COOPERATING WITH AN ASSISTANCE TOOL FOR SAFE DRIVING

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Abstract: The LAMIH particularly the research group Human-Machine Systems, has studied human-machine cooperation for many years, in a variety of contexts where safety is essential. Our approach is multi-disciplinary and uses different models and methods to elaborate symbolic and formal representations of human-machine cooperation. Our principal objective is to propose and evaluate a semi-formal framework for modeling cooperative activities between human or artificial agents, each of which has a different level of ability, reliability or adaptability. In the present study, human-machine cooperation was analyzed in order to define and evaluate a system capable of taking the full control of an automobile so as to avoid traffic accidents. *Copyright © 2005 IFAC*

Keywords: Man-Machine System; Driver Behavior; System design; Simulators; Statistical Analysis.

1. INTRODUCTION

Despite its apparent simplicity, the car driving task is very complex. It requires the continuous adaptation to temporal and dynamic constraints, and the management of multiple interactions while also taking the inter- and intra-individual variability of drivers into account. Novice drivers learn to ease into the traffic and drive along a route. They learn to use environmental references, and with experience, they build mental models that allow them to control several situations simultaneously. But not every situation can be anticipated, and drivers have trouble evaluating their environment because of limited abilities or technical impossibilities. Several authors refer to situation awareness when speaking of the perception of elements in the environment according to time, space, significance, and future status (Stanton, *et al.*, 2001; Endsley, 1995). When their situation awareness is poor or inappropriate, drivers have more trouble detecting problems in advance, and must then correct errors when this is still a possibility. Drivers maintain situation awareness by paying attention. But in general, scanning strategies only allow them to detect the more common emergency situations (Summala, 2000). Providing information to drivers may help them to spend less time searching for information (Walker, *et al.*, 2001), thus allowing drivers to better anticipate dangers and thus increase their safety margin (Van der hulst, *et al.*, 1998). The advanced assistance tool presented in this paper uses a dash board display to provide information. Such visual display of information is mainly perceived through driver's peripheral vision, and the validity of the information is confirmed by other information (Moray, 1990), for instance a glance lasting less than 3 seconds (Wikman, *et al.*, 1998). In order to limit driver distraction, this advanced assistance tool has only been tested in emergency situations (Stevens and Minton, 2001; Srinivasan and Jovanis, 1997).

2. THEORETICAL FRAMEWORK

Our approach to cooperation is more operational than structural, in that we try to describe the cognitive activities embedded in cooperation as well as the structural relationships between the agents. This approach began with a multidisciplinary investigation of the theoretical tools needed to design human-machine cooperation, from the standpoint of cognitive psychology and supervisory control. Most of the problems encountered in the study of cooperative activities between humans, or between humans and machines, can be addressed by enlarging the cognitive approaches used to study individual activities. Because driving is basically an individual activity that requires cooperative activity in order to be performed efficiently, such an approach, in which the individual agent is the basic unit of study, is particularly relevant to the analysis.

To study individual cognitive activities, we use the Dynamic Situation Management model proposed by Hoc and Amalberti (1995), which is itself derived from Rasmussen's model (Rasmussen, 1983). In addition, we have adopted Hoc's definition of cooperative activities (2001), which considers that cooperation is a cognitive activity that can be developed given two conditions: "(a) each agent strives towards goals and is able to interfere with the other agents' goals, resources, procedure, etc.; [and] (b) each agent tries to manage interference in order to facilitate individual activities and/or the common task when one exists. The symmetric nature of this definition can be only partly satisfied". The cognitive architecture implied by this definition includes three levels of cooperative activities : action, planning and meta-cooperation. Each level corresponds to a specific time span.

To implement the assistance and trigger its cooperation with the human operator, we applied the principles of the cooperation used in supervisory control, either in a horizontal structure involving dynamic task sharing between the human operator and the tool, or in a vertical structure in which a single agent determines strategies or actions. With the horizontal structure, the assistance tool must be able to deal with tasks independently, such as providing decision-making and action aid to the human operator. These tasks are called shareable tasks and require cooperation. Millot *et al.* distinguish two modes of cooperation: explicit allocation and implicit allocation 0(1989). In *explicit allocation,* the human operator uses a specific human-machine interface to allocate the shareable tasks, thus allowing the human agents to use their own criteria in allocating tasks to the assistance tool. In *implicit allocation,* task allocation is performed by an algorithm according to criteria defined by the designer (e.g. human workload or global performance). With the vertical structure, the assistance tool provides only decision-making aid to the human operator. Such vertical cooperation may be either active or passive. It is considered to be "active" if the decision is built step by step, by both agents; it is considered to be "passive" if the tool provides a complete decision to the human operator.

In order to distinguish the ability of an agent (human or artificial) to perform a task from its ability to communicate with another agent, we have defined two entities: "know-how" and "know-how-to-cooperate" 0(Millot and Pacaux, 1998). *Know-how* is related to cleverness in problem solving. Agents have the ability and the experience to build a know-how. *Know-how-to-cooperate* is related to cooperative activities performed by agents in order to exchange something (information, a decision, an action ...) with other agents. Defining a Common Work Space (Pacaux and Debernard, 2002) makes the exchanges between agents easier. This Common Work Space implements a virtual COmmon Frame Of Reference (COFOR), which can be seen as providing a state of the situation. The COFOR is composed of diverse elements, including *information* uncovered during information elaboration activities; *problems* highlighted by diagnosis activities; *strategies* suggested by schematic decision making activities; *solutions* recommended through precise decision making activities; and *implementation* of specific solutions (actions) that have been recommended.

The goal of our study was to examine how the two agents—the driver and the assistance tool—share the "shareable" tasks described above, and how they develop their "know-how-to-cooperate" capacity. The definitions provided by both supervisory control and cognitive psychology allow the type of assistance under study to be determined. In this paper, the type of assistance, or the know-how of the assistance tool, is defined as the tool's capacity to control the longitudinal and the lateral trajectory of an automobile, with the implemented task being " to avoid a collision". In this "collision avoidance" situation, the response time is too short to allow the driver to allocate the task. In such cases, the cooperation taking place involves performing automobile control actions rather than advance decision-making, thus excluding the explicit mode of cooperation. However, both types of cooperative structures were experimented with. Vertical cooperation was used in its passive form, allowing the assistance tool to provide warnings and information about the traffic situation; under experimental conditions, this was called the diagnostic mode (DM). On the other hand, horizontal cooperation in the implicit mode allowed the assistance tool to both provide warnings and information, and control the vehicle in order to avoid collisions; under experimental conditions, this was called the automatic mode (AM). The know-how of the assistance tool is composed of its ability to detect accident-creating situations, to make decisions and to control the vehicle. Its know-how-to-cooperate is its ability to realize that the driver either cannot or will not do something to avoid the collision. The tool, then, must be able to adapt to every driver's driving style (e.g. economical or sporting) and to every driver's general mental state (e.g. workload and stress or attention levels).

Few studies have dealt with automatic controls that prevent drivers from controlling their vehicle. The action of the assistance tool is often hidden to drivers, and no information is provided. Technical feasibility studies have tried to build model for controling the vehicle, but it seems difficult, especially under adverse conditions (Lauffenburger, *et al.*, 2003). Kato et al. has considered the building of a common work space, providing drivers with a diagram of the traffic situation, and allowing them to declare their intentions to other drivers. Though the technical feasibility was proved, no analysis was done of the cooperation between the driver and the assistance tool (Kato, *et al.*, 2002). Another interesting study presents the results of experiments with different assistance tools which provide diagnostic or automatic control. The results of this study underline that drivers prefer assistance tools that do not act directly on the vehicle (Comte and Jamson, 2000). The following sections describe the assistance tools that we propose and the experimental protocol that we used to study cooperation.

3. ADVANCED DRIVING ASSISTANCE TOOL

The assistance tool sets off a repetitive warning beep, and justifies the warning by displaying diagrams on a small screen placed on the dashboard. The diagrams represent one of the emergency traffic situations triggered during the experimental scenario. The situations are triggered and the assistance tool acts under the principles of the Wizard of Oz 0(Maulsby, *et al.*, 1993), which means that rather than programming the assistance tool to act, its actions are simulated by a human operator hidden in the room. This set up keeps the experimental platform under constant supervision and allows the Wizard access to more information than the subject driver, particularly in terms of the timing of the emergency situation. The Wizard can control the situation by slowing the vehicle down or by swerving to avoid an obstacle. The series of warning beeps inform the driver that the assistance tool is controlling the vehicle, meaning that the driver's actions will not change anything. The beeping stops when the assistance tool returns control to the driver, after it has ascertained that the situation is stable.
The emergency situations are presented with the diagnostic and the drawing associated:

- Emergency braking 1: in the right-hand lane, a vehicle positioned in front of the subject vehicle in the traffic stream, brakes suddenly. In the diagnostic mode (DM), the assistance tool displays only a diagram. In the automatic mode (AM), it slows the vehicle down (cf. Fig. 1).

- Emergency braking 2: in the right-hand lane, a vehicle positioned in front of the subject vehicle in the traffic stream, brakes suddenly. The assistance tool displays a diagram in DM, but slows the vehicle and swerves to overtake the braking vehicle in AM (cf. Fig. 1).

Fig. 1. Diagram associated with both “Emergency braking” situations

- Subject vehicle is cut off 1: the subject vehicle is overtaking several vehicles and one of them pulls out just in front of the subject vehicle. The assistance tool displays a diagram in DM, and slows the vehicle down in AM (cf. Fig. 2).

Fig. 2. Diagram associated with the situation “Subject vehicle cuting off 1”

- Subject vehicle is cut off 2: a overtaking vehicle in the left lane pulls back into the right lane, directly in front of the subject vehicle. The assistance tool displays a diagram in DM, and slows the vehicle down in AM (cf. Fig. 3).

Fig. 3. Diagram associated with the situation “Subject vehicle cuting off 2”

- Emergency braking 3: a vehicle positioned in front of the subject vehicle in the traffic stream breaks suddenly due to a pedestrian or a stopped vehicle. The assistance tool displays a diagram in DM, and slows the vehicle down in AM (cf. Fig. 4).

Fig. 4. Diagram associated with the situation “Emergency braking 3”

- Failure to give way: a vehicle does not respect the stop sign that gives the right of way to the subject vehicle. The assistance tool displays a diagram in DM, and slows the vehicle down and swerves to avoid the collision in AM (cf. Fig. 5).

Fig. 5. Diagram associated with the situation “Failure to give way”

The type of diagram was chosen based on the results of experiments done in 2001 with the driving simulator. Three types of diagrams were tested: a road sign “danger”, a pictogram with a short description of the situation like the ones shown above, and a real view of the road with precise description of the situation. The second type of diagram was preferred by the subjects and provided the best results in terms of provoked reactions (Dezouter, 2001). This type of picture was not too difficult to read and the red triangle, well-known by drivers, was easily visible on the screen.

Since it was not possible to teach the drivers in our study to read the diagrams without revealing the emergency situations programmed during the scenarios, drivers were asked to complete a questionnaire evaluating several diagrams, among them the six used in our experimental scenarios.

4. EXPERIMENTAL PROTOCOL

The experiments were conducted on the LAMIH driving simulator, SHERPA (acronym for “Simulateur Hybride d’Etude et de Recherche de PSA Peugeot Citroën pour l'Automobile”). SHERPA is a fixed-base simulator, able to project images on four screens, thus providing a 180° panoramic front view and a 45°rear view (cf. Fig. 6).

Thirteen subjects, 2 women and 11 men, participated in this experiment. They were each asked to make 3 scenarios, *i.e.*, 3 runs of 25 kilometers. The first run established the reference condition. In the second run, conducted in the diagnostic mode (DM), the assistance tool provided warnings, and in the last one, conducted in the automatic mode (AM), the assistance tool controlled the vehicle. During each scenario, the drivers had to react to events occurring during 5 traffic situations and to comment on them during a replay of their recorded reactions.

Fig. 6. LAMIH driving simulator

Much data about the interactions between the driver, the vehicle and the environment were recorded during the simulation runs, including driver control input, dynamic vehicle responses and scenarios. The drivers' postures (cf. Fig. 7), spontaneous verbalizations and comments during the replay, both concerning the scenarios and their state of mind during the different runs were also recorded.

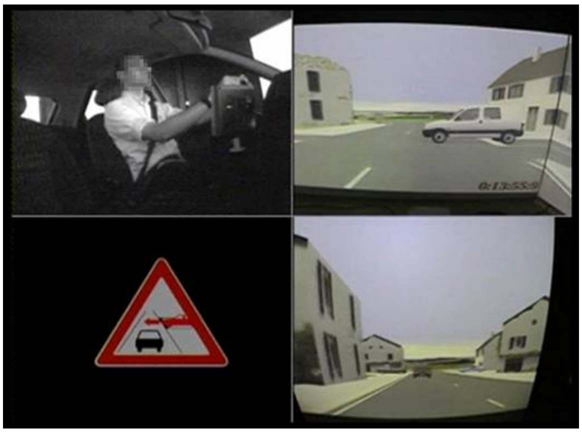

Fig. 7. Video recording (driver posture, front view, back view, diagram)

Before and after the training sessions and after the experimental run, the subjects were asked to complete questionnaires evaluating their driving characteristics (behavior patterns), the effects caused by the experiment and the simulator (fatigue, stress, headache, queasiness, eye ache), and their reaction to each separate situation in terms of “satisfaction, stress and effort”. Other questionnaires attempted to assess the cooperation between the driver and the assistance tool from the driver's point of view. One of these questionnaires, concerning the use of the assistance tool and its parameters, asked the driver to watch the replay of one, two or three interesting situations during which the driver had a short time to react, and to comment on the actions taken. Two other more general questionnaires were filled out following the first. One asked about the potential changes in the driving behaviour due to the assistance tool; the second asked about their interaction with the assistance tool, in terms of the type of task allocation, the display screen and the information presented on it, and their personal strategy for assistance tool use.

5. RESULTS

The first result was that all the experiment participants were surprised when the accident-causing situations were triggered. They all tried to avoid each collision as if it was a real accident situation.

5.1 Answers to the questionnaires about stress, satisfactiction and the effort needed to deal with the emergency situations

One questionnaire was used during the subjects' auto-evaluation of their reactions to the different emergency situations triggered during the experiment. Each subject was asked to watch the video recording and to answer many questions about the stress, satisfaction and effort engendered by each situation and for each experimental condition (without assistance, diagnostic mode, automatic mode). For each evaluation, the subjects were asked to position their response to the item by marking a cross on a 10-cm line.

For example: What was the level of effort needed to deal with this situation?

very low ____________________________ very high

The drivers' answers to the question about stress differ more according to the type of the emergency situation than according to the experimental mode (cf. Table 1).

Table 1 STRESS PROVOKED BY DEALING WITH SITUATIONS

	Without assistance	Diagnostic mode	Automatic mode	Results by situation
Emergency braking	3.95 (2.47)	4.23 (2.23)	3.05 (2.80)	3.71 (2.58)
Cut in	4.22 (1.96)	4.69 (2.18)	4.40 (3.11)	4.42 (2.44)
Pull out	4.47 (2.47)	4.55 (1.87)	4.62 (2.85)	4.55 (2.42)
Stopped vehicle	5.11 (2.22)	1.91 (1.26)	5.63 (2.77)	4.09 (2.69)
Failure to give way	7.00 (1.78)	7.21 (2.42)	5.47 (2.70)	6.56 (2.18)
Results by mode	4.62 (2.44)	4.62 (2.33)	4.16 (3.02)	

Data presentation : mean (standard deviation).

Very little can be said concerning the three modes. The results are mainly different in the "Failure to give way" situation. Because this situation took the drivers by surprise, leaving too little time to react, the only way to avoid the collision is to brake and swerve. Thus, it is perhaps more comfortable, and also less stressful, to know that an assistance tool is able to control the vehicle.

There is very little difference between the answers concerning the effort needed to deal with emergency situations, but they all underline that the more drivers are assisted, the less they need to expend effort to control the emergency situation (cf. Table 2). This seems to be the same regardless of the emergency situation.

Table 2 EFFORT NEEDED TO DEAL WITH SITUATIONS

	Without assistance	Diagnostic mode	Automatic mode	Results by situation
Emergency braking	3.78 (2.50)	3.96 (2.44)	2.75 (2.59)	3.47 (2.57)
Cut in	4.06 (2.35)	4.49 (2.43)	2.82 (2.78)	3.81 (2.61)
Pull out	4.18 (2.46)	3.33 (2.26)	3.81 (3.09)	3.77 (2.64)
Stopped vehicle	4.30 (2.25)	2.09 (1.67)	5.92 (2.65)	3.94 (2.67)
Failure to give way	4.86 (2.65)	4.62 (2.93)	2.86 (2.63)	4.08 (2.89)
Results by mode	4.12 (2.47)	3.89 (2.53)	3.18 (2.86)	

Data presentation : mean (standard deviation).

The results about the satisfaction pertain only to the modes "without assistance" and "diagnostic", because drivers can not evaluate their satisfaction if the assistance tool performed the action (cf. Table 3). In general, drivers show less satisfaction with their performance in the "Failure to give way" situation, and their satisfaction is marked less when they are unassisted . Certainly, it was more difficult to avoid the collision in this scenario than in the others (5.10), so they are happy to have an assistance tool to help them (6.12).

Table 3 SATISFACTION LEVEL TO DEAL WITH SITUATIONS

	Without assistance	Diagnostic mode	Results by situation
Emergency braking	6.91 (2.34)	7.10 (2.01)	6.84 (2.44)
Cut in	6.70 (2.12)	7.42 (2.77)	6.44 (2.79)
Pull out	7.91 (1.49)	7.35 (2.55)	7.04 (2.60)
Stopped vehicle	7.91 (1.59)	5.59 (2.09)	7.32 (2.10)
Failure to give way	3.93 (2.65)	6.12 (3.31)	5.10 (3.21)
Results by mode	6.78 (2.42)	6.98 (2.60)	

Data presentation : mean (standard deviation).

5.2 *Answers to the questionnaires concerning the adequation between the assistance tool's decisions and the drivers' decisions*

The following results come from the analysis of the drivers' answers to two questions concerning their assessment of the assistance tool's decisions. The questions are: "Do you agree with the actions taken by the assistance tool ?" (question 1), and "Is the decision made by the assistance tool the same as yours ? " (question 2). As before, drivers were asked to position their response to the item by marking a cross on a 10-cm line.

Table 4 ADEQUATION BETWEEN THE ASSISTANCE TOOL'S DECISIONS AND DRIVERS' DECISIONS

	Question 1	Question 2
Emergency braking	6.24 (3.93)	5.98 (4.17)
Cut in	8.58 (2.20)	8.64 (2.19)
Pull out	8.53 (1.71)	8.65 (1.70)
Stopped vehicle	9.57 (0.31)	9.38 (0.14)
Failure to give way	6.98 (2.48)	6.98 (3.27)
Results by question	7.54 (3.09)	7.47 (3.35)

Both questions are very similar; the first one assesses the actions of the assistance tool and the second one, its decisions. The similarity between the answers underlines the consistency of drivers, but also that the assistance tools actions conform to with drivers' decisions. Drivers mainly agreed with the assistance tool's action and decision in the first three emergency situations. The difference between these situations and the last two is the swerve. The automatic control of longitudinal movement better matches driver expectations than the automatic control of lateral movement.

5.3 *Driver's attempt to control the vehicle in the automatic mode*

Drivers react in difference ways to the use of the assistance tool. Some subjects try to control the vehicle even when it is under the control of the assistance tool, despite the fact that their actions cannot modify the trajectory; others prefer leave the control to the assistance tool. The reactions were coded using information from the raw data, the video records and the self-evaluation. Only 12% of the subjects never tried to control the vehicle during the automatic mode, whether by using the pedals or the steering wheel. Possible reason include trust in the assistance tool or a willingness to test it. Of all the subjects, 46 % did nothing to control the situation with the pedals from the beginning to the end of the situation. (cf. Fig. 8) (No action: 46%; Intentional: 21%; Instinctive: 33%). The subjects who tried to control the vehicle in the automatic mode can be divided into two groups: those who act intentionally, and those who act instinctively. Intentional action occurs at the end of the assistance tool's control, for example if the driver feels that the assistance tool isn't braking enough Instinctive action, on the other hand, is usually engaged just after the assistance tool takes control, meaning when the accident situation is triggered.

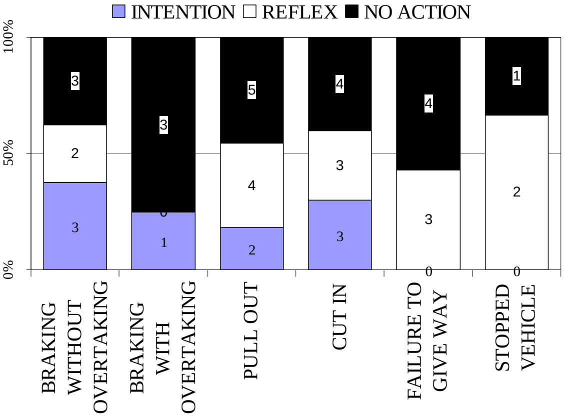

Fig. 8. Action of the subject on the pedals in the automatic mode for each emergency situation

Among the six emergency situations, the different situations led to more or less intentional action; only two led to no intentional action at all (cf. Fig. 8): the "failure to give way" situation, and the "emergency braking" situation caused by a stopped vehicle. For the first one, it would seem reasonable to attribute this lack of action to the surprising nature of the situation; the driver literally has no time to react. The second one, however, is difficult to explain because this scenario was not used very often. No instinctive action was taken in the "emergency braking" situation when a preceding vehicle slows down, and the assistance tool reacts by overtaking. This is perhaps because the assistance tool did exactly what the driver would have done. The only driver who tried to control the vehicle intentionally explained his actions as a reaction to the special "corner" situation. In the case of the “cut in” situation, it would seem that the drivers and the assistance tool don’t perceive the situation in a same way given that the drivers accelerated and the assistance tool slowed down.

Only 23% of the subjects did nothing to control the vehicle by using the steering wheel, which is half of the result for the pedals. These results lead us to believe that is may be easier to leave the control of the vehicle to the assistance tool for longitudinal maneuvers than for lateral ones. The 67% of the subjects that did try to act using the steering wheel can be divided into four behavior classes. Drivers in three of those classes—“Same”, “Less” and “More”—all wanted to turn in the same direction as the one decided by the assistance tool, though those in the "Less" and "More" groups would have turned to a lesser or greater degree (Same: 9%; Less: 37%; More: 30%). (Please note that although the drivers could turn the steering wheel, they had no effect on the action taken when the assistance tool was in control.). The 4th class, “Against”, represents drivers who tried to turn the steering wheel in the opposite direction from the one selected by the assistance tool (24%). An analysis of this result in terms of the different emergency situations offers an explanation for this behavior. The data for each emergency situation are presented in Fig. 9.

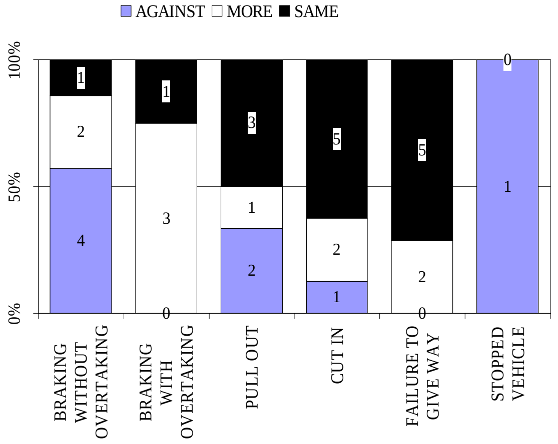

Fig. 9. Action of the subject on the steering wheel in the automatic mode for each emergency situation

It is interesting to compare the first two emergency braking situations. The first one, without overtaking, provoked four different reactions against the assistance tool, while the second one, with overtaking, provoked no reaction at all. This difference could be due to poor recognition of the drivers’ intentions. The drivers wanted to overtake, but the assistance tool decided to slow down and stay in the right lane. In the “cut in” and “failure to give way” situations, the drivers seem to agree with the action taken by the assistance tool. The speed of the emergency situation may have had an effect on these results, like the ones concerning pedal use, though the swerve selected by the assistance tool is what the drivers say they would have chosen.

5.4 *Acceleration at the end of the automatic control*

In the automatic mode, the assistance is able to slow the vehicle down and swerve if necessary to avoid a collision, but it cannot accelerate to reach cruising speed. So, before the period of automatic control ended, some drivers felt the need to accelerate (37%). Because the beep is not continuous, drivers don’t know exactly when the automatic control will end, so they accelerate a short time (35%) to find out if the mode has returned to manual. Only 2% accelerated a long time until manual control was returned. The communication between the tool and the driver could be improved by installing a signal light on the dashboard, for example.

There are two classes of drivers who accelerate after the end of the automatic control. The first one is composed of the drivers who accelerate immediately (54%), and the second one of those who delay their action (46%). The type of acceleration differs from driver to driver, and can be classified as weak (0% to 30% of acceleration), medium (30% to 60%) or strong (60% to 100%) (cf. Fig. 10).

The majority of the drivers accelerate immediately. Some drivers delayed the acceleration and then accelerated with moderation. This information will allow to improve the assistance tool, by helping to leave the vehicle in the best condition for the driver regaining manual control.

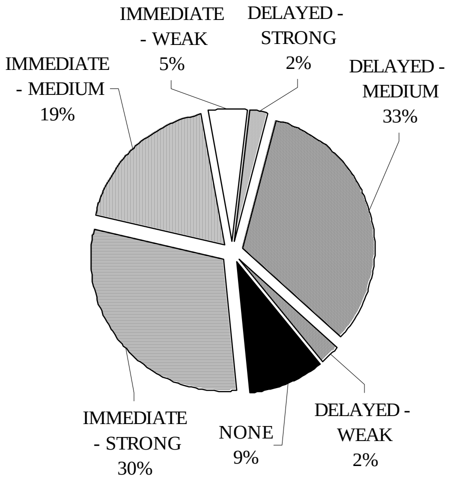

Fig. 10. Acceleration of the subject after the end of the automatic mode

5.5 *Driver’s use of the information on the lateral screen*

To facilitate cooperation with the assistance tool, the driver is able to feel the movements of the vehicle caused by the tool, but another possibility is watching the diagram displayed on the small screen to the right of the steering wheel. Any new information is signaled by a beep; otherwise the screen is blank. Driver interaction with this screen can be analyzed via the video recording of actual behavior and the drivers' responses on the questionnaires.

It appears that 35% of the subjects didn’t watch the screen. These drivers might not have had enough time to turn their heads to look at the diagram without missing essential information about the emergency situation needed to control the vehicle. In addition, by the end of the situation, the driver doesn't need the information any more. A comparison of the automatic and diagnostic modes shows that drivers are more liable to look at the screen when the vehicle is in automatic mode (not looking: AM: 28%; DM: 40%). In AM, drivers need the information to know what the assistance tool is doing, but in DM, drivers have less time to watch the screen because they have to control the vehicle. The subjects who watched the diagram were categorized into 3 classes. Because the diagram remains on the screen several seconds after the end of the emergency situation, a coding was done to determine when the driver was looking at it: "Before", "During" or "After" the situation. The use of the screen in the different modes is very different. In AM, drivers mainly look at the screen during the situation, whereas in DM, drivers mainly look at the screen before the situation (AM: Before: 10%; During: 51%; After: 39%) (DM: Before: 46%; During: 30%; After: 24%). These results confirm our first hypothesis: in AM, drivers need information during and after the situation to be sure that the assistance tool has detected the same situation as they have and to supervise what it is doing. In DM, drivers watch before and during the situation to see if the assistance has supplementary information that would help them better control the vehicle.

6. CONCLUSION AND PERSPECTIVES

In order to study the cooperation between drivers and an advanced driving assistance tool, an experiment was conducted on a driving simulator. Three experimental scenarios with five emergency situations were crossed with three experimental conditions: without any assistance tool, with a diagnostic assistance tool and with an assistance tool capable of controlling the vehicle. Thirteen drivers took part in the experiments, and filled out several questionnaires. The drivers' answers to these questions and the recorded raw data from the vehicle simulation were coded and analyzed to produce the results reported above.

Drivers acknowledge that they have to make less effort to control the emergency situations in the automatic mode. The "failure to give way" situation stands out from the other ones, both in terms of decreased stress, in the automatic mode, and increased satisfaction, in the diagnostic mode; it is perhaps because it is so difficult to control this very surprising situation. Drivers agree with the decisions of the automatic control more for longitudinal maneuvers than for lateral.

The data collected underline that only 12% of drivers leave total control to the assistance tool during the emergency situations. Many drivers (46%) tried to brake or to accelerate, and 67% of drivers would have preferred more control of lateral movement. This appears to be mainly due to poor recognition of the drivers' intentions and a different perception of the situation. The objective data confirm the subjective data presented above, i.e., drivers have perhaps more trust, or are more used to leave the longitudinal control to an automatic assistance tool than the lateral one. More and more cruise controls equip now cars (Tricot *et al.*, 2004); warning assistance tools concerning risk to leave the road only begin to be proposed by some car manufacturers.

Mainly because of communication problems, 37% of drivers accelerate before the end of the automatic control, which indicates that the driver/assistance tool communication must be improved. The diagnostic mode seems to leave less time for drivers to watch the screen on the dashboard. In DM, 40% of drivers don't look at the diagrams; those who use the screen usually look at it before starting the action, probably to compare their own information to that of the assistance tool. More drivers watch the screen in the automatic mode (72%), though usually during and after the action in order to supervise to assistance tool. The scanning behavior is different according to driving experience of subjects, and knowledge they have concerning the assistance tool, but these experiments cannot underline this type of result (Espié *et al.*, 2004).

These first results are encouraging, but it isn't possible to compare the three experimental conditions in order to analyze drivers' actions in each of them. The little number of drivers, the difficulties to repeat a same situation in a same context for each driver, and the difficulties to simulate the assistance tool, prevent the comparison.

New experiments will be soon completed with more drivers, with more or less experience, and a real assistance tool, instead of one simulated by a Wizard of Oz, and other types of communication, such as haptic information, will be tested. These experiments will be conducted on a new dynamic version of the driving simulator, with an integrated motion system. A 6 DOF Hydraudyne electrical platform has been installed in the simulator room and a new smaller car mock-up (Peugeot 206) is being equipped for use on the motion platform. The driving simulator realism will be improved, it is important to be able to feel the car movement, especially when an assistance tool can modify this movement.

ACKNOWLEDGEMENT

This study was conducted within the framework of the regional TACT GRRT project (TACT GRRT is the acronym for "Technologies Avancées appliquées aux Communications et aux Transports Terrestres / Groupement Régional Nord-Pas de Calais pour la Recherche dans les Transports) and has been funded by the Regional Council of the Nord/Pas-de-Calais (France) and the Europeen Union.

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