TO BE AVAILABLE OR NOT, THAT IS THE QUESTION: A PRAGMATIC APPROACH TO AVOID DRIVERS OVERLOAD AND MANAGE IN-VEHICLE INFORMATION

Bellet Thierry
Manzano Julie
The French National Institute for Transport and Safety Research (INRETS/LESCOT)
France
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ABSTRACT

This research takes place in the AIDE[1] project [1] and is an extension of the INRETS-LESCOT previous work done in CEMVOCAS[2] project [2]. Synthetically, LESCOT objective in AIDE is to design and develop a *Drivers Availability Estimator* module (DAE) in charge to assess drivers' ability to receive and process information while driving.
In order to study drivers' level of availability, an experiment has been conducted on open road, in real driving conditions. This paper will present the methodology carried out and the data collected. Thirty drivers have participated to this experiment. They had to drive an experimental car by using a guidance system. They also had to describe visual and auditory information displayed by a home made device introduced on the car. After driving, participants were interviewed in order to collect their opinion concerning the message impact on the primary driving task.
This paper will present the method used and the main results obtained. Then, we will discuss the concept of "availability" according to the driving conditions (current road infrastructure, goal followed, driving action carried out and event occurrences), and we will present the interest and the validity of this method for "demanding driving situation" classification, witch is the main goal of the DAE module diagnosis.

INTRODUCTION: CONTEXT AND OBJECTIVES

During the two last decades, the quantity of in-car information sources has considerably increased, under the combined effect of several phenomenons. The first change is due to the development of driving aid systems. If, up until now, only a few systems are already on the market (e.g. vehicle guidance and navigation aid, traffic information systems, car status alarms), several technologies are now in pre-market phase and/or start to be implemented on top-range cars. Even if each of these technologies has benefited of an ergonomics design in order to support their integration into the primary driving task, the increasing number of aid functions and the cumulative logic of the systems integration in the car (which everyone can install him/herself in his/her own vehicle) can nevertheless creates several risks. The first one is the risk of overloading the driver with information. The second one is the risk of inter-messages conflict if different pieces of information are delivered simultaneously. A centralised management device is consequently essential to avoid these risks.
Another source of information in the car is the telephone. With the development of mobile phone technology, the telephone has made a massive entry into vehicles without anybody really being capable of controlling this phenomenon. So, today we are witnesses to the introduction of a truly parallel task – telephoning – that is liable to enter into conflict with the driving task. In this context, it is essential to develop a device able to take into account the requirements of the driving situation in order to manage telephone in "real time". This is necessary both for filtering incoming calls in demanding situations, and to assist the driver in a more safety-conscious management of telephone conversation while driving.
Lastly, the interest in automobiles that is shown by information and telecommunications industries at present is a sign of a new diversification of information sources in the car (e-mails, fax, web services and other "office functions"). Here again, the easiness of transporting these technologies will make them difficult to control (some of them are already available on mobile phones). Therefore, it would be better to think about a global technological solution today, rather than hope to solve the problem on purely legislative levels at a later date.
In this context, several problems need to be solved in a very short term: how to avoid the driver overloading in front of this heterogeneous information flow? What information should be delivered, and when? How to avoid detrimental interference between different pieces of information? And, on an even more general level,

1 AIDE : Adaptive Integrated Driver-vehicle interfacE (6th PCRD Européen Project 2004-2008)
2 CEMVOCAS : *CEntralized Management of VOCal interfaces aiming a better Automotive Safety* (5th PCRD Européen Project 1997-2001)

how to avoid the negative impact of these sources of information on driving safety? All these considerations require to design an *integrative* technology that will provide a centralised management of on-board information. To be really safe, information management must be also adaptive. By *adaptive*, we mean being able to adjust the management and the Human-Machine Interaction modes according to the current driving context and the momentary driver's capacities. Indeed, the driver is not always in condition to receive and/or to process messages sent by information systems. Main reasons are the driver's own status (like physiological status) and the driving situation demand (complexity of the road environment, level of traffic, weather conditions, manoeuvre that requires all his/her attention).

The objective of the AIDE project [3] is to design, develop and validate an innovative Adaptive Integrated Driver-vehicle interfacE (AIDE) which aims to maximise the efficiency and the safety benefits of advanced driver assistance systems and to minimise the level of workload and distraction imposed by in-vehicle information systems and nomad devices (Amditis et al, 2005).

As an "adaptive" and "integrative" information manager, AIDE device should contribute to solve these problems by implementing a set of adaptive interface functions. These could include, for example, delaying non-critical information in demanding driving situations and adapting the timing and intensity of warnings in relation to the driver status and/or characteristics.

In the frame of this global AIDE project, INRETS-LESCOT sub-task is to design and develop a specific module called *Drivers Availability Estimator* (DAE). This module is in charge to assess drivers' level of availability to receive and process information while driving. This module will has to manage the information intended to the driver in an adaptive way, according to the requirements of the current driving task and the availability/unavailability status of the driver.

Availability is a user centred concept defined at LESCOT during CEMVOCAS project [2], in order to "translate" the driving demand problem in a pragmatic way focused on attention sharing and in-car information management: if the driving demand is high, driver's attention must be focused on the driving task and, consequently, s/he is not available to do another task. On the contrary, the driver is potentially available when the driving demand is low.

Nevertheless, availability is not equal to mental workload [4]. If a high workload generally means that the driver is unavailable, low workload doesn't systematically indicate that a message could be send at this time. Sometimes, low workload situation also require all driver's attention. Indeed, workload is only one of the sub-dimensions of the most global concept called "availability". A very important one, but only one of them. To illustrate our purpose, let us considering an example of driving action, like overtaking a vehicle. On the one hand, it is surely possible to find overtaking situations with a very high level of workload (like overtaking a long truck on a short straight line under the rain) but, on the other hand, overtaking situations with a low workload are also possible (overtaking a slow car on a straight line under the sun). Now, if you consider the problem of telephoning while driving, which is particular relevant in AIDE project: how many drivers would like to have a phone call just when they start to overtake? And how many would decide to launch a phone conversation just before to start an overtaking manoeuvre? Probably not any one. If they have the choice, all drivers will probably decide to achieve the overtaking before calling or answering. Overtaking situation is not a particular case. The same reasoning could be more or less applied to roundabout or highway entrances, left turn situations, intersection crossing when the driver doesn't have the priority, pedestrian occurrences on the road, and so on. For all of these demanding situations, the driver is not available for a phone call, even if the mental workload may be low.

As regards this analysis, what is the real "Shakespearean question" for on-board information management: workload, or availability? For us, availability assessment is more relevant than workload measurement for an intelligent information manager, especially when considering the filtering problem (to allow or not information diffusion), or in order to support a safer attention sharing between driving and extra-driving activities.

Availability is clearly dependant of driving situation demand. First at all, driving demand requires as much *strain* (external constrains) as *stress* (subjective level). We are surely agree with the classical ergonomics distinction between external demands *versus* individual reaction to these demands [4], but according to the "adaptive HMI" objectives, an availability / unavailability diagnosis seems more relevant and pragmatically easiest to implement than a workload assessment. At last, but not least, *availability* aims to take into account the *potential*, as well as the *effective* driving demand. Indeed, it is not relevant to send a phone call in a roundabout approaching phase, because of the potentiality rapid variation of the driving situation. At every moment, the situation can change and become critical. It is consequently essential that the driver stays focused on the driving task. For a safe information management, a phone call must be for example delayed from the beginning of the approaching phase, independently

of the traffic conditions and the driver's mental workload at this time.
Previous works done in CEMVOCAS project [2] has shown that it's possible to partly assess the driver's availability level by considering data coming from "basic" sensors which reflect the driver's actions on vehicle controls (like pedals, steering wheel, blinkers) and the dynamics of the car (vehicle speed, accelerometers). If improvements are required to have a more robust technology, CEMVOCAS final tests in real driving conditions with end-users have clearly confirmed the feasibility and interest of an "availability diagnosis" for managing on-board information. However, CEMVOCAS experiment has only empirically validated the *availability* concept by a pragmatic way. It is then expected through this new AIDE experiment, based on both objective performances and subjective measures, to collect new materials for an in-depth analysis of the availability concept.
The main focus of this paper will be the method implemented in real driving condition with potential end-users of AIDE device. Around of 50 hours of on-road ecological data have been collected and will be presented and discussed in the following sections.

METHOD

For this study, 30 drivers have participated. They had to drive an experimental car by using a navigation system. They also had to describe visual and auditory information displayed by a home made device introduced on the car. After driving, participants were interviewed in order to collect their opinion concerning the message impact on the primary driving task and their availability to receive and process it.

Apparatus

Each participant drove the INRETS-LESCOT experimental car (Renault Scenic). Various apparatus were located on the vehicle: miniature cameras, digital video recorder, sensors to collect driver's actions on commands, and external sensors for road environment perception (stereoscopic cameras and telemeter).
A computer was recording objective parameters collected via the vehicle sensors.
An experimental home made system, displaying visual (pictograms or texts) and auditory information (auditory messages) has been introduced in the vehicle.
During the entire experiment, drivers were filmed by video cameras. Five main views were recorded: a view of the driver (allowing driver's face observation and eyes movement analysis), a view of the road scene ahead (driving environment in front of the car), a view of the outputs of perceptive system available on the experimental car (allowing traffic conditions analysis), a view of the messages sending device used by the experimenter, and a view of some objectives parameters (speed of the car, pedals status, etc) also collected during the experiment. A microphone has been used to record all drivers' spontaneous comments and/or self-assessment measures during the driving task.

Itinerary

The experimental road we have selected is composed by 70 Km near Lyon, including motorway, national, rural roads and urban streets in order to have a whole of different situations related to the static and dynamics environment. Various configurations of road have been chosen both in urban and country areas like roundabouts, intersections, straight sections, curves, entrances and exits of motorways, an so on.

Driver's tasks:

The experiment was divided in 2 main phases of 1 h 15: The *Driving Part* and the *Interview Part*.
The Driving Part consisted to let the participant drive on the itinerary. While driving, the participant had to follow the route according to visual and auditory information given by the on-board navigation system. Simultaneously, s/he had to run a listening and describing task according to messages emitted by the on-board system described above. When considering this experimental task, the information to deal with were not related to the driving task and induced a verbal answer about what s/he had heard or seen from the onboard system.
On the route, messages were sent at 50 preset areas on the itinerary. These areas were the same for all participants. Other messages have been sent to assess the driver's availability in particular high demanding situations, if they occur (e.g. overtaking a truck, pedestrians in crossing, obstacle occurrences). However, when considering the route, the type of messages sent (auditory, textual or pictogram) was counterbalanced from a participant to another for each situation.
The informations were sent while the driver was performing his/her manoeuvre, like turning to the left or to the right at intersections, entering in roundabout, entering on motorway, going in a straight line, changing of lane, overtaking, etc. The number of sending auditory, textual and pictogram messages during the route was respectively the same. Finally, three groups of participant have been consequently formed. Moreover, in order to collect "data of reference", some drivers (control group) didn't receive any messages during the trip. All trials were carried out in daytime. Time of trials had

been chosen to avoid too high density traffic and traffic jam.
The *Interview Part* was taken place immediately after driving, on a laboratory room. The participant had to watch the video tape recorded during the driving phase. For all the situations with messages the driver had received when s/he was performing his/her manoeuvre, s/he had to provide subjective estimates on different scales (see later). When considering the group without messages, they had to evaluate these various concepts too, at the same areas, as the other group.

Experimental procedure

At first and before starting the test, the experimenter had to globally describe what the driver would have to do: to drive a car by using the navigation system, describe the various messages s/he received from the on-board system and make a self-assessment of his/her own driving performance after performing each manoeuvres while receiving a message. The experimenter provided some examples to explain what the participant had to do when s/he received a guidance message and other messages. In order to know if s/he had understood the required task, the driver had to train with the description of the visual and auditory messages s/he got before leaving INRETS place. Instructions given to drivers were to respect the Highway Code Book in agreement with the traffic rules. Before going, the driver had to adjust the rear-mirror view and the seat.
On the route, the first three messages were necessary to make the experimenter sure that the participant was able to hear, to read and to describe the messages while driving in easy conditions. This first step was considered as training too. Then, the test began and the answers from the participants according to the message were recorded. All along the driving test, an experimenter was behind the driver and worked on a computer which was sending information to the on-board system. Another experimenter was on the left seat and recurrently invited the driver to provide his/her *real time self-assessment of driving task performance*, more particularly after each message delivery.
After driving, the participant had to watch a video tape of the experimental driving phase on the laboratory room. For all the situations with messages the driver had received when s/he was performing his manoeuvre, s/he had to provide a subjective assessment of:

- The disturbance effects of the message.
- The difficulties to perform the driving task.
- The visual message acceptance.
- The auditory message acceptance.
- A new self-assessment of driving task performance (without listening the real time value recorded while driving).

These subjective measures have been collected via a set of Likert non graduates scales (10 centimetres black line including only 0 on the left and 10 on the right; subject must put a cross on it). In the same way, the group without messages had to evaluate these various dimensions too.

Data collected

For each message sent to the driver, 6 subjective measures concerning the message impact on the primary driving task have been collected for each participant and for each preset areas of the itinerary. The performance related to the description of messages has been evaluated by the experimenter: 0 when the driver was not able to describe the visual or auditory message s/he had received; 1 when the driver partially described the message and 2 when the driver perfectly described it. This last measure is an objective one for the driver's availability level assessment.

Participants

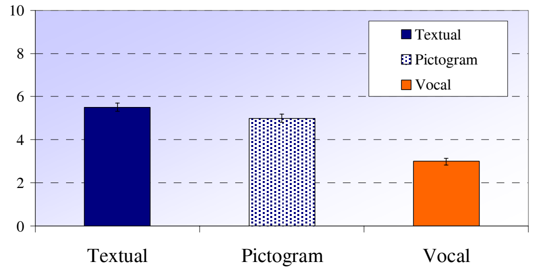
Thirty experienced drivers (15 males drivers, and 15 females drivers), between 23 and 60 years old, have participated to the experiment. They had a driving experience of 10 000 Km per year, which would be the average mileage for a regular driver in France, and driving licence of 5 years at least.
According to the experimental conditions, participants were divided into 2 groups:
One group was composed by 20 subjects who performed the driving task with visual and auditory messages (10 males drivers, and 10 females drivers).
The other group (control group) was composed by 10 subjects who achieved the task without receiving any information (5 males drivers and 5 females drivers).

RESULTS

In this section, we describe the results related to the subjective method implemented to assess driver's availability. Objective results concerning the messages performance are also displayed. All these measures are at first analysed for the whole itinerary and for all driving situations.

Global results for the whole itinerary and for all situations

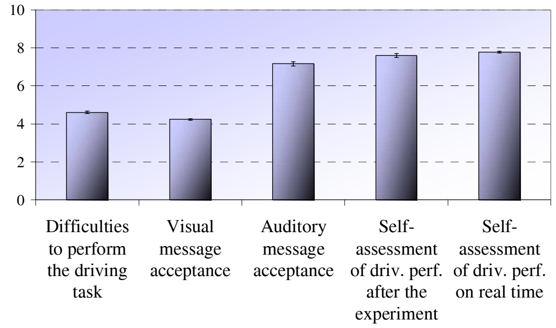
Message disturbance effect - In the following graphic 1, the subjective mean values of the disturbance effects of pictogram, textual and auditory messages are studied.



Graphic 1. Mean values related to disturbance effects of textual, pictogram and auditory messages for the whole itinerary.

When considering the disturbance effects of these 3 types of presentation, there are no significant differences between pictogram and textual messages (non parametric Mann-Whitney test, p=0,190).
On the contrary, concerning the disturbance effects induced by auditory messages, it is significantly lower (p<0,001).

Difficulties to perform the driving task - The graphic 2 displays the various mean values for other criteria related to the driver's availability for the whole situations.



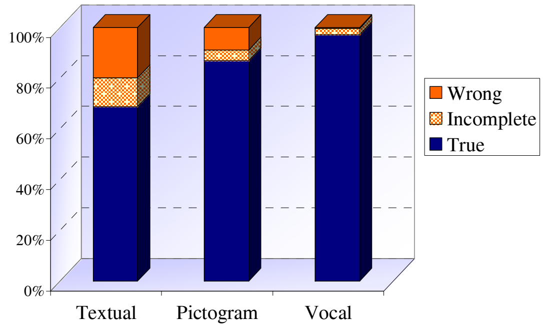
Graphic 2. Mean values of criteria related to driver's availability for the whole itinerary and for all conditions (with and without messages).

The mean value related to the difficulties that the participant had to perform the driving task is of 4,6. As we will see later, 4.6 (more or less 0.5) is also the frontier value between two main categories of driving situations particularly relevant for availability assessment: the *demanding situations* and the *non demanding situations*.

Visual versus Auditory message acceptance - Concerning the acceptance of the visual versus auditory messages, there are significant differences (non parametric Wilcoxon test, p<0,001): for drivers, auditory messages are easier to deal with than visual messages and the auditory message acceptance is significantly better than visual message acceptance (for text as well as for pictogram).

Real time versus after experiment self-assessment of the driving performance - Results related to self-assessment of the driving performance on real time *versus* after the experiment are not significantly different (parametric test t with paired samples, p=0,013). In fact, drivers are estimating their driving performance on real time as the same way as after the experiment.

Message performance - While driving, the participant had to describe or repeat the messages sent by the on-board system. The value affected to the message performance was 0 for a wrong description of the message, 1 for a partially correct description of the message and 2 for a correct description of the message.
The message performance of the driver for the whole itinerary is presented on the graphic 3 below.



Graphic 3. Textual, pictogram and auditory messages performance for the whole itinerary.

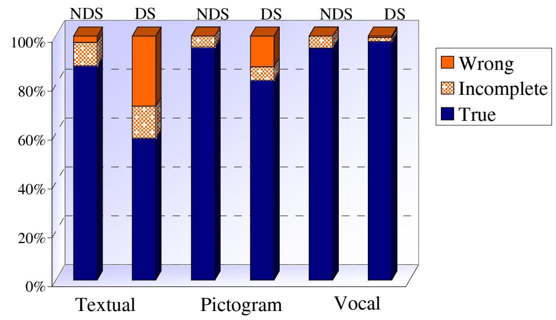
The performance is significantly changing according to the type of presentation of the message (KHI2 test, p<0,001).
In fact, the quality of the messages description is better for auditory messages (97% of true responses) than for pictogram messages (87% of true responses). Moreover, as a general rule, an auditory or a pictogram message will be easier to process than a textual message (69% of true responses). Furthermore, while driving, participants were more disturbed by a textual or a pictogram message than by an auditory message as it appeared on the graphic 1.
These results – which are in line with several classical results available in ergonomics literature (for example [5], [6], [7]) – are explaining why, in our experiment, the message performance is getting worse when the message is visual, especially textual**.** The main interest of this result for this section is the confirmation that our experiment doesn't introduce any experimental bias.

Demanding versus Non-Demanding situations

As explain in the introduction part, one of the aim of this experiment is to provide new materials for

an in-depth analysis of the *availability* concept empirically assessed and validated in CEMVOCAS project. According to CEMVOCAS experience, acquired on a close itinerary, message delivery during this new experiment has been partly done during *demanding situations*, partly done during *non-demanding situation*.
A typical non-demanding situation is an urban, motorway or rural straight line, without any traffic (or with a low traffic). In these cases, drivers are available and their attention share is generally not a problem for a safe driving.
Demanding situations constitute a more complex category. The level of availability depends on the road infrastructure complexity, the traffic condition, and the difficulty of the current manoeuvre carried out by the driver.
It is at least expected from this experiment to provide rational method and measures for driving situations categorization, according to the different level of availability assessed by the drivers.
In this second section, we present results focused on the global distinction between *demanding* versus *non-demanding* driving situations. Then, the third section will present an in-depth analysis of demanding situations.

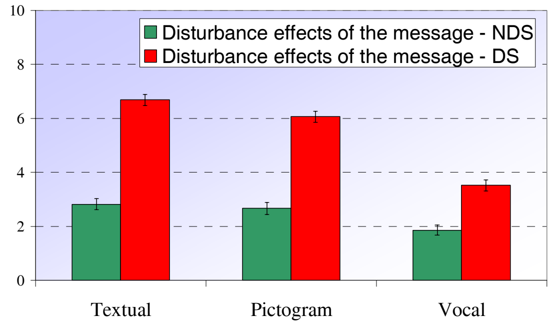
Message performance - The message performance of the driver for non-demanding *versus* demanding situations is presented on the graphic 4 below.
The performance is significantly changed according to the type of presentation of the message for demanding situations (KHI2 test, p<0,001) but not for non-demanding situations (KHI2 test, p=0,154).
For non-demanding situations, the rate of correct responses is higher than 85%: 88% for textual messages, 95% for pictogram messages, 95% for auditory messages. By contrast, when considering demanding situations, the quality of the messages description is better for auditory messages (98% of true responses) than for pictogram messages (82% of true responses).



Graphic 4. Textual, pictogram and auditory messages performance of the driver for Non Demanding Situations (NDS) *versus* Demanding Situations (DS).

Moreover, an auditory or a pictogram message will be significantly easier to process than a textual message (only 58% of true responses) in these complex situations.
When the sending message is a pictogram (KHI2 test, p<0,001) or a text (KHI2 test, p<0,001), there is a significant difference between non-demanding *versus* demanding situations indicating that these types of messages are more difficult to take into account by the driver when he's performing a difficult manoeuvre. For the driver, an auditory message will be easier to understand and take into account what ether the complexity of the situation. For this type of message, there are not significantly differences between non-demanding *versus* demanding situations (KHI2 test, p=0,474).

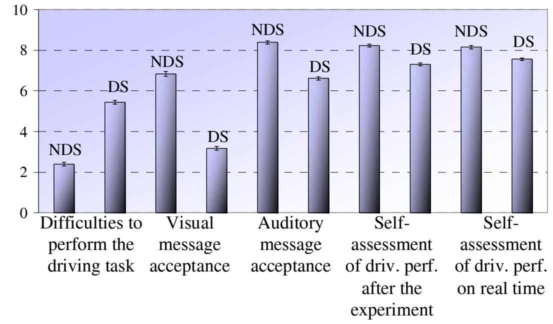
Message disturbance effect - In the following graphic 5, the subjective mean values of the disturbance effects of pictogram, textual and auditory messages are studied for demanding *versus* non-demanding situations.



Graphic 5. Mean values related to disturbance effects of textual, pictogram and auditory messages for Non Demanding Situations (NDS) and Demanding Situations (DS).

When considering mean values obtained for disturbance effects of textual, pictogram and even auditory messages, there are significantly higher when situations are demanding (parametric t test, p>0,001). In fact, values for disturbance effects of textual and pictogram are exceeding 6 for demanding situations. For non-demanding situations, these values are lower than 3.
By comparison, auditory messages disturbance effect in demanding condition is less important, but stays nevertheless high and significant.
These results indicate that, if drivers are generally able to receive auditory message whatever the conditions, negative impact and stress increasing could occur in demanding conditions.
Concerning textual or pictogram messages, disturbance effects are very high for demanding situations.
For non-demanding situations, drivers declare to be generally able to receive any type of messages without any major disturbance effect on the driving activity.

<u>Difficulties to perform the driving task</u> – The graphic 6 displays the various mean values for other criteria related to the driver's availability for demanding *versus* non-demanding situations.



Graphic 6. Mean values of criteria related to driver's availability for Non Demanding Situations (NDS) and Demanding Situations (DS) and for all conditions (with and without messages).

In connecting with the group of *non-demanding situations* previously defined, the driver was going in a straight line on urban, motorway, national and departmental areas with no or low traffic. For this category, the mean values for the *difficulties to perform the driving task* is of 2,4 on our subjective Likert scale.
Concerning the *demanding situations*, the driver was turning to the left in crossroad, crossing intersection without the priority, dealing with a right or a left tight curve, overtaking, was going in a straight line with traffic, entering in a roundabout, entering in a motorway, leaving a motorway, line changing to the left or to the right.
By contrast with non-demanding situations, *the difficulties to perform the driving task* are here significantly higher (more than the double) for a mean value for of 5,45.
This subjective measure is consequently strongly linked to the driving demand and well reflects the driver's level of availability. Indeed, the participant had significantly more difficulties to drive when situation were complex to manage (parametric t test, p<0,001).

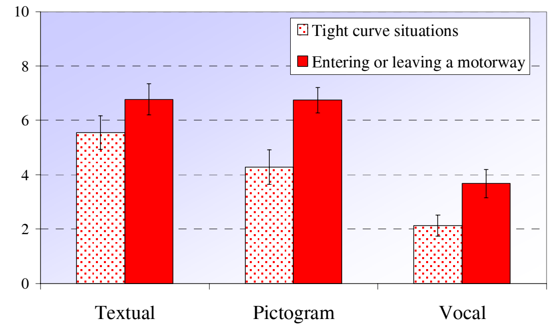
<u>Visual and Auditory message acceptance</u> - In the same way, a visual or an auditory messages are easier to accept when the situation is not difficult to manage (parametric t test, p<0,001), especially when the message is vocal (parametric t test, p<0,001). Thus, all these types of messages could be presented to the driver for non-demanding situations.

<u>Real time and after experiment self-assessment of the driving performance</u> - The mean values related to the driver assessment of his/her driving performance on real time and after the experiment are not significantly different each over for non-demanding as well as for demanding situations (parametric test with paired sample, p<0,001). These results are confirming the results obtained for the whole itinerary and let think that they could be gathered in only one measure instead of 2 measures. Moreover, the mean values related to the driving performance assessed on real time or after the experiment significantly decreased with the complexity of the situation (parametric test with independent sample, p<0,001). However, even for a demanding situation, driver's performance value exceeds 7 (whatever the moment of assessment: on real time or after the experiment). It means that our subjects are globally satisfied by their driving performances for the whole itinerary.

In-depth analysis of demanding situations

In this section, we are presenting an in-depth analysis of driver's availability measures in demanding conditions. We focus our analysis on two particular cases of demanding situations: dealing a tight curve on the left and on the right *versus* entering or leaving a motorway area (with traffic).
We will see in this section how the different subjective measures are evolving between these two groups of demanding situations.

<u>Message disturbance effect</u> – The graphic 7 below is presenting the disturbance effects of textual, pictogram and auditory messages on the driver in curve *versus* s/he on motorway entering or leaving (with traffic).

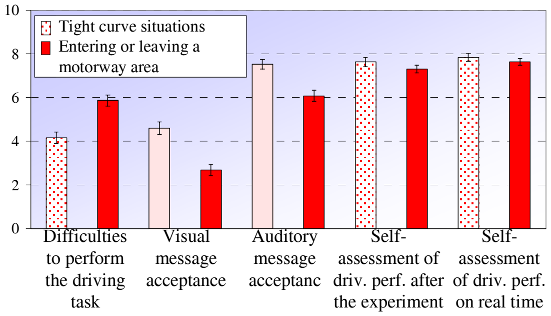


Graphic 7. Mean values related to disturbance effects of textual, pictogram and auditory messages in the case of dealing with a curve versus entering or leaving a motorway area.

When considering mean values obtained for disturbance effects of pictogram and auditory messages, there are significantly higher when entering or leaving a motorway area than dealing with a tight curve (parametric t test, p<0,05). However, as regards to the mean values obtained for disturbance effects of textual messages, there are no significant differences between these two

types of situations (parametric t test, p=0,365). The mean value of disturbance effect of textual messages in the case where the driver is dealing with a curve (5,59) is quite similar with the mean value of disturbance effect of a message for all conditions (with and without a message) in the case where the driver is entering or leaving a motorway area (5,55).
Therefore, even if the mean values obtained for disturbance effect of a textual message was different when considering non-demanding situations *versus* demanding situations; this difference does not appear when considering demanding situations group. However, for pictogram and auditory message, the difference between these two types of situation is more important and these measures are evolving from a medium demanding situation to a high demanding situation.

Difficulties to perform the driving task - The graphic 8 displays the various mean values for other criteria related to the driver's availability when entering or leaving a motorway area dealing with a tight curve.



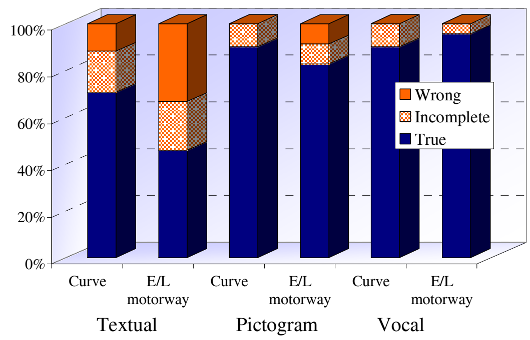
Graphic 8. Mean values of criteria related to driver's availability in the case of dealing with a curve versus entering or leaving a motorway area and for all conditions (with and without messages).

Concerning the situations where the driver is dealing with a tight curve, the mean values for the *difficulties to perform the driving task* is 4,15 on our subjective Likert scale.
Concerning the situations of entering or leaving a motorway area, *the difficulties to perform the driving task* are here significantly higher (parametric t test, p<0,05). The mean value of difficulties to perform the task is 5,87.
For this measure, the mean values for each category from a middle demanding to a very high demanding situation progressively evolve without a big difference from a category to another.

Visual and Auditory message acceptance - In the same way, a visual or an auditory messages are easier to accept when the driver is dealing with a tight curve than when is entering or leaving the motorway (parametric t test, p<0,05).
However, the mean values related to auditory message acceptance are increasing more slowly without an important difference than the mean values linked to the measure of the visual message acceptance.

Real time and after experiment self-assessment of the driving performance - The mean values respectively related to the driver assessment of his/her driving performance on real time and after the experiment are not significantly different when considering the situations of dealing with a curve *versus* entering or leaving on a motorway area (parametric t test, p=0,474 for real time self-assessment of driving performance and p=0,376 for after experiment self-assessment of the driving performance).
As regards the real time and the after experiment self assessment, the mean values are changing when considering the various categories of situations more or less demanding from the dealing curve situations to the entering or leaving a motorway. They can increase or decrease considering the type of situations categories analyse.

The message performance - The message performance of the driver for "curve" *versus* "motorway" situations is presented on the graphic 9 below.



Graphic 9. Textual, pictogram and auditory messages performance in the case of dealing with a curve *versus* entering or leaving a motorway area.

The message performance is changing according to the type of presentation of the message for the two types of situations. For tight curve situations, the rate of correct responses is equal or up to 70%: 70% for textual messages, 90% for pictogram messages, and 90% for auditory messages.
By contrast, when considering entering or leaving motorway area, the quality of the messages description strongly decreases for textual messages (46% of true responses). For pictogram messages (83% of true responses) and especially auditory messages, performance is not so changing (96% of

true responses) (KHI2 test, p=0,401 for pictogram message and p=0,446).
Therefore, the objective measure of message performance is clearly changing when considering textual messages but not pictogram or auditory messages from a medium demanding situation to a high demanding situation.

DISCUSSION

This research is focused on the in-car information management problem, by considering the driving demand, on the one hand (road infrastructure, event occurrences, manoeuvre to be performed), and the driver's level of availability, on the other hand. Some previous results collected in CEMVOCAS project have empirically validated (i.e. end-users opinions) the *availability* concept for an efficient HMI adaptation.
Through this new AIDE experiment, it is then expected to define methods and tools, based on objective performances and subjective assessments, to analyse and measure driver's level of availability.
Five subjective measures have been collected by using the video film recorded during the driving phase: the *disturbance effects of the message*, the *difficulties to perform the driving task*, the *visual message acceptance*, the *auditory message acceptance* and a *self-assessment of driving task performance* (additional to a *real time self-assessment* recorded while driving).
The objective measure studied in this paper is the message performance based on reading /describing visual or vocal messages.
The results obtained from subjective and objective measures of driver's availability are firstly studied for the whole itinerary, then for demanding versus non-demanding situations, and lastly for different levels of demanding situations.

Global results for the whole itinerary

Two main important results are presented in this section dedicated to the whole itinerary analysis. Firstly, human drivers availability to receive vocal message while driving is systematically higher than availability for visual messages (text as well as pictogram). Both, objectives measures (message performances) and subjective assessments (message disturbance and message acceptance values) clearly confirm this well-know fact: drivers have more chance to be disturbed by a textual or a pictogram message, than by an auditory message.
These results are not new, but confirm that the methods and the tools implemented for this experiment haven't introduced any experimental bias at this level.
The second interesting result in this section concerns measures of self-assessment of the driving performance on real time *versus* after the experiment. As presented, we haven't observed any significant difference between the 2 moments of the self-assessment measurement (while driving *versus* in lab). This result is probably the most important for this section. Indeed, as it was not possible to ask to the driver 5 subjective measures while driving, only one of them (i.e. real time self-assessment of the driving performance) has been collected during the driving task. Therefore, it was expected that "in lab" data collected, based on the experimental film as support, would be similar than a real time assessment. Regarding this result, our expectation seems to be confirmed. It let us to think that drivers can well estimate all the subjective dimensions related to the availability concept even if the criteria measures are not collected on real time, but via a video film recorded during the driving phase.

Results concerning demanding situations

Demanding *versus* non-demanding situations comparisons reveal that all the collected measures, objective as well as subjective data, are significantly different between the various driving situations. As a consequence, they are well adapted in order to assess the driver's level of availability.
Concerning the objective measure related to *message performance* - in relation with the driving situation demanding level and the modality of presentation (visual *versus* vocal) - several significant effects have been found. For non-demanding situations, the rate of correct responses is very high for all messages, even if text performance is lower (88%) than pictogram / vocal messages (95%). By contrast, Visual message performance (more particularly concerning text) significantly decreases in demanding conditions, and consequently provides a good indicator of a low level of availability of the driver. These types of messages are more difficult to take into account by the driver when he's performing a difficult manoeuvre. It is not (or less) the case for auditory messages.
Concerning our subjective measures collected trough various Likert scales, they are also deeply linked with the driver's level of availability.
First at all, the *difficulties to perform the driving task* scale provides a high discriminating measure to distinguish demanding *versus* non-demanding situation: in easy driving conditions, the mean measured value is 2,4 points, against 5,4 points in demanding conditions.
The *disturbance effect* subjective measure is also 2 (vocal) or 3 (visual) times superior in demanding *versus* non-demanding situations. All theses differences are significant, for all types of messages. They reveal a negative impact on the driving activity in demanding conditions and, probably, an increase of cognitive stress. This

impact is more limited for auditory messages, even if it is nevertheless effective. The same results have been found via the *visual message acceptance* and *auditory message acceptance* scales, which are directly related with availability concept in their visual *versus* auditory dimensions.
For the two last measures, related to the driving performance self-assessment (on real time and after experiment), a significant difference also appears between demanding *versus* non-demanding situation. Nevertheless, the discriminating capacities of these two measures are limited, due to the high mean values systematically given by our drivers, whatever the demanding conditions.

Results concerning in-depth analysis

As discussed in introduction, one of the fundamental objectives of this experiment was to design methods and measurement tools for driving situations categorization, according to the different level of availability self-assessed by the drivers.
As described in the previous section, significant differences have been observed, which validate the abilities of the implemented methods for demanding *versus* non-demanding situations distinction. Nevertheless, in-depth analysis reveals that it is also possible to provide a more detailed classification of demanding situations.
As examples, two particular cases of *demanding situations* have been presented in this paper: dealing a tight curve on the left and on the right *versus* entering or leaving a motorway area (with traffic). These two categories of situations are very different in terms of mean values related to the driver's availability measures. Indeed, dealing with a curve, even if it is a tight and difficult bend, is less demanding than entering or leaving a motorway area with normal or high traffic conditions. The main subjective and objective measures collected in this experiment are significantly different from one to the other case.
Moreover, between these two categories (medium *versus* high demanding situation), several other categories of situations have been identified as more or less demanding. This last result is not reported in the present paper, but the curves versus motorway distinction demonstrate that it is possible to provide a multi-level classification of demanding situations, hierarchically structured, in relation to the driver's availability.

CONCLUSION

In another way, data collected during this experiment and analysis presented in this paper have been used for the DAE design and development, in order to automatically assess the driver level of availability from objective parameters collected in real time by the car sensors. This part of the project is described in another paper [1].

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