DEVELOPING GUIDELINES FOR MANAGING DRIVER WORKLOAD AND DISTRACTION ASSOCIATED WITH TELEMATIC DEVICES

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Paper Number 07-0082

ABSTRACT

The explosive growth of in-vehicle telematic devices has brought with it a safety concern since there is the potential for distraction of the driver away from the driving task. To address this concern the Alliance of Automobile Manufacturers (Alliance) formed a work group of experts from the auto industry, government and other stakeholders (ITSA, SAE, CEA, AAA, NSC, TMA and others) and tasked them with developing a "best practices" document to address essential safety aspects of driver interactions with future information and communication systems. This effort, which has been ongoing for 6 years, has produced 3 iterations of the document "Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems." These Guidelines address the design, use and installation of information and communication systems with the goal of minimizing driver distraction associated with their use. The publication of the Guidelines has been followed by a letter of commitment from the Alliance members to design all their production vehicles to these Guidelines within specific designated timeframes.

The Working Group has made a commitment to harness and apply state-of-the-art scientific understanding to the continuing evolution of its Driver Focus Guidelines. In that effort the group has benefited from work in Europe, Japan and the U.S. sponsored by both the private and public sectors. The purpose of this paper is to explore the extensive ongoing relevant research in the area of driver distraction and workload management and show how it has been utilized in the latest iteration of the Guidelines. The intent is that the Guidelines can be utilized to design telematic systems that stretch the envelope for systems that enhance the safety of drivers consistent with the state-of-the-art knowledge with regard to minimizing the potential for driver distraction.

BACKGROUND

On July 18, 2000 the National Highway Traffic Safety Administration (NHTSA) held a public meeting to address growing concern over motor vehicle crashes and driver use of cellular telephones and other electronic distractions present in the vehicle. At that meeting, NHTSA challenged industry to respond to the rising concern in this area.

As a result of this challenge, the Alliance agreed to develop a "best practices" document to address essential safety aspects of driver interactions with future in-vehicle information and communication systems. These systems, also known as "telematic" devices, include such items as cellular telephones, navigation systems, or Internet links. In December 2000, the Alliance submitted to NHTSA a comprehensive list of draft principles related to the design, installation and use of future telematic devices. This list of draft principles was based, in large part, on the European Commission recommendations of December 21, 1999, on safe and efficient in-vehicle information and communication systems (2000/53/ECO). At that time, the Alliance agreed to seek input from experts and interested parties to develop the principles into a more comprehensive document including more fully defined performance criteria and verification procedures.

A work group of experts, Alliance members and other interested parties was formed in March, 2001 under my Chairmanship and included participants from the Intelligent Transportation Society of America, the Society of Automotive Engineers, the Consumer Electronics Association, the American Automobile Association, the National Safety Council, the Association of International Automobile Manufacturers, and the Truck Manufacturers Association. The NHTSA and Transport Canada (TC) participated as observers in the process and the Insurance Institute for Highway Safety was a corresponding member.

In a letter dated April 22, 2002, the Alliance transmitted Version 2 of the draft guidelines to then NHTSA Administrator Runge. At that time, Alliance members committed to design and test future telematic devices in accordance with the guideline document. Version 2.1 of the guideline document was likewise transmitted to NHTSA on November 19, 2003. Alliance members reaffirmed their commitment to continue to design and develop future information and communication systems in accordance with this updated document. Most recently, on June 26, 2006 the Alliance transmitted various changes made to the guideline document over the preceding couple of years. In the transmittal letter, the Alliance stated that the enclosed changes were already being used in the design and development of future products. Further, the Alliance committed to continue to review information related to driver workload and its impact on safe driving as it becomes available and to work with NHTSA to better understand this complex issue.

INTRODUCTION

When drivers interact with in-vehicle information and communication systems (telematics devices) that have visual-manual interfaces there is the potential for distraction of the driver from the driving task. The Alliance Guidelines document was developed as a tool for designing telematic systems that minimize the potential for driver distraction during this visual-manual interaction while the vehicle is in motion. The current Guidelines do not address spoken dialogue (i.e., voice activated) devices. Future work will be undertaken to develop and issue guidelines that address voice-activated systems. It was decided to initially address only visual-manual systems since it was believed that an extensive body of relevant research in the areas of driver distraction and workload management was ongoing at the time.

The Alliance Guidelines document is organized according to twenty-four principles divided into five sections. The five sections address: 1) Packaging and installation of the system into the vehicle in a way that facilitates appropriate placement relative to the forward field of view and to minimize interference with driving; 2) Information presentation that meets accepted practices relative to legibility and understandability, timeliness, accuracy, controllability, and minimization of undesirable effects; 3) System interaction such that the driver is able to maintain safe control of the vehicle, feels comfortable with the system and is ready to respond safely to unexpected occurrences; 4) System behavior issues such as the treatment of information that must be made inaccessible during driving and provision of information about system malfunction; and, 5) Provision of instructions on the use of systems.

Elaborations have been drafted for each of the principles. These elaborations include specific criterion/criteria, technical justification, verification procedures, and illustrative examples on how they satisfy the principle. In order not to create unnecessary obstacles or constraints to innovative development of products the principles are expressed mainly in terms of performance based goals to be reached by the HMI. The statement of principles further assumes that manufacturers will follow rigorous process standards when developing products in accordance with the guidelines. Vehicle manufacturers already have robust product development processes that help ensure the integrity of their vehicle development programs from concept to production. The document encourages manufacturers of telematics devices who lack such a process control system to implement recognized industry process standards and examples of such recognized process standards are listed for reference.

COMMITTMENT TO USE LATEST SCIENCE

The Working Group has benefited from work in Europe and Japan as well as the U.S. The challenge of managing driver distraction in the presence of new technologies is a global one, just as the automotive business itself has become a global one. And the Alliance through the Working Group has made a commitment to harness and apply state-of-the-art scientific understanding to the continuing evolution of the Driver Focus guidelines.

A significant recent upgrade of the Alliance Guidelines focused on Principle 1.4, which requires that visual displays be positioned as close as practical to the driver’s forward line of sight. This Principle is based on the JAMA Guidelines concerning the monitor location of image display devices, and test results on which these Guidelines are based. Yoshitsugu, et al. determined the lower limit of a display’s downward viewing angle at which drivers focused on the display are still able to perceive they are closing on a preceding vehicle within the distance needed to avoid a rear-end collision. The JAMA study also examined perceptible distance to a lead vehicle at various eye height locations. The results revealed that as driver’s eye height above ground increases, the further they could see down the road. The JAMA study also examined display locations at various horizontal angles from centerline of driver. These results suggest that an angle measured in three dimensions from driver-seated position is appropriate as lateral displacement of the display increases. Together, the results from both of these additional research manipulations provided the basis for the addition of a second verification criteria (1.4B), which computes the 3D angle, thus providing a better approximation of the driver’s actual downward visual angle than the 2D angle as specified in the JAMA

Guidelines. In order to eliminate ambiguities and create a common understanding and practice a ground plane definition already in use and agreed to by the SAE was incorporated. A simple measurement method based on only two points was implemented as an Excel-based tool. It allows for quick and easy determination of the 3D downangle and whether a vehicle meets the Guideline 1.4 criteria. The 2D method is particularly suitable for early design phases where the vehicle is in grid coordinates. The 3D criterion is suitable for later design phases where a ground plane has been defined for the vehicle. Both methods ensure that displays covered by Principle 1.4 will be placed high enough for a driver to use peripheral vision to monitor the roadway for major developments during quick glances to the display.

International efforts to address driver distraction have recently focused on how best to assess visual demand as it relates to driving performance. Both the Alliance Driver Focus Working Group and ISO Working Group 8 have efforts to review state-of-the-art science in an attempt to drive toward convergence on measurement of visual demand.

A number of relevant research projects have been underway over the past few years – many of which explore surrogate methods for assessing visual demand. Among these are:

- CAMP (Driver Workload Metrics Project sponsored by Ford, G.M., Nissan, & Toyota)
- ADAM (Advanced Driver Attention Metrics sponsored by DCX & BMW)
- IVIS DEMAnD Modeling Project (VTTI)
- Naturalistic Driving (100-car study at VTTI)
- HASTE, Roadsense, AIDE (EU)
- Transport Canada & NHTSA research
- JAMA (Japan)
- IHRA – ITS (Global)
- Others

SOURCES CONTRIBUTING TO THE NEED FOR CONVERGENCE

The following paragraphs summarize some of the more salient findings of recent relevant research projects and briefly discuss how they relate to the criteria contained in the current version of the Alliance Guidelines:

To address long tasks exceeding the 20 second total glance time specified in the Guidelines, BMW has recently proposed the "R-Metric" or resumability metric as an alternative means of assessing visual demand where:

$$\text{R-Metric} = \frac{\text{Total Glimpse Time to Task}}{\text{Total Time to Complete Task}}$$

If R < 1 then the tasks visual demand is deemed acceptable. Some long complex tasks with long eyes off the road times can be deemed acceptable with this metric and conversely some short visual tasks can be deemed unacceptable with this metric. A key question for state-of-the-art research then becomes: What does natural driving behavior indicate about eyes-off-road time, especially as it relates to crash risk?

Virginia Tech Transportation Institute (VTTI) has conducted a study of 100 drivers in a "naturalistic" setting to obtain pre-crash/crash/near crash/incidents data as well as driver performance. Drivers in their own or leased vehicles with specialized instrumentation, which was unobtrusive and inconspicuous to other drivers, were simply told to drive as they normally would over a period of approximately one year. The analysis of eye glance behavior indicates that total eyes-off-road durations greater than 2 seconds significantly increased individual near-crash/crash risk. This confirms the importance of eyes-off-road time and its role in detection of unexpected events and appears to justify the maximum single glance time of 2 seconds specified in principle 2.1 of the Alliance Guidelines.

The Society of Automotive Engineers (SAE) has an ongoing effort that has some similarity to the Guidelines document but is not exactly the same. SAE J2364, which has been issued in modified form, specifies a total eye glance time of 15 seconds or alternatively a TSOT of 20 seconds using the occlusion method. This compares to the similar Guidelines requirements of 20 seconds and 15 seconds respectively.

VTTI, under the sponsorship of the Federal Highway Administration, developed a behavioral model (IVIS-DEMAnD) that predicts driving task performance decrements of drivers interacting with in-vehicle information systems (IVIS) along with software that integrates the behavioral model with past research on the behavior of drivers when using IVIS. A key aspect of the model is the color coding of expected driver attention demand into yellow and red line demand values as derived from empirical data on driving performance indicating where driving performance was affected at $p<.05$. Yellow highlighting of the predicted measure indicates that driving performance will be affected relative to baseline driving with no in-vehicle task. Red highlighting of the value indicates that driving performance will be substantially affected relative to baseline driving with no in-vehicle task. Table 1. shows the measures in the expected demand summary and their critical values:

Table 1.
Measures in the Expected Demand Summary and Critical Values from IVIS DEMAnD Model

INDIVIDUAL MEASURES	AFFECTED (CODED YELLOW)	SUBSTANTIALLY AFFECTED (CODED RED)
Single Glance Time	1.6 seconds	2.0 seconds
Number of Glances	6 glances	10 glances
Total Visual Task Time	7 seconds	15 seconds

The coded red values for single glance time and number of glances are the same as specified in Principle 2.1 of the Guidelines and the total visual task time of 15 seconds compares to the 20 second total task time in the Guidelines.

The Crash Avoidance Metrics Partnership (CAMP) had a project objective of developing performance metrics and test procedures for assessing the visual, manual and cognitive aspects of driver workload from telematics systems. The project used phased testing of 234 licensed drivers using both 'driving performance measures' of driver workload taken under test track and on-road driving conditions as well as surrogate metrics, which include models, simulations or laboratory procedures.

The CAMP occlusion surrogate test was shown to have generally low test-retest reliability but was repeatable when data were averaged across persons by task. The occlusion test was predictive of task completion time while driving, lane keeping, car following, speed control, and total glance time and number of glances away from the road (task related). A number of in-vehicle tasks were classified into higher and lower workload levels based on literature, analytical modeling, and engineering judgment. Occlusion test results were then used to classify the tasks as higher or lower using 7 different rules based on mean and 85%-ile values for static time, TSOT and R. Rule 5 (mean TSOT>7.5 seconds meant the task was higher workload) was best, resulting in only 1 false positive classification error.

CAMP recorded eye glance behavior and lane exceedances during performance of tasks while driving in a simulator. At the trial level, lane exceedance trials tended to have more glances, longer TGTs and longer single glance durations away from the road. At the task level, the proportion of Lanex trials for a task tended to increase as TGT, glance counts, and max single glance times per task increased. Single glances 4 seconds prior to the start of a lane exceed of 6 inches or more were longer than for the 4 seconds random period of driving only. The overall conclusion: How often and long you take your eyes off the road affects your driving.

The Japan Automobile Research Institute (JARI) conducted a study of the upper limit of glance time, associated with various tasks while using four navigation systems, that does not interfere with normal driving. Table 2. shows the upper limit of total glance time (TGT) for the four navigation systems when used in four different driving environments. The table combines results based on both a subjective measure of uneasiness feeling to the driver and an objective measure of lateral lane control.

Table 2.
Upper Limit of TGT That Does Not Cause Uneasiness Feeling & That Does Not Affect Lateral Control

	2-LANE URBAN	1-LANE URBAN	JOBAN EXPRESS	METRO EXPRESS
Touch Panel	8.4	8.2	8.2	≈8 sec
Joy-Stick	8.9	8.6	9.7	8.3
Remote Control	10.2	N.A.	10.2	N.A.
Rotate Knob	8.2	N.A.	10.6	N.A.

Based on these results, the researchers concluded that the upper limit of TGT from combining both the uneasiness feeling and the lateral lane deviation results was approximately 8 seconds. The operational tasks were repeated using the occlusion method with various open/close patterns. A shutter open time of 1.5 seconds and close time of 1.0 second was most closely correlated with both TGT and single glance time. The TSOT that was found to be equivalent to 8 seconds TGT was approximately 7.1 seconds. Elder drivers had longer TGT than younger drivers for the navigation systems using joystick and remote control but had similar TGT for the touch screen navigation system.

Transport Canada contracted with Humansystems to assess the validity and reliability of the Alliance Guidelines. In Phase II, Principle 2.1 in the Alliance Guidelines was evaluated using the occlusion method. Two types of tasks were examined, address and point of interest (POI) destination entry into four different navigation systems, with each task encompassing two complexity levels. The low-level complexity tasks met the 15-second criterion for TSOT, whereas none of the high-level complexity tasks could meet the criterion. The report recommended that Principle 2.1 define tasks to be completed, define the desired level of complexity, and a means of measuring it. In developing the Guidelines the Working Group paid particular attention to ensuring that all criteria and evaluation procedures were performance based as opposed to design specific, so as not to discourage innovation. The recommendation to specify tasks goes counter to the basic philosophy of performance-based requirements. The Alliance Guidelines specify that all tasks that are capable of being performed when the vehicle is in motion be required to meet the 2.1 requirements. Humansystems noted that two of the nav systems locked out POI entry when the vehicle is in motion. The manufacturers of these vehicles apparently judged that it was not in the best interest of safety to allow the driver to access these functions while the vehicle is in motion and chose to lock them out. Humansystems also recommended that the occlusion option include a method to account for system response delay. Subtracting out system response delay in essence would make the TSOT requirement less conservative. It has been judged that system response should be timely and clearly perceptible in order to contribute to the reliability of the driver-system interaction; accordingly timely response has been specified elsewhere in the Guidelines; in Principle 3.5. Finally, Humansystems recommended that a method to monitor and record errors be devised. If a system is prone to operator error then this should be reflected in longer TSOT times. Drivers will make different errors with different systems, it would be difficult, if not impossible, to imagine every possible error. Once again, this recommendation runs counter to the basic goal of performance-based requirements. Rather than categorizing specific errors, the concern should be whether the driver can accomplish the secondary task without unduly compromising the primary driving task.

Europe and Canada have been interested in exploring surrogate reference tasks as a replacement for natural reference tasks like radio tuning. The criteria for acceptable eye glance duration and total glance time in the Alliance Guidelines are defined by means of a reference task. In particular, the 85th percentile of driving performance effects associated with manually tuning a radio is chosen as a first key criterion. This is because manual radio tuning has a long history in the research literature regarding its effects on driver eye glance behavior, vehicle control, and object and event detection are well understood. As noted in the Guidelines document, it represents the high end of conventional in-vehicle systems in terms of technological complexity as well as in terms of impact on driver performance and thereby is a plausible benchmark for driver distraction potential beyond which new systems should not go. Recent criticism of the manual tuning of a radio as a benchmark has claimed that modern radios are not tuned as radios in the past, due to their array of electronic memory options. However, recent on-track and on-road studies in CAMP have documented that the visual demands of radio tuning vary only slightly across 20 years (see Table 3.).

Table 3.
Consistency in Visual Demand Measures for Manual Radio Tuning

SOURCE	TOTAL GLANCE TIME (TGT), SEC	GLANCE COUNTS	MEAN SINGLE GLANCE TIME (MSGT), SEC
Rockwell (1986) Studies over 10 years	Not reported	Not reported	1.3 s to1.4 s
Bhise Forbes and Farber (1986) Studies in early 1980's	Not reported	2 to 7 glances	1.1 s
Dingus et al. (1987) Studies in mid-1980's	7.6 sec	7 glances	1.1 s
Kishi, Sugiura and Kimura (1992) (Highway)	Not reported	Not reported	1.1 s
CAMP (2005) Studies in 2003-2004 (Track Study)	9.0 sec	8 glances	1.2 s
CAMP (2005) Studies in 2003-2004 (Road Study)	9.4 sec	9 glances	1.1 s

HOW CAN WE ACCOMPLISH CONVERGENCE ON THE ISSUES?

Throughout the 2006 year the Alliance Working Group has continued to examine means to resolve differences and update the Alliance Guidelines document in the hope of making it truly representative of state-of-the-art research. The approach to resolution has been two pronged. First, during the summer of 2006 invitations were advanced to leading scientists to meet with the WG and share their latest research results and insights. In that endeavor the WG heard presentations from the following:

- Vicki Neale, Ph.D., Director, Center for Automotive Safety Research, VTTI and Co-Author of 100-car Naturalistic Driving Study
- Peter Burns, Road Safety and Motor Vehicle Regulation Directorate, Transport Canada, Humansystems review of the Alliance Guidelines, other TC research and desirability of adding rigorous process standards to the Guidelines
- James Sayer, UMTRI, The Effects of Secondary Tasks on Naturalistic Driving Performance
- Louis Tijerina, Ph.D., CAMP research
- Klaus Bengler, Ph.D., ADAM research

Following this series of presentations it was evident that some of the ongoing work was confirming the relationship between visual demand and safety related measures and work at other institutions was headed in different directions. This divergence, coupled with the recognition that substantial additional research was ongoing in Japan and Europe, led the Alliance Working Group to launch a second effort to reach convergence; namely, to host a Workshop on Driver Metrics. Transport Canada agreed to host the Workshop at their facilities in Ottawa Canada, October 2nd and 3rd, 2006, under the sponsorship of the Alliance. The workshop was coordinated with ISO/WG8 to precede relevant ISO meetings.

The Workshop was designed to bring together HMI experts from around the world to openly discuss their findings and testing methods and to share their lessons learned with the international research community. The Public Policy Center at the University of Iowa was contracted as an independent second party to convene and moderate the workshop. Deliverables included the construct of a website where all the presentations could be viewed (http://ppc.uiowa.edu/drivermetricsworkshop), a comparative matrix of measures (or other method for providing information in usable form) and a final report.

Each speaker was asked to cover certain topics:

- Background on Metric
  - Definitions
  - Pertinent Literature
- Key Findings
- Advantages/Disadvantages of Metric
- Relationship to Driving Performance
  - Lateral Control
  - Longitudinal Control
  - Event Detection
- Difficulties/Issues with Metric
- Appropriate Applications of Metric
- Lessons Learned
- Gaps/Future Needs

WHAT HAS BEEN LEARNED?

. At the time this paper was authored the University of Iowa had not yet published their synopsis of what was learned at the Workshop. The following is the author's summary of some key points that have emerged from both the Workshop and a review of pertinent research:

- Various studies have confirmed the relationship between visual demand and safety relevant measures
  - In 100-car study when eyes off the road time exceeded 2 seconds in the 5 seconds preceding a conflict the risk of a crash or near crash was elevated
  - CAMP lane exceedance trials had more glances, longer TGT, and longer max single glance duration
- Some findings in the latest research suggest the current limits in the Guidelines for visual demand may need to be made more stringent
  - JARI research reported by Asoh suggests that Total Glance Time should be ≤8 seconds
  - CAMP analysis of decision-rules showed best agreement with prior classification of tasks when mean TSOT≥7.5s meant it was high visual demand
  - IVIS DEMAnD Model code yellow and red values for total visual task time are 7 to 15 seconds
- Further research is needed on event detection and developing surrogate test procedures which are sensitive to it
  - Direct measurement of eye glance does not fully address the

attentional component of visual demand
    - Sternberg test shows promise for evaluating combined visual and cognitive loads of tasks
- Differences between institutions remain regarding the R-Metric
    - BMW believes that it is easy to use and has high potential as a classification tool for visual demand and resumption after interruption
    - Humansystems evaluation of 4 nav systems showed that the R value did not appear to be effective in discriminating between task types
    - CAMP results indicated that R is unrelated to on-road and test track driving performance and driver eye glance measures
- The lane change test holds promise but may need some improvements/tweaks
    - TC and CAMP research shows that Mdev is not enough and further work is needed to identify suitable criteria
    - TC is comparing LCT findings with conventional driving measures in a simulator
    - JARI studies showed that LCT effects were smaller for experienced test subjects
    - AIDE funded work to distinguish visual from cognitive distraction
- More work needs to be done to establish the relationship of all metrics to real world crash risk (as in 100-car study)
- Surrogate reference tasks may hold some advantages over natural reference tasks such as radio tuning. However, recent studies have shown that the visual demand of radio tuning has varied very little over the past 20 years and radio tuning remains a robust benchmark against which to judge new systems.

WHAT ARE THE NEXT STEPS?

In its continuing commitment to harness and apply state-of-the-art scientific understanding to the continuing evolution of the Driver Focus Guidelines the Working Group has identified the following areas for additional work during 2007:

- Hopefully, the University of Iowa will be able to display the results of the Ottawa Workshop in a matrix or other concept which will lend itself "to bringing the picture closer together"
- Review current limits on visual demand to see if they need to be made more stringent
- Inclusion of Event Detection in the tests for visual demand
- Continue to follow development of scalable reference tasks as a potential replacement of radio tuning as a reference task
- Further examine the R-Metric
- Refine Lane Change Task and make a decision as to inclusion in Guidelines
- Treatment of Visual Only Tasks

Further, the Working Group has agreed to expand the Guidelines document to include principles for Voice Interfaces, which are increasingly being incorporated into modern information and communication systems. Work on voice principles began in earnest in 2006 in the Alliance Working Group.

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