INFORMATION RELAYING SYSTEMS AND DRIVER PERCEPTION: EXPERIMENTAL ANALYSIS OF VARIABLE MESSAGE SIGNS USING CAGLIARI EYE TRACKER

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ABSTRACT

Variable Message Signs (VMS) are electronic traffic signs used on roads to alert motorists of incidents or obstructions such as traffic congestion, accidents or roadworks. These devices are becoming increasingly important in road transportation and in some countries they are also used to provide information about speed limits on a specific road segment (not yet in Italy).

The first important study concerning driver perception and comprehension of VMS in Italy was conducted by our research unit. The findings indicated the general indifference of drivers towards reading messages and difficulties in remembering the text, but provided no insight into driver perception.

The aim of this paper is thus to investigate driver perception using an eye tracker (head-mounted Mobile Eye).

A sample of individuals, divided into different age groups, fitted with the Cagliari University Eye Tracker, were monitored on a given urban route where two different panels (text and text-pictogram) have been installed. Using this instrument it was possible to analyse driver behaviour with respects to the Variable Message Signs.

The Eye Tracker tracks drivers' gaze and produces at the end of the test a gaze plot showing eye gaze point patterns (saccadic eye movements). Using a specific analysis software it has been possible to examine the visual activities of subjects during task execution, discriminating between objects considered visual distractions and those regarded as "receptor signals", in this case the VMS.

Using the eye tracker it will be possible to establish whether drivers see panel or not and for how long their gaze remains fixed on the VMS. The findings of this study will also provide guidelines for the correct use and installation of these panels.

INTRODUCTION

Drivers are subjected to a series of stimuli from the surrounding environment such as road signs, the presence of other vehicles, pedestrians, etc. which however should not distract their attention. For this reason, good design of a driver information system begins with the design of the man-machine interface existing in all vehicles, and finishes with improvement the driver's field of vision up to the design of the car interior and of the road itself. This broad array also includes the design of road signs and markings which provide information and guidance for road users by delivering concise information about the driving environment. The analysis of the aspects associated with the effectiveness of road signs in relation to driver's sensory perception, presupposes that the road sign forms the key link in the driver-vehicle-road-environment system and the effectiveness of the entire system therefore depends on good design.

The use of modern eye tracking technology makes it possible to determine the gaze point and direction and how driver attention varies as information from the outside environment changes.

Recent biodynamic models organize objects entering the field of vision into objective and distractor signals, thereby distinguishing between information that needs to be rapidly captured in order to execute a task and unnecessary information superimposed on the field of vision. This models calculate the time required to capture messages and quantify the attentional load demanded of a work cycle in which an activity is constantly repeated. The distractor signals generally include anything that disturbs or distracts user gaze and should in any case be examined so as to distinguish them from the objective signals.

The problem of human cognition and the ways in which messages relayed through Variable Message Signs are perceived, are addressed by information theory and by the models representing this basic mental process which represents the moment between the acquisition of signals coming from the outside environment in the form of stimuli and the moment the resulting decision is made.

In particular,

1. Simulation of the signal acquisition process through the biodynamic model, for highlighting the basic physiological and functional characteristics of human sense organs. This forms the essential cognitive basis for identifying different modalities and structures of the signals forming the message so that the information may be captured more easily, more effectively and more rapidly;

2. Representation of the perception process by means of information models, for studying and setting up the structure and ways messages are relayed, so as to maximize human perception and comprehension. This knowledge forms the basis of the man-machine interface design;

3. Decision making process, studying the different decision options incorporated into the so called decision theory models, is simulated by structuring and representing the different decision options that a driver should and must take as a consequence of

changes brought about by new information provided by in-vehicle systems and by the outside environment.

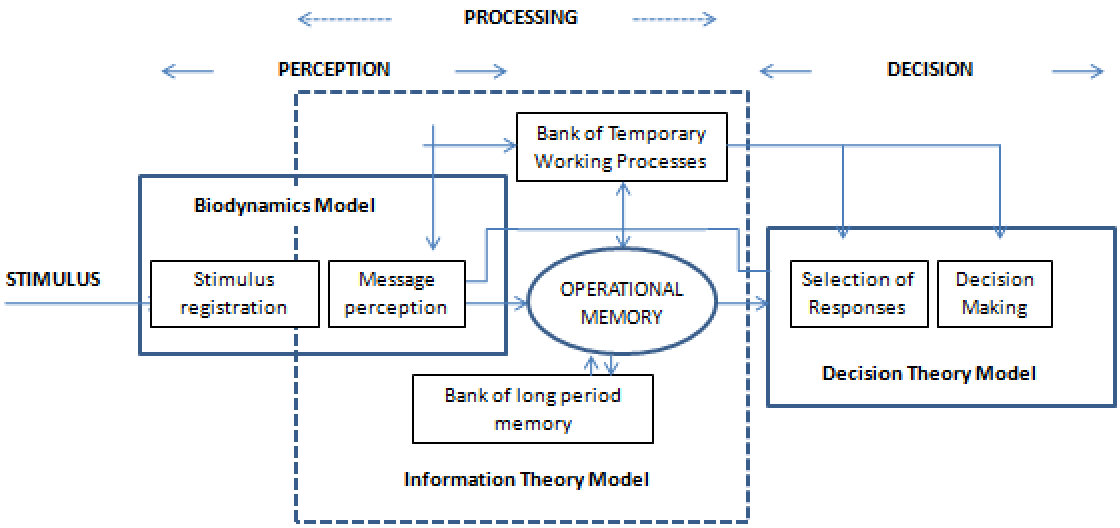

Fig.1 – Three memory cell model

The three memory cell model is used for representing the mental process of processing information received in the form of stimuli through the sense organs.
The first phase concerns external stimuli acquisition through the sense organs. The stimulus, once recorded is converted into a sensory trace which is stored in that part of the brain known as stimuli register or sensory memory.
The mechanism underlying the registration process, especially to ensure that the memory trace is not ambiguous and the message complete, is one of the fundamentals of biodynamics research that is based on sequences of the following type:
What is the eye made of – how does the eye register a stimulus- how can the eye better register a stimulus – how can a given stimulus be provided such that it is registered completely and unambiguously.
The passage from the sensation to the perception stage involves all those stimuli that rank as information to be retained in the long term memory bank, or that is also needed for decision making, depending on the task being executed..
All the stimuli undergo a perception phase, but many will be automatically discarded without the perception stage actively intervening. In fact during the perception stage the stimuli are selected, compared and sorted and conveyed to the working memory, the long term memory or directly, selecting from among response options, for decision making.
As can be seen from the figure, the perception stage interacts with the long term memory and with the temporary working memory. The working memory is that process which a stimulus is subjected to when is it not clearly perceived, in other words when, as is frequently the case, it is ambiguous, or occurs so rarely that any trace has been erased from the long term memory bank where perceptions are stored.
The working memory is responsible for the short term storage of information that needs to be matched up with information from previous experiences, registered as signals and processes

with given perceptive characteristics. The information in the working memory is constantly being updated, it is the workbench where information is compared, evaluated and transformed into cognitive models. The latter are retained in the memory until such time as the response selection and decision making processes are completed. The short term memory draws on the long term memory if the process is repetitive or introduces/replaces a part of it, in the event a change in the stimulus associated with the same information is registered.

To perform effectively, a cognitive process processed in the primary memory needs to be filed as attention resource. The specific visual stimulus of a hole in the road we are driving along at night is first acquired, instantaneously compared with the stimuli bank of the working memory and recognized/perceived as a hole through a cognitive process. This process is stored, associating the signals received with the recognized object such that the object is perceived as a hole in infinitesimal time based drawing on previous experience.

This happens because the long term memory bank has stored those signals associated with the hole with which the new information is compared, and in the event that these signals have been erased from the working memory as they are likely to decay if not refreshed. The working memory works as a temporary storage unit and retains the information until such time as a different signal is received, for instance reaching the end of that road.

However, depending on the importance a particular signal holds for an individual and for his/her own security, in addition to the frequency with which it may recur, this signal, also as a cognitive process, is either stored in the long term memory and consequently refreshed, or stored for the first time, while the trace in the working memory, where it is temporarily stored as attention resource, decays.

STATE OF ART

The main studies concerning eye tracking and road signs are summarized below.

A study conducted by Sodhi et al. (2002) of the University of Rhode Island Kingston, Vastenburg e Kaars of the Hogeschool Van Amsterdam, Holland and Kirschenbaum of the Naval Undersea Warfare Lab, Newport, investigated eye movement of drivers navigating a test route while completing various driving tasks, using an eye tracking device (HED). Because of the increasing presence of In-Vehicle Information Systems (IVIS) in modern vehicles, questions are now being raised about the impact of these systems upon vehicle safety. Manual, visual, and auditory methods are being used to interact with various in-vehicle devices such as radios, compact disk players, cell phones, laptop, palmtop computers, collision avoidance, global positioning navigation systems, speech based e-mail and other modern information equipment. These devices provide obvious benefits to the driver, however costs associated with changes in driver workload and monitoring efficiency are not so clear. Wierwille and Tijerina (1998), who conducted a study on developing formal definitions of the level of attention required in operating in-vehicle devices, found that "the amount and frequency of visual attention to in-vehicle devices is directly safety relevant". Car radios have been largely accepted as an acceptable driving distraction while other in-vehicle information systems have not been so readily accepted (McKnight and Mcknight 1991) and (Cain and Burris 1999). Fundamentally a distraction is anything that takes attention away from primary task. In the case of a driver, this is anything that takes the driver's attention away from the driving task. In the absence of knowledge about levels of distraction that result from secondary tasks, it is difficult to predict what the effect of multiple tasks is on the primary (driving) task. A number of investigations have been directed at evaluating the effects of such equipment on driving performance. Pachiaudi and Chapon (1994) and Cain and Burris (1999) say that cognitive load placed on the driver while operating a vehicle, it appears that hands free conversations do result in reduced cognitive loads, nevertheless there is an increase in the load compared with normal driving. Sodhi et al. focused their attention on the use of eye tracking methods to monitor how various distracters affect a driver, assuming a relationship between eye movements and attention.

Most of the models however are limited to studying in-vehicle devices because of their assumption that "the task environment in which eye-movement data are collected is (at least for the most part) static". With regard to motorists, the scenery outside the vehicle is constantly moving. The driver is tracking other vehicles, signs, and objects outside the vehicle with smooth movements. To detect patterns in driver's eye movements new methods of analysis need to be developed.

A new method of analyzing dynamic scenes requires an understanding of visual search in a dynamic setting. With the addition of smooth eye movements, the analysis of scan paths for dynamic scenes is more difficult than the associated problem in a static scene, since conclusions about eye movements and their relation to the actual scene can only be made at discrete intervals relating to the recording of the scene camera (Stark and Ellis, 1981). Driving is one of many tasks that occurs in a dynamic setting and therefore exhibits this problem. Drivers are limited by their visual resources, can only focus on a single stimulus and search up to three targets a second effectively (Moray, 1990). Frequently the need arises to concurrently monitor too many different visual stimuli such as the speedometer, rear view mirror, a car in front, to the side, or other aspects of the visual scene not actually related to driving. When visual resources are allocated to secondary tasks a decrease in the amount of visual resources allocated to the driving task necessarily occurs (Rumar 1988). Time sharing is used as a method of partially overcoming this limitation. With time-sharing individual visual tasks are completed by sequences of saccadic movements and fixations. After enough information has been acquired from one stimulus, a saccadic movement is executed, aligning another stimuli with the central region of the fovea. The sequence is repeated over again until one of the tasks has been completed (Wierwille 1993). The primary stimulus in many instances is the forward view of the automobile with a range of secondary stimuli competing for the spare visual capacity (Rockwell 1988). A problem can occur when a driver chooses to monitor too many secondary stimuli instead of the primary task, resulting in a lack of attention to the primary task. The driver therefore cannot interpret enough information from the road. Drivers naturally develop a safety mechanism to counteract this problem, by limiting the amount of time focus is directed off the road for comfort, to a maximum of approximately 1.6 seconds (Wierwille 1993). Due to this limitation a difficulty exists when information needs to be extracted from highly complex, or unknown secondary tasks, such as the cluttered dashboard of a new car or dialing a cell phone. In this situation the time to search and complete a task may have to be longer than the comfort limit. When information is extracted from complex scene experienced drivers exhibit a larger number of eye movements with decreased fixation length (Chapman and Underwood 1998).

Other problems can be identified in a drivers visual field. The visual field is a region of flexible size and shape that includes both areas of direct focus and indirect focus. The useful area of the visual field or functional field of view has been described as "the area around the fixation point from which information is being briefly stored and read out during a visual task" (Williams 1988).

A relationship between the size of the visual field and workload also exists, when too much information is being processed the useful field of view contracts to prevent overloading of the visual system (Rantanen and Goldberg 1999 and Miura 1990). In addition, a reduction in the mean gaze duration can be found (Miura 1990). The reduction in visual field size can be related to two separate phenomena. Tunnel vision, represented by a clear reduction in aperture angle of the visual cone, and a general decrease in peripheral visual performance independent of the visual cone angle (Rantanen and Goldberg 1999).

Drivers affected by these changes rely on a greater number of shorter fixations to detect and acquire information from targets (Miura 1990 and Crundall et al. 1998). Crundall et al. (1997) concludes that slower reaction times result. An on-the-road driving study, using a commercial eye tracker as a method of determining where an individual’s attention is focused, was conducted to further understand the effects that distractions have on drivers as well as verifying the results of some previous experiments.

Purpose of the investigation conducted by Sodhi et al. (2002) was to analyze the gaze pattern of drivers while being distracted. In the experiment 24 licensed drivers were asked to drive a route of about 20 miles fitted with the head mounted eye-tracking device HED. They were recommended to use the vehicle they normally drove, to ensure familiarity with the controls. During the test drivers were confronted with several distractions, presented by one of the investigators. When driving past a pre-determined position on the route, for each distraction the researcher played back a pre-recorded CD track initiating the specific distraction.These were:

1. Turning on the radio and change the station to 1610 AM.
2. Noting fuel prices from approaching filling stations.
3. Answering a phone call from a non-hands free device and completing a computational task.
4. Looking in the rearview mirror and describing the vehicle behind.
5. Answering a hands free phone call and completing a memory task.
6. Reading the odometer.
7. Startle sound of a cellular phone (3 rings).

For Recart and Nunes (2000) eye movements in many cases are assumed to be predictors of attention. An eye tracking system can therefore be used to collect information about how a driver responds to different situations on or off the road.

The main studies on variable message signs and driver behaviour have been conducted in European and non-European countries.

Warren e Radu (2003), of the School of Linguistics and Applied Language Studies of Victoria University, undertook a psycholinguistic investigation of the messages displayed on these signs. This study suggests that the ordering of the line text in VMS display is important.

Differences observed in the data reflect the relative position of the information in text that obviously requires a driver reaction.

The first recommendation is that the text requiring driver reaction should be placed on the first line of the display. It was also found that the logical ordering of “statement of event” – “action to deal with that event” was effective for messages in which the statement of event was concise. A second recommendation is an exception to the first, namely that brief and non-general scene information (such as “ACCIDENT”) should be placed on the first line of the display.

The study has also revealed some marked differences between the current messages used in the VMS displays and some of the formerly used messages. The latter consistently received higher urgency ratings and faster responses. The authors suggest that this is related to the amount of text presented in those messages: brief is better, and interestingly not only from the point of view of processing time but also in terms of how urgent the message is perceived to be.

Another study concerning Variable Message Signs and Factors which influence the use of VMS on motorways was conducted in the UK (Kubacka et al. 2006). This study examined how to improve the use of VMS, regarding implementation, accuracy and driver perception. The aim of the study was to investigate driver opinion and attitudes towards VMS on the M1 motorway (Southbound London) and to discover specifically whether and how drivers would respond to different types of VMS (recognizing driver preferences); what factors would influence drivers behavior and identify whether new developments of the British Highway Agency could be successfully implemented throughout the motorway network. The results show that motorists take notice of VMS and think the service is helpful and positive; more than 50% of drivers expressed a favourable or very favourable opinion of VMS characteristics; the highest score falls to understandability and usefulness of VMS and the lowest to accuracy.

In Norway Erke, Sagberg & Hagman (2007) investigated the effects of VMS on speed and route choice on two sites on motorways. The study involved the use of two different panels that displayed information about a closed road section ahead and recommendations for alternative routes. The increased attention demand indicators were braking, changing lane and speed reduction.

Chatterjee, Hounsell, Firmin and Bonsall (2000) studied driver response to VMS information, using questionnaires to investigate the effect of different messages on route choice. Through a statistical analysis of stated intention questionnaire data, they developed logistic regression models relating probability of route diversion to driver, journey and message characteristics.

Borowsky, Shinar, Parmet (2007) examined sign location, recognition and driver expectations. An experiment was conducted with twenty participants, using a LCD screen, connected to a Pentium on which different scenes were displayed. Participants were instructed to watch the traffic scenes as if driving down the road, and for each picture they would be asked a question. The relative contributions of the various factors were evaluated using a logistic regression with a random intercept. The results of this research showed the need to locate traffic signs according to traffic code and driver expectations.

Another problem concerns the language used in panels, in fact in countries where different languages are spoken, or on a transnational corridor, the choice of language is very important.

The first study conducted by Harjula, Luoma e Rämä (1997) investigated driver acceptance of a VMS displaying bilingual messages. The panel displayed Finnish and Swedish text messages in turn (2 sec in each language). In this study a total of 350 drivers were interviewed, ahead of the sign, and asked to recall the messages and their preference. Drivers did not report any difficulties in reading the information displayed by this method. Some older drivers felt that display time was too short, whereas others felt that reading the message was more complicated. However the principal implication of the study is that most drivers accepted the VMS displaying bilingual messages.

Another study of the Finnish Road Administration (Rämä, Schirokoff, Luoma, 2004) was designed to increase harmonisation of variable message signs in the Scandinavian countries.

Three main sign categories have been used: regulatory messages, danger warning signs and informative signs. The study showed that many features are already harmonised in accordance with the Vienna Convention or common practice. The most harmonised areas are the colours and the use of symbols and pictograms in regulatory and danger warning signs.

Fancello et al. investigated the level of message perception interviewing 127 drivers in Cagliari (Italy) passing beneath the first overhead VMS sign to be installed in the city. Interviews were conducted over three days displaying three different messages concerning alternative routes and information on penalty points for driving offences. 65% of the drivers interviewed reported they had not read the message, and of these 25% stated that they were concentrating on driving, 25% that they had not noticed the sign and 16% that they were absorbed in thought.

A second study concerning a larger sample size was conducted on motorists in Brescia, where the use of VMS is well-established. 842 drivers passing beneath two different VMS boards located at different points of the city were interviewed. In this case, almost 85% of the sample reported not having read the message, 34% of whom stated they had not seen it, 24% that they were concentrating on driving while 22% said they were distracted by a conversation or by the radio.

The findings of these investigations highlight the general disinterest towards VMS. However, the doubt remains whether the drivers had actually seen the panel but did not remember its content.. Clearly, this issue is not easily resolved without an objective measure of drivers gaze point.

This objective has been achieved using an eye tracker, an instrument that monitors eye position and movements. With this device it is possibile to determine in an “objective” manner where drivers fix their gaze and the time spent observing nearby objects. Thus the oculometer will be used to determine whether the driver sees the VMS sign and gaze fixation time.

METHODOLOGY

The purpose of this paper is to determine drivers’ level of perception of variable message signs and using eye tracking techniques, the length of time drivers fix their gaze on the board as well as their comprehension of the text.
A test was conducted on urban and non-urban routes where VMS boards with different characteristics are installed. The first board displays messages containing pictogram plus text (4 rows each of 15 characters each), while the second displays only text messages on 7 rows with a maximum of 12 characters per row.
Drivers wore the eye tracker throughout the test and were accompanied by an operator who recorded the parameters measured by the device, checking the test was proceeding correctly.

Fig.2 – VMS 1

Fig.3 – VMS2

The Eye Tracker

Using eye tracker data processing software, it is possible to identify the points of fixation i.e. when the gaze pauses on objects in the surrounding environment, that contain important information and that can be associated with but can be distinguished from saccades, rapid eye movements that redirect gaze and that may coincide with distractor signals.

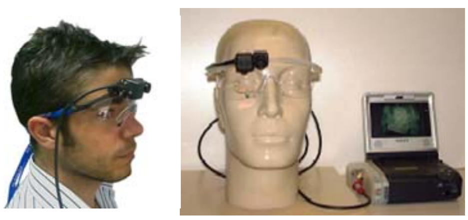

Fig.4 – Eye tracker

The software also allows to accurately study driver points of fixation and look zones which are useful for improving design.
The data examined here concern the "scene", i.e. eye direction with respect to the scene image, in scene image pixels.

Results

The test concerned 14 drivers, 43% of whom had at least 10-15 years driving experience, 21% had 5-10 years driving experience, while 14 % had been licensed to drive for over 30 years.
A large majority of the drivers had problems with eyesight (64%), 43% of whom wore glasses (a special mask was devised for mounting the eye tracker) and 21% contact lenses. As far as the test routes were concerned, 50% of drivers were familiar with the route, driving along the roads at least once a week, while the remaining 50% rarely or never drove along them.
Most of those tested were driving in the inside lane and were not queueing when they passed beneath the VMS (64%), while 21% were overtaking.
79% of drivers passing beneath VMS1 were travelling at a speed of between 70 and 90 km/h, 14% at over 90 km/h. Most of them were queueing or overtaking when they passed under the VMS board (71%), 57% travelling at a speed of 30-50 km/h, 36% at less than 30 km/h.
Ninety—three percent of drivers passing underneath VMS2 reported not having seen the panel, 79% of whom was overtaking. The large majority (71%) did not even glance at the VMS: 57% were travelling at between 30-50 km/h, 36% at less than 30 km/h.
As for the second panel, only 3 of the drivers who reported having seen the panel, remembered part of the text. This particular driver observed the message for 1.37 consecutive seconds, despite which he was unable to repeat the message exactly. At the time of passing beneath the VMS the driver concerned was travelling at less than 30 km/h and was queueing.
Only data for those drivers for whom at least one eye movement lasting 0.03 sec in the direction of the VMS was recorded and for whom the data measured with the eye tracker was as homogeneous as possible, were used in the analysis.
In particular, in order to determine whether the presence of the VMS produced abrupt changes in eye position, the indicator values for central vision of the road (corresponding to "normal" driving behaviour) and vision of the sign, were compared.
For those drivers who had read the message, the analysis aimed to determine whether their eye movement was compatible and did not involve diverting their gaze to the extent that it could pose a safety hazard while driving. The data all referred to the same stretch of road where conditions could be considered homogeneous, limitedly to the visibility period of the VMS. Obviously for each one the position on the x and y axes varies depending on the physical characteristics of the driver, posture, height of vehicle, etc.
The eye tracking device monitors eye movement with a precision to within 0.03 sec, and does not record movements coinciding with blinking which occurs with a frequency of roughly 10-20 a minute (Esteban et al. 2004).

The data concerning point scattering along the horizontal plane and the variation of the x and y coordinates of the scene were all represented along a single plane in order to facilitate comparison.

The recorded data were analysed as a function of driver gaze points during the visibility/readability period of the VMS board. The first analysis concerned gaze fixation time for the two panels.

Tab.1 – VMS1

VMS 1	Driver 2	Driver 3	Driver 11	Driver 12	Driver 13	Driver 14
Maximum consecutive time spent looking at panel	0.57	1.5	0.09	0.16	0.64	0.44
Total time spent looking at panel	1.53	1.62	0.3	0.2	0.64	2.44
Position when passing beneath VMS	Road free inside lane	Road free inside lane	Road free inside lane	Overtaking	Road free inside lane	Queueing inside lane
Average speed in stretch of road where panel is located	70-80 km/h	80-90 km/h	70-80 km/h	80-90 km/h	90-100 km/h	60-70 km/h
Text remembered	Road works	Road works delays Via dei Conversi	-	-	Road works delays Neighbouring roads	-
VMS message	ROADWORKS VIA DEI CONVERSI DELAYS NEIGHBOURING ROADS					

As can be seen from the table, driver 3, the only one who remembered the complete sense of the message, spent 1.5 consecutive seconds reading it.

All those drivers who remembered the message looked at the board for more than 0.5 consecutive seconds. The table highlights the importance of consecutive time spent looking at the message rather than overall time.

As for the second panel, only 3 of the drivers who reported having seen the panel, remembered part of the text. This particular driver observed the message for 1.37 consecutive seconds, despite which he was unable to repeat the message exactly. At the time of passing beneath the VMS the driver concerned was travelling at less than 30 km/h and was queueing.

Tab.2 – VMS2

VMS 2	Driver 1	Driver 5	Driver 9
Maximum consecutive time spent looking at panel	1.37	0.34	0.33
Total time spent looking at panel	1.37	0.34	0.5
Position when passing beneath VMS	Queueing inside lane	Queueing inside lane	Queueing outside lane
Average speed in stretch of road where panel is located	< 30 km/h	< 30 km/h	30 – 50 km/h
Text remembered	Lavori	-	-
VMS message	ROADWORKS VIA DEI CONVERSI PROBABLE DELAYS		

Jacobs and Cole (1979) determined that the time needed to correctly read a road sign can be approximated by the formula t(s) = 0.32N - 0.21, where N is the number of words on the sign. On the other hand Hall, McDonald and Rutley (1991) predict a longer time to read all place names on a sign with their formula t(s) = 0.784 + 0.167N.

The values calculated with these formulae would therefore confirm that the time required to correctly read the two messages in the case at hand, can be calculated as 1.39 secs for the first message and 1.07 secs for the second. These values say a lot about the difficulties in perceiving and comprehending VMS text messages when they contain too much information.

The eye tracking system generated a series of coordinates that identify the position of the drivers' gaze over time Eye data from two participants (9 and 3) were omitted from the analysis because of poor tracking quality. Fixations corresponding to front forward position were classified as central fixations. Gaze shifts needed to look at the variable message signs were calculated with respect to these values.

As already mentioned, an important aspect of information acquisition and processing in driving is the relative motion between observer and object observed and the resulting need to allow sufficient space and time for the processes of perception and interpretation to take place..

In keeping with the characteristics of information acquisition and processing while driving a vehicle, Italian regulations (Implementation Regulations for Highway Code) establish that consecutive repeater signs should to be installed, giving advance warning, indications and lastly a confirmatory sign (Fig. 4).

The total time required for detecting, identifying and reading road signs plus driver reaction time is calculated, as far as the Italian Highway Code is concerned, as 10.5 sec.

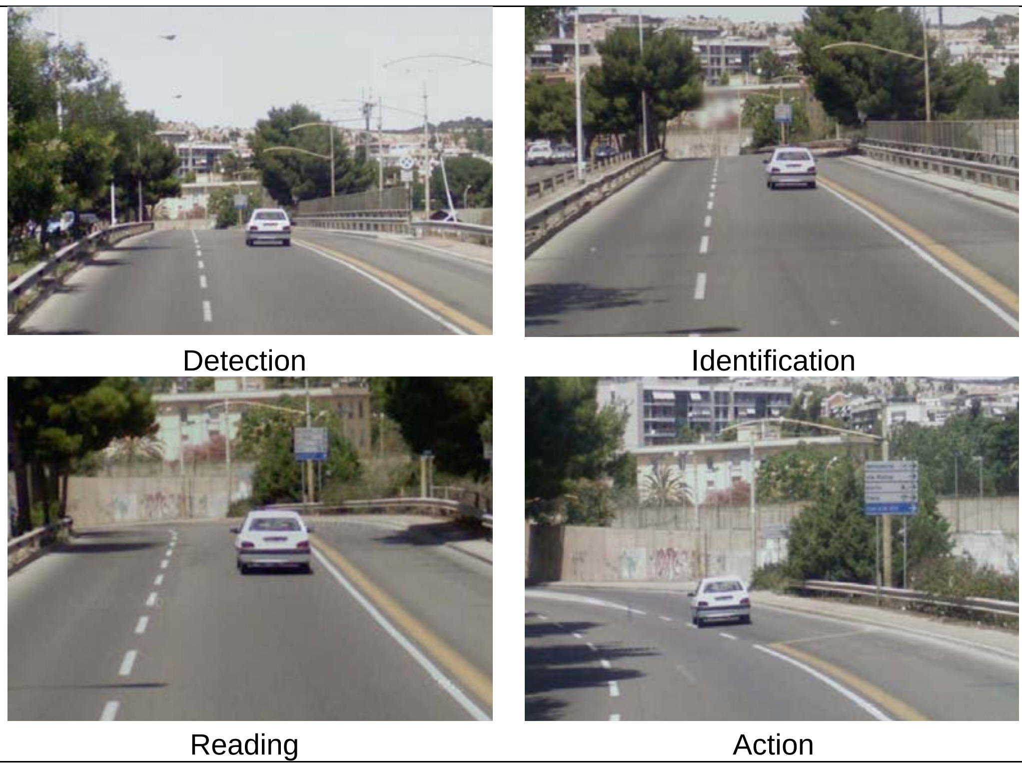

Fig. 4 –Road sign perception stages

In order to verify the detection and information acquisition processes of motorists, only the data collected for the first variable message sign were considered, for which longer fixation times were recorded.
As mentioned above, the time required to read the board is 10.0 seconds over a total distance of 240 m:

1. Detection 30 m;
2. Identification 70 m;
3. Reading 70 m;
4. Action 60 m.

The period corresponding to the first three stages has been identified as that required for signal perception, with a duration of 7.5 seconds while the last stage denoted action occupies the remaining 2.5 seconds.

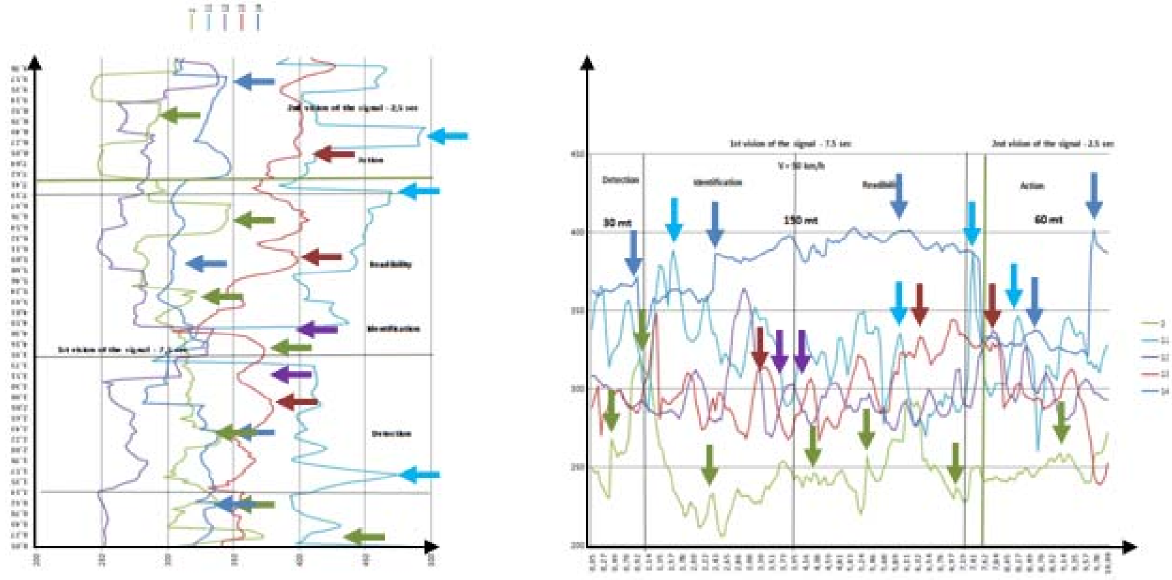

Fig. 5 – Scatter of points for Scene x

Examination of the graph shows that all the drivers looked at the board at least once during the perception-comprehension period.

Tab.3 – VMS1 Perception

	Number of times driver looked at VMS				
Drivers	*Detection*	*Identification*	*Reading*	***Total***	*Action*
2	1	3	1	**4**	2
11	1	1	1	**3**	0
12	0	1	1	**2**	0
13	1	1	1	**3**	0
14	1	1	1	**3**	1

As can be seen from the table, the number of glances at the VMS is concentrated chiefly in the perception phase, in other words in the information acquisition stage. During this stage the driver approaches the VMS, perceives the information contained therein and only in the event he/she has not perceived all the necessary information does he/she glance once again at the board during the "action" stage to confirm what he/she had previously perceived.

Conclusion

The present paper, which describes the preliminary results of a broader on-going investigation conducted by Cagliari University on variable message signs and road signs in general, confirms the findings reported in the literature concerning the difficulties drivers experience in VMS perception.

The first results of this investigations will be used as a basis for improving the design and display of information in variable message signs.

The use of the eye tracker made it possible to identify a number of aspects that need to be investigated in more depth. Particularly, as earlier findings have indicated, the message does not remain imprinted on the driver's memory and above all despite having glanced at it, he/she is unable to remember the contents

The drivers participating in the test all showed little interest in the variable message sign. Previous studies (Fancello et al.) have indicated that regular drivers tend to obliterate many objects from their field of vision, including variable message boards.

Another aspect worthy of attention is the installation of VMS within the city center itself. The position of the second board made it difficult and even dangerous to read. Drivers have to cope with numerous hazards in city driving, such as junctions, driveways and pedestrians and this restricts their ability to absorb information displayed on road signs.

Being in a queue or driving slowly does not facilitate reading, on the contrary, it makes it more complicated as the driver tends to look straight ahead at the road in front of him and or in his mirrors.

Calculating gaze duration, in particular for the second VMS, the "safe" driving time interval, i.e. the length of time a driver takes his eyes off the road ahead, has been exceeded. This safe interval, is established as 0.7-0.8 consecutive seconds at the most. Of course, the driver may glance at the message a second time if he has not managed to absorb the information completely, and this behaviour was observed in the case at hand.

Clearly, this safe time interval decreases with increasing speed and will depend on driving conditions, particularly when the driver is queuing and is driving behind other vehicles. Consequently VMS should be designed accordingly, especially when different messages are sent on multiple displays.In the case at hand, the messages were static, notwithstanding which none of the drivers were able to repeat the message exactly.

Thus it becomes counterproductive to display lengthy messages even in a single display and, as confirmed by the findings of this study, at least 0.57 consecutive seconds are required to remember the information contained in the message. This finding is further confirmed by earlier studies which indicated that drivers found it easier to understand messages arranged in two lines on two displays.

The test indicated that a gaze duration of 1.5 secs during driving is too long and does not necessarily result in the driver comprehending the message. As far as the first variable message sign is concerned, though fixation time was long, this can be justified by traffic conditions. However, in the case of the second VMS which was only seen by one driver, the particular conditions and the position of the board, near to the entrance to one of the city hospitals, meant that drivers could not divert their attention from driving, because of the numerous pedestrians and vehicles exiting from side access roads.
Further, the size of the VMS board makes it difficult to detect and two motorists travelling in two lane traffic did not actually see it.
Further research will focus on how driver perception varies with psychophysical characteristics and lighting, conducting appropriate tests.

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