Cognitive Load and In-Vehicle Human-Machine Interaction

Andrew L. Kun[1)], Peter A. Heeman[2)], Tim Paek[3)], W. Thomas Miller, III[1)], Paul A. Green[4)], Ivan Tashev[3)], Peter Froehlich[5)], Bryan Reimer[6)], Shamsi Iqbal[3)], Dagmar Kern[7)]

[1)] University of New Hampshire
andrew.kun@unh.edu

[2)] Oregon Health & Science University
heemanp@ohsu.edu

[3)] Microsoft Research
timpaek@microsoft.com
ivantash@microsoft.com
shamsi@microsoft.com

[4)] University of Michigan Transportation Research Institute
pagreen@umich.edu

[5)] Telecommunications Research Center (FTW)
froehlich@ftw.com

[6)] AgeLab, MIT
reimer@mit.edu

[7)] Bertrandt Ingenieurbüro GmbH
dagmar.kern@googlemail.com

ABSTRACT

Interactions with in-vehicle electronic devices can interfere with the primary task of driving. The concept of cognitive load helps us understand the extent to which these interactions interfere with the driving task and how this interference can be mitigated. The workshop will address cognitive load estimation and management for both driving and interactions with in-vehicle systems, and will also endeavor to provide guidance on problems, goals, hypotheses and approaches for future research in this area.

Categories and Subject Descriptors

H.5.2 Information interfaces and presentation: User Interfaces. H.5.1 Multimedia information systems.

General Terms

Design, Experimentation, Human Factors, Measurement.

Keywords

Cognitive load, estimation, management, driving.

1. INTRODUCTION

In-vehicle human-machine interaction (HMI) requires varying degrees of visual and cognitive resources. Concerns over excessive visual demands in the vehicle have existed for some time. More recently concerns over the impact of HMI on drivers' cognitive resources have gained attention. A user's cognitive load (also called cognitive or mental workload) is commonly defined as the relationship between the cognitive demands of a task and the cognitive resources of the user [1]. A central question in designing HMI for in-vehicle devices is how the HMI will impact the driver's cognitive load [2]. In-vehicle devices are often operated while the vehicle is moving. While the primary task of the driver is to ensure driving safety, the availability of such devices often lures drivers into getting engaged in peripheral tasks while driving. Poorly designed HMI requires an increased level of cognitive resources, reducing the driver's ability to dedicate sufficient cognitive resources to the driving task, and can lead to possibly disastrous consequences. The Yerkes-Dodson Law provides a theoretical background for modeling the effect of driver cognitive load on driving performance, and can be seen as a pivotal concept in the detection and management of cognitive load [3]. While research results on in-vehicle cognitive load are frequently presented at automotive research conferences and in related journals, so far no dedicated forum is available for focused discussions on this topic.

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2. WORKSHOP GOALS

The workshop has four goals:

1. **Explore issues in cognitive load estimation:** Estimating cognitive load while driving is a challenging task. On-road experiments are desirable [4], [5], but introduce many scientific and technical challenges (e.g. how to interpret data collected in an experiment in which the safety of participants was the highest priority). Laboratory-based experiments are common [6], [7], but researchers must account for the ecological validity of such experiments [4]. Thus, the workshop will explore on-road studies and those performed in a laboratory setting (both using immersive driving simulators and other techniques), and the connection between the two. The workshop will also explore various measures of cognitive load (performance, physiological and subjective).

2. **Explore issues in cognitive load management:** How can we design in-vehicle HMI such that the driver has the cognitive resources to safely operate the vehicle, even while interacting with in-vehicle devices? Researchers and practitioners have explored a number of approaches for workload management [8], from simply turning off HMI in certain situations, to introducing novel interaction methods which hopefully do not introduce undue cognitive interference with the driving task (voice interfaces [9], [10], augmented reality [11], [12], mediation [13], tactile interfaces [14], subliminal notifications [15], etc.). Other work [3] suggests that effective implementations of these and other systems need to adapt to the driver's state. The workshop will explore various aspects of managing the driver's cognitive load.

3. **Explore issues in developing benchmarks for design evaluation:** The design of safe in-vehicle HMI requires comprehensive and reliable test procedures, to evaluate how the HMI affects the overall cognitive load of the

driver while operating a vehicle. A number of research projects focus on developing benchmark tasks to be performed by drivers while they are also engaged in HMI. Successful completion of the benchmark indicates that, under a set of constraints, the HMI does not introduce undue cognitive load. From guidelines developed by the Alliance of Automobile Manufactures, the ISO and the SAE, benchmark tasks such as the Lane Change Task and the Peripheral Detection Task have emerged. Other studies such as the European HASTE program [16] investigated the use of surrogate tasks to systematically explore the effects of different aspects of HMI on driving. Recent research [4], [5] indicates that a delayed digit recall task is a promising surrogate HMI task. The workshop will explore aspects of benchmark development, including simulator-specific benchmarks.

4. **Chart a path for future research and development:** In light of current approaches to cognitive load estimation and management, and approaches to the development of benchmarks, what research and development avenues should be explored in the next 2-10 years? What are the problems researchers and practitioners should explore, what are some of the goals that should be set, what are some of the hypotheses that should be tested, and what approaches are likely to be fruitful in testing these hypotheses? The workshop will initiate an effort to create one or more white papers to provide guidance on this topic, targeting fellow researchers and practitioners, as well as industry and funding agencies.

The workshop organizers solicit research papers on topics related to goals 1, 2 and 3: issues in cognitive load estimation and management for interactions with in-vehicle devices, and issues in developing benchmarks. Authors are encouraged to also include at least one paragraph addressing goal 4: charting a path for future research and development. Additionally, position papers on goal 4 are also solicited. Topics of interest will include:

- Cognitive load estimation in the laboratory,
- Cognitive load estimation on the road,
- Sensing technologies for cognitive load estimation,
- Algorithms for cognitive load estimation,
- Performance measures of cognitive load,
- Physiological measures of cognitive load,
- Visual measures of cognitive load,
- Subjective measures of cognitive load,
- Methods for benchmarking cognitive load,
- Cognitive load of driving,
- Cognitive overload and cognitive underload,
- Approaches to cognitive load management inspired by human-human interactions.

3. ACKNOWLEDGMENTS
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