis, and (2) identifying the skills the actors lack in the situations in question in order to incorporate them into training – especially by the micro-analysis.

Characterization of the situations of vulnerability

Statistical processing can be carried out in order to obtain a clearer picture of the contexts in which the situations of vulnerability arose. This processing was able to identify the proportion of situations that were associated with each analysis category.

For the category called “the journey as a whole”, 48% of the situations of vulnerability experienced by the studied beginners occurred during a home-to-work trip, and 68% on usual roads, i.e. every day routes. Concerning the category “the context of the situation”, 44% of the situations of vulnerability occurred in built-up area, 20% on highway, and 19% on main road. In details, 14% happened on a curve and 11% on a roundabout. For the category entitled “the motorcyclist’s internal dynamic”, the situations of vulnerability occurred when the motorcyclist reported feeling afraid in 30% of the cases and being late only in 2% of the cases.

The objective is to gain a better understanding on PTW riding and on the actual behaviour of novices to overcome the lack of scientific knowledge on these issues. These types of results are also relevant for an application level: they provide valuable information for improving prevention and training. Several contexts of riding (e.g. curve, roundabout) are typically associated with a feeling of vulnerability for the novices. This implies to a further integration of these contexts in the educational content delivered in motorcycle-schools.

Identifying motorcyclists’ weaknesses in situations of vulnerability

The data that is presented in “activity graph” can be used to identify motorcyclists’ shortcomings in the situations in question. In the case of Figure 6, the motorcyclist’s problems were related to controlling the machine in a demanding situation (a tight right-hand bend) while trying to ascertain some information. In the situation described in Figure 7, the car driver changed lanes just in front of the motorcycle without having seen it. Even if the car driver was guilty of dangerous behaviour, the motorcyclist could perhaps have anticipated the situation better and made sure that he was visible. Results of this type have direct implications for training goals if we found the same problems for different participants. If these difficulties are recurrent, it could be appropriate to improve present-day training by emphasising the skills related to these situations. The trainees could learn from the experiment during training (under controlled situations)

and not by discovering these situations and the associated abilities after they have passed their test.

DISCUSSION

The limitations of the proposed set of tools are presented below. Firstly, the conceptual ambition to analyze the riding activity in such a detailed manner meant the recruitment of a relative reduced sample. It is clear that increasing the number of subjects would help to achieve validation and wider applicability. Secondly, one can put the stress on the fact that data collection can interfere with the rider’s activity. Measures have to be taken to reduce the disruption caused by the presence of the researcher and/or the cameras in order to ensure there was as little interference as possible with the activity. The measures in question related to three points: ensuring the observation devices and their operators were not too obtrusive, integrating the observation techniques gradually, and providing guarantees for the participants (anonymity, confidentiality) which were set out in the participation contracts. Finally, this approach requires an efficient collaboration of the drivers through the data collection process. They will complete the diaries and they will comment their activity during interviews. The quality of the follow-up of the riders is highly dependent on their motivation towards the experiment. A considerable amount of work has thus to be done with the motorcyclists in order to involve them as much as possible in the research and to explain them the type of situations to be included in the diary.

CONCLUSION

This paper has proposed a number of theoretical and methodological tools for identifying and analyzing situations of vulnerability in a natural context. Although the examples have been taken from a study that dealt with motorcyclists, most of the remarks of this paper are also valid for the analysis of situations of vulnerability for other road users (motorists, pedestrians, cyclists, etc.).

It is necessary to choose certain methodologies from among the data collection techniques available for CACD. These choices may be based on a number of criteria: (1) the characteristics of the activities under observation, the actors and the situations, (2) the specific temporal characteristics of the activities under observation, (3) the theoretical and practical aims of the study, (4) the temporal constraints affecting the study, imposed, for example, by an ongoing design process, (5) ergonomic expertise for analyzing the activity (Theureau, 2003). This means that it is necessary to have a minimum amount of knowledge about the activities that are to be studied. In the case of the SIM2CO project, an ethnographic observation of the beginner motorcyclists was performed prior to the in-depth study.

Furthermore, the approach that is proposed in this paper is highly “collaborative” (Haines and Wilson, 1998) in

the sense that the participants are actively involved. As the riders are in the best position to judge how dangerous the situations they encounter are, they have been given an important role throughout the data collection process. They are also fully involved in the design process and improving the existing training situations in the framework of SIM2CO project.

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