EVALUATION OF DRIVER MENTAL WORKLOAD FACING NEW IN-VEHICLE INFORMATION AND COMMUNICATION TECHNOLOGY

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ABSTRACT

Innovative technology can induce improvement in road safety, as long as its acceptability and its adequacy are checked, taking into account the diversified driver's population needs and functional abilities through a Human Centred Design process. Relevant methodology has to be developed in this purpose. Evaluation of the driver's mental workload is an important parameter, complementary to objective ones such as control of the vehicle and driver's visual strategies. This paper describes experiments conducted in the framework of the European project AIDE aiming at validating the DALI (Driving Activity Load Index), a tool set up to allow evaluation of mental workload while using in-vehicle systems; the main results and conclusion from this approach are presented.

SAFETY ISSUES OF IN-VEHICLE INNOVATIVE TECHNOLOGIES

Context

If the driving task has little evolved since the creation of the car, this situation is changing today under the combined effect of widespread of driver information and communication systems and emergence of advanced driver assistance systems. These systems brought a strong hope in terms of improvement in road safety, in mobility, in transport environment with traffic optimization, as they allowed an electronic support to human being functional abilities and to road management. Several functions are already available, dealing with drivers' perceptive, cognitive and motor abilities such as preparation to unexpected events, decision taking under time constraint, and reaction time in emergency. Nevertheless, the driving task is a complex activity, and the system functions have to match with the driver's expectations, needs, requirements and capacities. This is really a challenge when realizing that there is a wide heterogeneity of drivers, meaning that the same product has to fit with an important range of contexts and users. This statement is true for any product, but is even more challenging in the context of the driving task, due to its real time constraint and the severity of the issue in terms of road safety. All these considerations lead to conduct investigations about Human Centred Design process, in order to avoid as much as possible misconceptions, and in order to ensure safety, reliability and acceptability of the proposed functions for a wide range of environments and types of drivers.

Informative and assistive functions

Nowadays, the various in-vehicle functions proposed by communication and information systems to the driver have diversified purposes, linked to safety and comfort.

Some of them clearly aimed at facilitating the driving task and at improving safety of traveling. For example, the access to navigation information allows a lowering of the attentional level involved in orientation process of the driving situation, even for elderly drivers (8). The transmission of traffic information in real time can be at the origin of critical situations avoidance. Alert messages, concerning road infrastructure or weather events arisen downstream, and displayed as quickly as possible to the driver, allow the activation of anticipation process. Adaptive cruise control, while maintaining a safe headway with the car ahead, decreases the drivers' stress and mental workload. In direct connections with the objectives of road safety, the active assistance systems conceived specifically to take effect in critical situations, can balance some reaction latencies and decision uncertainties, inherent to the human functioning in driving situation.

Some other functions proposed by these systems are disconnected to the driving task, devoted to entertain the driver or developed in the context of professional use, such as mobile phone use and connection with electronic mail. Due to the fact they are irrelevant for the driving task itself, experimental investigations showed that this type of

functions are prone to have negative impact on the road safety, as requiring additional attentional demand in comparison with a reference driving situation, where no system would be available.
At this stage, these functions have been classified under two categories: IVIS for In-Vehicle Information System and ADAS for Advanced Driver Assistance Systems. In the framework of the European project AIDE ((2), the following definitions are proposed:

- *In-vehicle Information Systems (IVIS):* Systems with the main purpose of providing information to the driver *not directly related to the primary driving task*, including telematics and communication services, infotainment (radio, CD, DVD, mp3, email). These functions potentially impose a *secondary task* that may interfere with the primary driving task. An important sub-category of IVIS are so-called nomad systems, i.e. systems brought into the vehicle by the driver or passengers.
- *Advanced Driver Assistance Systems (ADAS):* Systems with the *main purpose* to enhance safety and/or comfort by *supporting the driver on performing the primary driving task.* Examples include lateral control support, collision warning, safe following, vision enhancement and driver fatigue monitoring.

Thus, according to these definitions, ADAS have the role of supporting the driving task while, by contrast, IVIS imposes other tasks that may interfere with driving.
Some other definitions propose that ADAS functions cover only systems with more or less automation properties, while IVIS functions cover systems that transmit information to the driver, who stay in charge of the final control of the vehicle.
Following the first definitions, a technology, such as "identification of vehicle speed", for example, will be identified as ADAS functions, as speed is linked to the driving task.
Following the second definitions, this technology can transmit only "alert" messages to the driver, having then the status of IVIS, or can take the control of the vehicle and automatically slow down, becoming an ADAS.
Whatever the final decision and agreement about the adequate vocabulary, the various functions lead to rather different Human Machine Interaction requirements, and evaluation criteria – and hence to different challenges for HMI design.

In fact, the effective achievement of the expected benefits on road safety will depend on conditions of systems design and implementation: in particular, in which extent the system answers to drivers needs, is compatible with their functional capacities whatever their age and satisfies the criteria of relevance, usability and acceptability.
This is true for informative systems, requiring additional attention from the driver to be used, where the benefit of this cognitive load has to be put in balance with the potential interference created with the driving task.
This is also true in the case of automation technologies, where assistance systems is able to take care of some control tasks traditionally assigned to the driver, and which brings the problem of the tasks dispatching between human and machine, as well as the choice of the logic used for the management of this control sharing, substitute or co-operative.

METHODOLOGY FOR HUMAN CENTRED DESIGN

Human Centred Design of innovative technologies

In-vehicle devices have to be intuitive, self-explanatory and non intrusive. In order to reach this goal, the human-centred design approach is relevant at each step of the development: setting up the concept, development of the mock-up and the prototype, implementation of the system, with series of iterations to improve the final result (10).
The Network of Excellence HUMANIST (HUMAN centred design for Information Society Technologies), funded by the European Commission DG InfSo, gathers research activities directly linked to this issue: identification of the driver needs in relation to ITS, evaluation of ITS potential benefits, joint-cognitive models of driver-vehicle-environment for user centred design, impact analysis of ITS on driving behaviour, development of innovative methodologies to evaluate ITS safety and usability, driver education and training for ITS use, use of ITS to train and to educate drivers (www.noehumanist.org).

Generally, the ergonomic approach for design and evaluation processes aims at:

- assisting designers to allow quicker and more efficient design process by setting up ergonomic criteria, taking into account the wide heterogeneity of drivers' needs and requirements
- evaluating safety for drivers using these devices.

In order to process a human-centred design, it is necessary to investigate deeply the drivers' behavior in relation to the various stages of the driving task: operational (basic vehicle-control processes), tactical (choices of vehicle maneuvers according to rules and road environment) and strategic (decisions at high level such as route to follow) in addition to the drivers functional abilities (visual, auditory and cognitive capacities) according to age and experience of driving. Identification of drivers' behavior according to new technological development requires several types of investigations, as there is a wide heterogeneity of the population in terms of functional abilities and requirements. Several researches devoted to identification of drivers'needs have been already conducted for functions such as navigation and guidance, Advanced Adaptative Cruise Control, Intelligent Speed Adaptation, Lane Change Assistance (5).

Evaluation of driver's behavior and functional abilities

There are discussions and propositions about tools and methods to be developed in order to investigate the impact of system use on road safety according to users population variability.
Classically, the parameters to take into consideration in this framework are related to vehicle (trajectory deviations consequent to the system use), drivers' visual strategies (visual demand due to on-board screen) and overall drivers' workload according to the situation.
Vehicle deviation trajectories can be a good parameter in relation to visual strategies. Unfortunately from an experimental point of view, and fortunately for road safety, this parameter reveals very high and very rare workload situation, where the driver is on the way to loose control of his vehicle. Some complementary measurements are necessary in order to identify the increase driver's workload with more accuracy than this type of extreme situation.

Evaluation of driver's mental workload

One of the possible definitions of the workload is that it is the ratio of the task demands to the average maximal capacity for each individual (12). To put it in an other way, the assessment of workload is coupled with the task difficulty as experienced by the individual (3). The individual can adapt his behavior to an increased demand of the task, leading for him to more effort and a higher cost, with the consequence of no perceptible effect on the performance. On the contrary, this individual in the same context can adopt the strategy to have a stable level of effort with a decrease of the resulting performance in managing the task. So, objective performance measures are not sufficient by themselves to evaluate the overall constraint of a given situation, evaluation of the corresponding effort for this task is missing to be able to characterize the overall parameters of the context.
In order to measure the individual's mental workload, several approaches are encountered in the literature:

- measurements of the physiological parameters in order to correlate mental workload : this method has been considered quite disappointing (1) and requires a heavy methodology in real road situations.
- method of dual task : the principle is to evaluate the availability of the individual capacity to perform a task supplementary to the primary one. The workload is considered as being important when the available capacity left by the primary task is poor. This method is considered as a typical laboratory approach, taking into account the consequences in terms of interference in real situations (14). Furthermore, using an in-vehicle system is already a dual task: adding a supplementary task raises questions about the driver choice in terms of priority (which task is considered as the main one).
- method consisting in formalizing the own driver judgment about the workload he experienced : this approach considered as "subjective" has been developed according to various methods such as the S.W.A.T. - Subjective Workload Assessment Technique (13), the NASA TLX - Task Load Index- (4)...

This type of tool allows evaluation rather than measurement by establishing relative comparison between situations.

Subjective Task Load Index

The mental workload is multidimensional and, among other things, depends upon the type of task. An efficient tool called the NASA-TLX, NASA-Task Load Index, set up by the NASA for the evaluation of pilot's workload, has been used for many decades to evaluate subjective mental workload of operators (6, 11, 14). A modified version of the NASA TLX has been proposed (8) in order to adapt it to the driving task. As we want to evaluate the workload during a well-defined task, namely the driving task when using an in-vehicle system, we set up a tool focusing on the specific dimensions to take into account for this task. We called it DALI for Driving Activity Load Index.
The NASA TLX assumes that the workload is influenced by *mental demand, physical demand, temporal demand, performance, frustration level* and *effort*. After assessing the magnitude of each of the six factors on a scale, the individual performs pair wise comparisons between these six factors, in order to determine the higher source of workload factor for each pair. A composite note quantifying the level of workload is set up by using both factor

rating and relative weights computed from the comparison phase.
The basic principle of the DALI is the same than the NASA-TLX, with a scale rating procedure for six pre-defined factors, followed by a weighing procedure in order to combine the six individual scales into a global score. The main difference lies in the choice of the main factors composing the workload score.
Considering the NASA-TLX, one of the factors to be rated is called the ***Physical*** component and is usually defined in the following terms: " How much physical activity was required ? -pushing, pulling, turning, controlling, activating,...-" It appears that this question would not be very relevant when considering the driving activity where the control of the vehicle is quite automatic for an experienced driver, and where maneuvers are not supposed to be physically demanding in our nowadays modern cars.
Another example is the mental component defined in the TLX as follows " How much ***Mental*** and perceptual activity was required? - thinking, deciding, calculating, remembering, looking, searching,...-". This statement covers both perceptive and cognitive aspects of the workload, and we think it would be interesting in the context of the driving task to be able to identify impact of each of these various modalities.
Finally, the evaluation of the ***Performance*** factor can be made using objective data. The subjective rating of a good performance by the driver can show discrepancies with the measured one, but this difference might be due to many other factors than the mental workload itself - low or high self-esteem, motivations to fit to the standard performance,...-
The procedure to set up the DALI was to ask various experts involved in the driving task studies to define which were, in their opinion, the main factors inducing mental workload for people driving a vehicle equipped with an on-board system (car phone, driving aid system, radio,...).

This investigation leads to the following definitions for the 6 workload dimensions for the DALI:

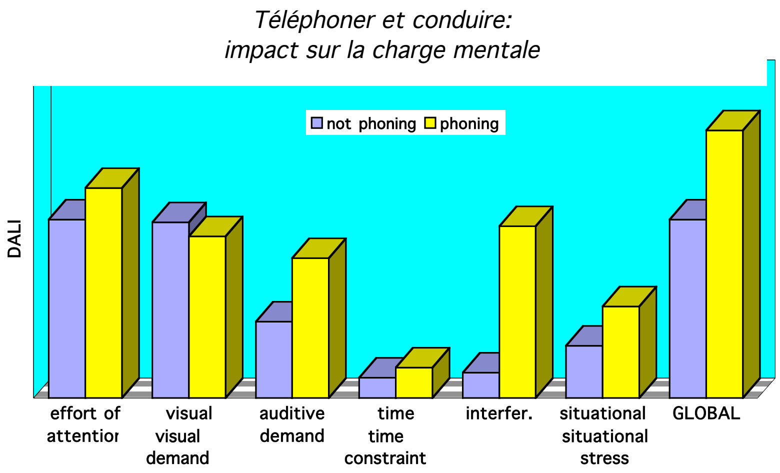
Title	Endpoints	Description
Effort of attention	Low / High	To evaluate the attention required by the activity - to think about, to decide, to choose, to look for,...
Visual demand	Low / High	To evaluate the visual demand necessary for the activity
Auditory demand	Low / High	To evaluate the auditory demand necessary for the activity
Temporal demand	Low / High	To evaluate the specific constraint due to timing demand when running the activity
Interference	Low / High	To evaluate the possible disturbance when running the driving activity simultaneously with any other supplementary task such as phoning, using systems or radio,...
Situational stress	Low / High	To evaluate the level of constraints / stress while conducting the activity - fatigue, insecure feeling, irritation, discouragement, ...

This tool has been used in two specific ergonomic evaluations conducted in real road situations, aiming at investigating a guidance/navigation system and a hand-free car phone usability by a diversified sample of drivers.

The Driving Activity Load Index for the evaluation of the driver's mental workload

<u>Workload in relation to navigation functions and phoning</u>

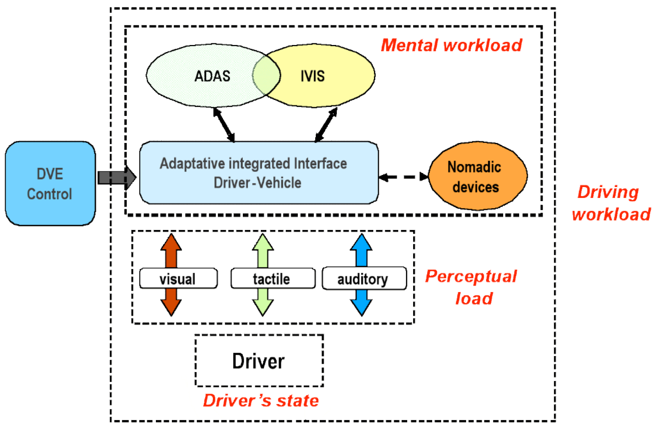
The DALI has been previously used for the evaluation of a Guidance/Navigation System (7), which allowed to show that the system was presenting an incorrect timing for the auditorymessage display, not adapted to the driving pace maneuvers, and inducing high driver's workload in terms of auditory demand. The DALI values resulting of the comparison between a guidance arrow display versus an electronic map confirmed the fact that the first context was inducing less interference with the driving task for the driver than the second context.
The DALI has been also applied to the context of the evaluation of driver's mental workload linked to mobile phone use (9).



The tool showed a statistically significant impact of the phoning task on the global cost of the driving task, in comparison with a reference situation. The detail of the DALI factors showed that the stronger effect of the phoning was interference with the driving task and auditory demand, inducing also stress for the driver.

Validation of the DALI in the AIDE project

This paper describes a recent experimentation aiming at validating the DALI method in a generic context.



The study has been conducted in the framework of the European project AIDE (Adaptive Integrated Driver-vehicle InterfacE) supported by the DG InfoSo.

The general objective of this project is the assumption that if the Driver, the Vehicle and the Environment (DVE state) is monitored, the driver-vehicle interface can be adapted accordingly in order to optimise safety and usability for the driver. Within the objective of designing this adaptative interface, one important part of the process is to define adapted methodology to evaluate developed prototypes through iterative phase.

a. Aim of the evaluation and assessment methods activity

The aim is to develop a generic, cost efficient and industrially applicable methodology for evaluating ADAS and IVIS.

- Development of **methods and tools for quantifying the behavioural effects** of in-vehicle systems (in particular workload, distraction and behavioural adaptation).
- Development of methods for **extrapolating from these effects to actual road safety**
- Development of a **general evaluation methodology** for application in different stages of product development, including standardised test scenarios. Linked to European Statement of Principles
- Applying the methodology to the **evaluation of the AIDE prototypes**

b. Evaluation of DALI in real road context

A real road experiment has been conducted in order

to define advantages and limits of DALI method for the evaluation of driver's mental workload. If the objective of the experiment was to test tools and methods, then a knowledge a priori of the level of workload induced by the situation is the way to proceed. Indeed, definition of the context will allow to evaluate if the tools reflect correctly what is expected in terms of conditions and in which way the results from the subjective evaluation tool correspond to the workload deliberately induced on the driver.
So, the general principle of the conducted experiment was to set up experimental sessions that are varying objectively in terms of requirements for the driver, inducing then various levels of mental workload to deal with these contexts.

The 4 tested experimental sessions were presenting the following characteristics:

- to vary according to the level of workload induced on the driver
- to be as realistic as possible in a context of driving task

- **2 situations with a high task demand**

High (Context + System) HCS: While driving, the driver had to run a task according to stimulations emitted by an on-board system. The information to deal with is not related to the task and induced a manual action or a verbal answer. The route to follow is given by a guidance system. The workload was linked to ***perceptual processes***, ***decision making*** and ***motor and/or verbal output*** (detailed description in annex)

High (Context) HC: Before the experimentation started, the driver had to consult a paper map to know the route to follow. Then, he can stop anytime to check again the directions. The workload was linked to the ***mental representation*** of the route and to ***memorize*** it.

- **2 situations with a low task demand**

Low (Context + System) LCS: The driver had to follow the route according to visual and auditory information given by a guidance system. The workload was linked to ***perceptual processes*** but the decision making and the mental representation/memorization were lighter than in the previous sessions.

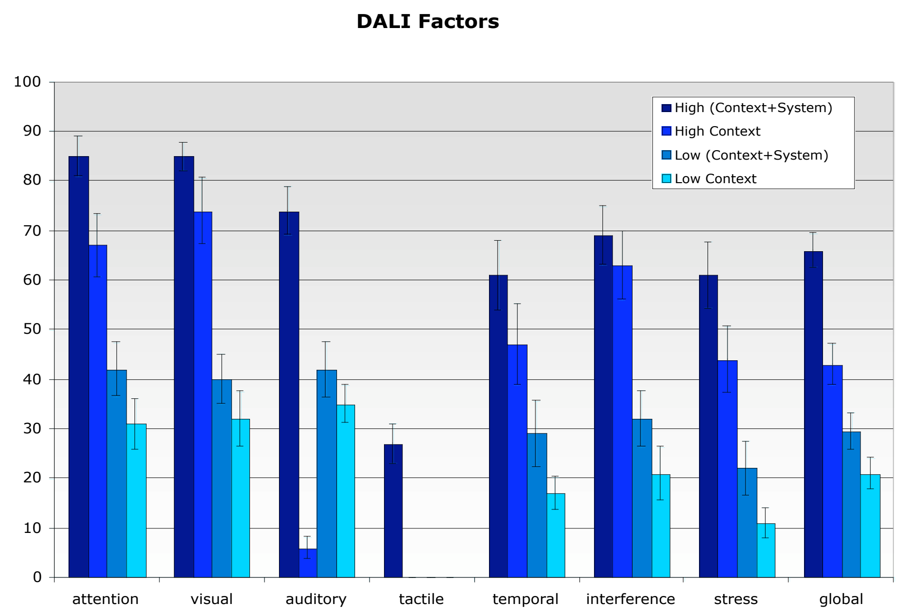
Low (Context) LC: During the route, the experimenter gave clear and on time directions to follow. The workload was linked only with the management of the driving task, without any added activity.

The subjective evaluation tools have been applied at the end of each of these sessions.

To summarise, process for the experimental procedure was the following:

- To set up diversified situations varying on purpose by their level of demand: cognitive process (e.g.: to memorise the route) and perceptivo-motor process (e.g.: to run manual action following auditory, visual or tactile stimulations)
- To apply the tool for each of these sessions in order to gather subjective data
- To check that the highly demand session corresponds to the highly values for the tools and to identify in which way

In the following graph, the values for each factor and for the global score are displayed for the 4 experimental sessions varying by their level of complexity and induce workload on the driver.



*In addition to the 6 factors used in the previous studies (**Effort of attention, Visual demand, Auditory demand, Temporal demand, Interference, Situational stress**), a supplementary factor : **Tactile demand**, has been used. Proprioceptive perception is not very well known nowadays in the context of the driving task, and there are more and more projects about haptic systems for the driver. In this experiment, the objective was to investigate how this stimulation is perceived by the driver in comparison with the auditory and the visual ones. Theoretically, tactile stimulations are not inducing high level of mental workload, and we made this hypothesis a priori. The use of this stimulation in this experiment was an opportunity to evaluate the subjective evaluation tools for this specific case.*

The non parametric test Wilcoxon has been conducted in order to analyze the significance of the difference between experimental session.

Wil cox	Effo rt of	Visua l	Audit ory	Temp oral dema	Interf erenc	Stre ss	Gl ob
LC	NS	NS	NS	NS	NS	0.05	0.0 1
LC S	0.00 5	0.001	0.000	0.05	0.002	0.02 5	0.0 25
HC S	0.05	NS	0.000	NS	NS	NS	0.0 03
LC SH	0.00 0	0.000	0.000	0.005	0.000	0.00 0	0.0 00
LC	0.00 5	0.001	0.000	0.05	0.000	0.02 5	0.0 25
LC	0.00 0	0.000	0.000	0.005	0.000	0.00 0	0.0 00

Global workload

There is a significant difference between the 4 experimental sessions in terms of subjective assessment of workload by the driver when looking at the DALI results (Wilcoxon, Z= 3,007, p=0,003; Z= 2,224, p=0,026, Z= 2,539, p=0,011; Z= 3,923, p<0,001).
These sessions were defined with this goal, so this result is very positive while checking the validity and the sensitivity of this tool.
The chosen sessions were varying according to various characteristics that can participate to this global workload: an analysis of the detail of the results for each factor allows to better identify and understand what are the components of this global score.

Workload linked to cognitive components

Attention
There is a significant difference between the **High** and the **Low** workload sessions in terms of attentional requirements (Wilcoxon, Z= 2,840, p=0,005; Z= 3,869, p<0,001). In the **High** contexts, the attention required to interact with the complex on-board system is higher than the one to find his route according to the memorised information, but the difference is not that significant (Z= 1,991, p=0,047). In the Low context, there is no significant difference in terms of attention between using a guidance system and following the instructions of a co-pilot.

Interference
In terms of interference, there is no significant differences between the **High Context With or**

Without System (between HCS & HC: Wilcoxon, Z= 0,471, p=0,638), indicating that navigating with a paper map would be rated as interfering with the driving task as using a very complex in-vehicle system or "ergonomic mock-up" displaying several messages and there is no significant difference between the **Low Context With or Without System** (between LCS & LC: Z=1,896, p=0,058)**,** indicating that using a well designed in-vehicle guidance system is equivalent in terms of interference with the driving task to be guided by a human co-pilot. Nevertheless, there is a significant difference when comparing **High Context and Low Context**, indicating, among other thing, that navigating with a paper map is more interfering for the driving task than using a guidance system(between HC & LCS:Z= 3,037, p=0,002, between HCS & LCS: Z= 3,662, p<0,001).

Stress

There is a significant difference between most of the different types of driving contexts in terms of stress (Wilcoxon, Z= 2,382, p=0,017; Z= 2,041, p=0,041, Z= 3,880, p<0,001), with a lesser value between the **High Context + System** and the **High Context** (Wilcoxon, Z= 1,729, p=0,084). The factor stress is reflecting a global evaluation of the task constraint for the driver, and, in a coherent manner, is very low in the situation where the co-pilot is supporting the driver, a bit higher when a guidance system is fulfilling this part, much higher when the driver has to memorise his route and very high when the driver has to manage a secondary task in addition to the driving task.

Workload linked to perceptive components

Visual Factor

Considering the visual demand of each session, there is a significant difference between the session with high workload **High (Context + System) & High (Context)** and the one with low workload **Low (Context + System) & Low (Context)** (Wilcoxon, Z= 3,218, p=0,001; Z= 3,95, p<0,001). The DALI allows to show there is no significant differences between the 2 sessions "using an on-board system displaying complex stimulations" and "using a paper map to find the route" (Wilcoxon, Z= 1,312, p=0,190; Z= 1,231, p= 0,218). There are also no significant differences between the session "to be guided by a guidance system" and "to be guided by an other person". Taking into account the fact that in both situations, the driver relied on the auditory information coming from the system or from the co-pilot, it is relevant to find no significant visual workload in these two contexts.

Auditory Factor

Considering the auditory demand of each session, a very low value of workload is displayed in the situation where the driver has to memorise his route with a paper map and to find his way based upon the road directions in comparison with the 3 other situations (significant difference (Wilcoxon, Z= 3,954, p<0,001; Z= 3,771, p<0,001; Z= 3,804, p<0,001). Indeed, in this case, even if the general workload of the situation appeared to be high, the DALI results show that the auditory demand is not involved in this workload.
Furthermore, there is no significant difference between the situation "using a guidance system" and following instructions from a co-pilot, showing that the auditory messages coming from the on-board system did not induce a noticeable workload by the driver (Wilcoxon, Z= 1,144, p=0,253).

Tactile Factor

Implementation of vibrations in the seat of the vehicle was a first approach to define if the driver was able to detect this kind of "unusual" stimulus with accuracy, and if this stimulus was inducing workload. The tactile stimulations were quite well detected and induced a light workload in comparison with situations where this stimulation was non-existence (Wilcoxon, Z= 3,703, p<0,001). Nevertheless, this workload is far less important than the one induced by auditory and by visual stimulations for the same session.

Workload linked to temporal components

Like for the **global score**, for the **stress** and for the **attention**, the **temporal** demand is highly different in relation to the type of session (Wilcoxon, Z= 1,118, p=0,264; Z= 1,556, p=0,120, (Wilcoxon, Z= 2,116, p<0,034; Z= 2,843, p=0,004). Indeed, like the other 3 factors, this factor is revealing a global estimation of the cost of the task. As driving task is under time constraint, it is then not surprising to have a workload value in terms of timing closely linked to the level of the task complexity.

c. Summary of main results from the DALI factors

The values of the DALI factors showed the significant difference between the 4 experimental sessions, defined a priori on purpose with an increased level of workload for the driver: this tool allowed in a quick and reliable way to identify the global workload of a given context, and to bring additional precision about the level of load for the vision, the audition, the stress, the attention components for each of these driving contexts.

The values of driver's load (visual, auditory and attentional demands) are not significantly different in the context « using a regular guidance system implemented in the vehicle" and the context of a "co-pilot giving verbal guidance instructions to the driver". These results showed that the implemented system in this case was correctly design in terms of visual and auditory messages (timing, loudness, content) and is not inducing noticeable attentional requirement in terms of management of a secondary task. Nevertheless, the DALI results showed that there is a slightly higher level of stress while using the system in comparison with relying on the human co-pilot. These results showed that this tool is sensitive to various aspects of the driving task, and can then support the design process by identifying which part of the task was heavier for the driver. In this specific case, the conclusion would be that the guidance system is correctly design, but that its use requires a phase of familiarisation for the driver to be fully comfortable with it.

The values of driver's load in terms of interference are no significantly different between the High Context With or Without System, indicating that "navigating with a paper map" would be rated as interfering with the driving task as "using a complex ergonomic mock-up" displaying several messages.
The values of driver's load in terms of interference are no significantly different between the Low Context With or Without System, indicating that using a well designed "in-vehicle guidance system" is equivalent in terms of interference with the driving task to be guided by a "human co-pilot". Nevertheless, there is a significant difference when comparing High Context and Low Context, indicating, among other things, that "navigating with a paper map" is more interfering for the driving task than "using a guidance system".

CONCLUSION

This tool allowed showing significant differences between the experimental sessions in terms of perceptive, cognitive, stress, temporal demand and interference induced by the driving task.
One of the main advantages is the possibility to identify origins of the driver's workload, allowing then to correct the situation at this identified level (e.g. interference and visual load indicate that an in-vehicle system will have a visual demanding visual display). The possible improvements would be to add factors linked to specific aspect of the driving task useful to evaluate impact of ADAS (e.g. level of stress to keep distance with the vehicle ahead, in the case of a system having an impact on this specificity of the driving task). It is planned to conduct further investigations to improve this method by varying the type of situations. The "DALI tool kit", gathering the detailed method in addition to the automatic computation of the statistics and the display of the graphs, will be soon available on the web site, in order for any researcher to be able to use it in his/her scientific context.

REFERENCES

(1) Casali J., and Wierwille W.A. (1984). "On the measurement of pilot perceptual workload : a comparison of assessment techniques addressing sensitivity and intrusion issues". Ergonomics, 27, 10, pp 1033-1050.

(2) Engströn J., Arfwidsson J.' Amditis A., Andreone L., Klaus Bengler' K., Cacciabue P.C.,' Johannes Eschler J., Nathan F., Janssen W. (2005) Meeting the challenge of future automotive HMI design: an overview of the AIDE integrated project, ITS Mondial congress, San Francisco, US.

(3) Gopher D. & Donchin E. (1986). Workload - an examination of the concept. In K.R. Boff, L. Kaufman & J.P. Thomas (eds.), Handbook of perception and human performance. Volume II, Cognitive processes and performance. New York : Wiley.

(4) Hart S.G. and Staveland L.E. (1988), Development of the NASA TLX : results of of empirical and theoretical research. In P.A. Hancock and N. Meshkati (eds.)? Human Mental Workload. North Holland, Amsterdam, 139-183.

(5) HUMANIST report A.4, (2006), Identification of drivers needs and functional abilities in relation to new ITS systems and services, Deliverable A.4, 138 p., www.noehumanist.org.

(6) Matthews R., Legg S., Charlton S., (2003), Distraction, driving, multiple-task, workload, performance, Accid Anal Prev, 35 (4), 451-7.

(7) Pauzie A., 1994, Human interface of in-vehicle information systems, VNIS' 94, Yokohama, Japan.

(8) Pauzié A. & Forzy J-F, 1996, Ergonomic evaluation of guidance and traffic information in the CARMINAT program, III Annual World Congress on Intelligent Transport Systems, Orlando, CDRom.

(9) Pauzié A. & Pachiaudi G., 1997, Subjective evaluation of the mental workload in the driving context, in " Traffic & Transport Psychology : Theory and Application " , T. Rothengatter & E. Carbonell Vaya (eds.), pp 173-182, Pergamon.

(10) Pauzié A., 2002, In-vehicle communication systems: the safety aspect, Injury Prevention Journal; 8, 0–3.

(11) Piechulla W., Mayser C., Gehrke H., Konig W., (2003), Reducing drivers'mebntal workload by means of an adaptative man-machine interface, Transportation Research Part F: Traffic

Psychology and Behaviour, Vol 6 (4), pp. 233-248 (16).

(12) Rouse W.B., Edwards S.L. & Hammer J.M. (1993). Modelling the dynamics of mental workload and human performance in complex systems. IEEE transactions on systems, man and cybernetics, 23, 1662-1671.

(13) Reid G., Shingledecker C., Nygren T. & Eggemeier T. (1981). Development of multidimensional subjective measures of workload, International Conference on Cybernetics & Society, Atlanta, 403-406.

(14) Shingledecker C. (1982). Performance evaluation of the embedded secondary task technique. Aerospace Medical Association Annual Scientific Meeting, 151-152.

(15) Vitense H. S., Jacko J.A., Emery V.K., (2003), Multimodal feedback: an assessment of performance and mental workload, Ergonomics, Taylor & francis (eds.), V46, 1-3.