Performance Metrics for Assessing **Driver Distraction**

The Quest for Improved Road Safety

Edited by Gary L. Rupp

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ISBN 978-0-7680-3496-7
Library of Congress Catalog # 2010935923
DOI 10.4271/R-402
SAE Order No. R-402

Printed in USA

INTRODUCTION

SAE International is pleased to present "Performance Metrics for Assessing Driver Distraction: The Quest for Improved Road Safety", edited by Dr. Gary L. Rupp, who retired in 2007 from Ford Motor Company where he developed multiple ergonomics models and CAD tools.

Dr. Rupp has led many SAE and ISO committees, and authored various vehicle ergonomics standards. He chaired the ISO Road Vehicle Ergonomics Subcommittee (TC22/SC13) for 10 years, and still chairs the SC13 USA Technical Advisory Group.

"Performance Metrics for Assessing Driver Distraction: The Quest for Improved Road Safety" is a unique book in the field of measuring and assessing the impact of secondary tasks imposed on drivers, while driving.

Transportation professionals, designers of driver-vehicle interfaces, ergonomics researchers, and students will find it invaluable. Its content is meant to support the development of better metrics relating to cognitive load, driver distraction, and the development of less obtrusive in-vehicle information and communication systems (IVIS), including aftermarket nomadic devices.

Government and industry have considered road safety and driver distraction a top priority, which will only become more important in the future. The continuing introduction of new infotainment devices into vehicles, and into roadway infrastructure, requires a thorough evaluation of their impact on the driver, in order to improve or at least not degrade road safety.

The book was developed from the technical presentations that took place at the 4th International Driver Metrics Workshop, which in 2008 convened international experts in the field of driver performance and human-machine interaction.

"Performance Metrics for Assessing Driver Distraction: The Quest for Improved Road Safety" is sure to become a must-read and classic reference in a nascent and vital area of expertise.

SAE International

PREFACE

4th International Driver Metrics Workshop: Introduction and Workshop Goals

Gary L. Rupp
Editor

INTRODUCTION

In-vehicle information and communication systems (IVIS) should be designed with consideration given to the potential demands and risks associated with their use while driving. Although it is ultimately the driver's responsibility to operate the vehicle and onboard equipment safely, others are responsible for providing them with equipment that is compatible with safe driving. System interface design and the associated user tasks are much easier to change than is the driver's behavior, so the focus needs to be on optimizing the interfaces and tasks that the driver encounters.

Driver metrics are intended to measure and assess secondary task demands imposed by in-vehicle devices as well as the effect on the driver that secondary tasks impose on the primary task of controlling the vehicle on the roadway. They provide a mechanism to evaluate human-machine interfaces (HMI) and can be used as a means to assess the distraction effect on drivers from using in-vehicle devices. Driver metrics and their associated measurement procedures also provide a set of design and evaluation tools that can be used during vehicle development. The target of these evaluations has primarily been in-vehicle information and communication systems (IVIS), with original equipment navigation/route guidance systems being a commonly cited example. However, the metrics are also applicable for assessing aftermarket nomadic devices that drivers bring into their vehicles.

A considerable amount of time and research effort has been applied toward developing driver metrics and the associated evaluation procedures. This book provides a summary of the current state of driver metrics research and applications. The chapters in this book were developed from presentations given at the 4th International Driver Performance Metrics Workshop that took place in San Antonio, TX in June 2008.

PRIOR DRIVER METRICS WORKSHOPS

Previous driver metrics workshops were held in Turin (2001), Ottawa (2006) and Milan (2007). All the workshops aimed to gather international experts on driver performance metrics and to provide them a forum for detailed discussion of research findings, test methods, lessons learned, metric criterion values, comparison among the various metrics, and future research needs. The workshops were developed as a scientific and technical exchange, not as policy discussions.

The Turin workshop dealt with driver metrics derived from a visual occlusion procedure. Visual occlusion was initially conceived and investigated by Senders, Kristofferson, Levison, Dietrich, and Ward as a way to measure the visual attentional demand imposed on the driver while driving [1]. The occlusion procedure discussed in the Turin workshop allowed the participant an intermittent view of the task being performed, usually by means of special goggles whose shutter open and close times were tightly controlled by the experimenter. Most of the presentations given at the 2001 workshop are available at http://www.umich.edu/~driving/occlusionworkshop2001/. Some of the presentations were published in a special issue of Applied Ergonomics [2]. In 2007, ISO 16673 "Occlusion method to assess visual demand due to the use of in-vehicle systems" was published [3]. The ISO 16673 standard has two driver performance metrics, total shutter open time (TSOT) and a resumability ratio $R = TSOT / TTT_{Unoccl}$, where TTT_{Unoccl} is the total task time when no visual occlusion procedure is used.

Presentations from the 2006 international driver metrics workshop were not published in a book or special publication. McGehee and Rakauskas in Chapter 2 of this book summarize the outcomes from that workshop. The four focus areas of the 2nd workshop were: Occlusion, Lane Change Test (LCT) [4], Naturalistic Driving, and Direct Eye Glance Measurement. The workshop presentations are available at http://drivingassessment.uiowa.edu/driving_metrics_workshop_2006.

The 2007 workshop consisted of presentations and discussions about driver metrics that were investigated in the Adaptive Integrated Driver-vehicle InterfacE (AIDE) program [5]. The focus was on metrics that were candidates for HMI guidelines or for standardization. To A summary of that workshop and the presentations are available at http://drivingassessment.uiowa.edu/driver_metrics_workshop_(AIDE)_2007.

FOCUS OF THE 2008 WORKSHOP

The 2008 Driver Performance Metrics Workshop (DMW) expanded on results from the prior workshops. The 2006 workshop focused in part on the visual and visual-manual metrics derived from two different test procedures. One procedure involved a series of simulated lane changes. The other involved the visual occlusion technique. The 2006 and 2007 workshops identified auditory-vocal and cognitive metrics as additional needs to more fully assess driver performance when using the many new devices that are being proposed for future road vehicles or already are present in today's vehicles. These metrics were the focus of the 2008 workshop.

The test procedures discussed in the 2008 workshop focused on performance metrics related to Object and Event Detection (OED) tasks. OED tasks represent object or events external to the driving task. Drivers should be capable of detecting and responding to these events in an accurate and timely manner. The three test procedures to evaluate driver OED performance that were of primary interest for the 2008 workshop were

1. Peripheral Detection Task (PDT)
2. Modified Sternberg Method
3. Situational Awareness Metrics / Methods

A fourth area of interest was naturalistic driving studies and the associated driver metrics.

Each presenter was asked to address the sensitivity of the metric for discriminating between levels of measurement, proposed methods for analyzing the test results, and provided evidence of test repeatability. They were also asked to discuss whether the metric and associated test procedure had sufficient research data to support consideration as an international standard. Other questions that were to be addressed included:

1. What are the strengths and weaknesses of the metric(s) you have used?
2. For what driver tasks are the metric(s) applicable or not applicable?
3. What are the lessons learned? How can the metric be improved?
4. How does your proposed metric correlate to real world driving – on road or test track– and to crashes or crash risk?
5. What criterion value(s) do you recommend for your metric?
6. What process was used to establish a criterion value(s) for the performance metric(s)?
7. Are the metric and method ready for standardization?
   - Do you believe the metric(s) is sufficiently validated, sensitive, and reliable / repeatable?
8. If the metric and method are not ready for standardization, what research is needed to enable standardization?

All the workshop presentations can be accessed via the website: http://drivingassessment.uiowa.edu/driving_metrics_workshop_2008.

CHAPTERS IN THIS BOOK

Chapter 1 by Burns, et al. resulted from a panel discussion examining the use and application of driver metrics from the viewpoint of government agencies, vehicle industry and research organizations. Chapter 2, as noted previously, is a summary of the key findings from the 2006 international driver metrics workshop. Chapter 3 by Angell addresses key issues and recent findings about driver situation awareness and driver object and event detection. These chapters help set the stage for the chapters that follow and for future work related to driver metrics.

Chapter 4 by van der Horst and Martens is an excellent summary of vision-based peripheral detection tasks (PDT) as a means of assessing driver cognitive load. Chapter 5 by Engström introduces a tactile-based detection task (TDT) as an alternative to the visual PDT. Several studies have indicated that measuring cognitive load or driver distraction by means of the PDT or TDT is very promising. Both of these thought-provoking chapters discuss the theory, methods, and metrics for each procedure and are must reads for anyone who uses or plans to use these methods and metrics.

Chapter 6 by Benedict and Angell summarizes the results of two studies of a modified Sternberg method for assessing the visual and cognitive load of in-vehicle tasks. These studies indicated that driver metrics from the modified Sternberg procedure were highly correlated with event detection performance during on-road and test-track driving for a variety of in-vehicle tasks. Chapter 7 by Angell provides a detailed comparison of the modified Sternberg method to the peripheral detection tasks and the lane change test. It examines correlations among the metrics and suggests possible methodological improvements and directions for future work.

In developing driver metrics it's important to understand the relationship between the performance metric and the crash risk resulting from a driver performing in-vehicle tasks. Hopefully, driver metrics have some relationship to crash risk, i.e. they are in some way surrogate measures of the crash risk. Crash risk is a difficult measure to derive from traditional experimental studies. Naturalistic driving studies can provide unique data in this regard. Chapter 8 by Perez, et al. provides an overview of a naturalistic driving study and applications of the data for understanding the causes of crashes or near-crashes. Models developed from characterizing driver behaviors observed in the naturalistic data are also discussed.

Driver metrics can also be developed from data collected via a specially instrumented vehicle. Typically, the vehicle is driven on a pre-defined route over public roads in real traffic with an experimenter riding in the back seat. These types of studies are a step below naturalistic driving in terms of realism and crash experience. The chapters by Malta, et al. (Chapter 9) and Boyraz, et al. (Chapter 10) employ this type of data collection. These two studies are part of an international collaboration involving universities in five different countries: Japan, Italy, Singapore, Turkey, and USA. Malta studied four speech-based tasks and evaluated driver performance measures such as gas pedal force and pedal velocity as well as speech response delay. Boyraz studied several different secondary tasks such as cell phone dialogue, conversation, radio and climate control operation, etc. She developed and describes a linear classification scheme based on steering-related measures in order to discriminate normal from distracted driving.

Situation awareness methods and metrics have not often been applied in a driving context. Three chapters address situation awareness in detail. Chapter 11 by Bolstad, et al. provides a foundation for applying situation awareness to driving and in-vehicle devices. Methods, measures, and models are discussed. Chapter 12 by Metz, et al. describes a novel method for assessing situation awareness. Drivers are given a 3-second window to decide if their current driving situation is safe to begin a secondary task, which has a reward scheme based on driver performance. Measures related to the optional task and the driving task as well as eye movements are presented and discussed in terms of driver situation awareness and compensation strategies. Chapter 13 by Takahashi and Akamatsu describes an instrumented vehicle study focusing on driver eye glance behavior in real traffic. The authors developed a model to describe the frequency of drivers' rearward glances and used one of the model parameters as a metric for situation awareness.

Chapter 14 by Bengler, et al. describes the preliminary results of a carefully designed study of the lane change test (LCT) and its associated metric(s) that was conducted by eight different laboratories representing six different countries. This study is especially important because it describes the extent of research effort that may be needed to successfully develop a true driver performance metric. An ISO technical specification (TS) is being developed to standardize this methodology for conducting such inter-laboratory calibration studies [6].

Chapter 15 is a summary of the primary outcomes of the workshop and the next steps to be taken.