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A workload model to evaluate distracters and driver's aids

Cansu Kandemir [a, *], Holly A.H. Handley [a], Deborah Thompson [b]

[a] 2123A Systems Research & Academic Building, Engineering Management & System Engineering, Old Dominion University, Norfolk, VA 23529, USA
[b] Volvo Group North America, Group Trucks Technology (GTT), Advanced Technology & Research (ATR), 7825 National Service Road, Mail Stop AP1/3-41, Greensboro, NC 27409, USA

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A B S T R A C T

The aim of this study is to examine the use of a driver workload simulation model to provide commercial vehicle interface designers a tool to investigate the effects of various types of distracters and driver's aids under varying conditions, prior to test in a simulator or implementation in a prototype. To build the model, a driving scenario was first identified based on the National Highway Traffic Safety Association (NHTSA) driving route. The driving model was created using IMPRINT, a discrete event simulation tool that characterizes four classes of human resources that may contribute to driver workload: visual, auditory, cognitive and psychomotor (VACP). For this initial model we tested limited number and type of distractions. The initial use of a sample of driver aids and their importance to mitigating driver distractions has also been included.

Relevance to Industry: This study investigated the use of a driver workload simulation model to provide commercial vehicle interface designers a tool to investigate the impact of the multiple activities an operator performs while driving. A simulation model can predict the changes in driver workload due to multiple secondary tasks performed in varying driving conditions.

1. Introduction

This study investigated the use of a driver workload simulation model to provide commercial vehicle interface designers a tool to explore the impact of the different activities an operator performs while driving. With the increasing number of technologies being designed as “features” of a vehicle dashboard, workload simulations using multiple resource theory can be used to ensure that a driver is not “overloaded” using a concurrent set of technologies. While the concept of workload modeling is not new, its application to the driving domain as a design tool is a novel application of the existing theory. To create the model, a driving scenario was first identified based on the National Highway Traffic Safety Association (NHTSA) driving route. While the NHTSA guidelines currently only cover automobiles, it is anticipated that they will also encompass commercial trucks in the near future. The driving scenario was decomposed into the different actions the driver performs, as well as the different interfaces present in the vehicle. The model assigns workload values to the operator while completing the tasks depending on the task type, the interface used, and the level of different human mental resources (such as visual, auditory, motor) required. The simulation results provide insights into the workload levels of the driver under these conditions and the likelihood for driver overload. This model illustrates a potential design tool for interface designers to investigate the effects of various types of distracters and driver's aids under varying conditions, prior to test in a simulator or implementation in a prototype.

The model can be used to help understand the impact of changes to vehicle displays with the goal of improving driver performance and mitigating the effect of distractions. In this paper, we use the term “distracter” as a practical convention for referring to secondary tasks that may compete for driver mental resources during multitasking and may potentially lead to distraction. For this initial model we have limited the number and type of distractions; however, the model can be adapted to implement any particular task that is deemed a distracter by the researcher based on empirical evidence. The results of the simulations can be used to help reduce or redistribute workload over time or components by changing task sequences or interfaces. This information can be used to identify what countermeasures are appropriate to use with different types of distractions. For example, some distractions can be addressed through task or interface design, some through

* Corresponding author.
E-mail addresses: ckandemi@odu.edu (C. Kandemir), hhandley@odu.edu (H.A.H. Handley), deborah.thompson@volvo.com (D. Thompson).

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safety-assisting systems, some through education or behavioral change programs, and finally some through changes to policy and/or enforcement. The outcome of the developed model is the ability to identify problematic task sequences or interface use that should be further investigated to develop mitigation strategies. This paper includes initial use of a sample of driver aids and their importance to mitigating driver distractions.

The model was developed by leveraging previous studies utilizing the Improved Performance Research Integration Tool (IMPRINT) (Improved Performance Research Integration Tool, 2009). IMPRINT has been used to model the task sequences and workload components of operators of military heavy vehicles (Mitchell et al., 2004; Mitchell, 2009). These models have help determine the number of operators required to manage the range of tasks required by military missions without overloading the operators. For this driving model, the number of operators was limited to one and the tasks were aligned with the driving scenario. The model was successful in providing feedback to interface designers on operator workload levels under different combination of distracters and driving aids. While the IMPRINT approach for modeling driving tasks and the accompanying workload was previously validated (Wojciechowski, 2004), the next phase of development for this model can be to improve its external validity through driving simulator or subject testing.

1.1. Background

Drivers of commercial vehicles are being increasingly tasked while driving, due to both the demands of driving as well as due to advanced displays and external communication devices. This driver “multi-tasking” has been identified as a factor in distracted driving, a leading contributor to accidents and other driving related incidents (NSC, 2012). The distracted driving phenomenon is being studied in depth through driving simulators and observational studies to identify causes and develop mitigation strategies (Drews, 2008; Truelove, 2012). However, a simulation model can provide designers of vehicle displays an initial assessment of the impact of a display redesign or new vehicle functionality that may add to the workload of the driver. Moreover, it can evaluate the potential impacts of interface or task changes on driver workload early in the design process that can potentially impact the ability to safely complete driving tasks. The output of the model can be used to adjust designs or change task sequences to reduce the impact on the driver.

The driving environment is generally complicated by additional devices brought into the cab by the vehicle operator. These “nomadic devices” include cell phones, tablets, and non-integrated global positioning systems (GPS). Also, there may be additional devices called “driver aids” integrated into the driving system to assist in various driving situations and increase the driver's comfort. The use of these devices, in addition to the traditional vehicle interfaces, must be included in the analysis of the vehicle interface systems. Driver aids systems are studied by various researchers with different warning types (such as visual, auditory) and different warning timing through driving simulators (Scott and Gray, 2008; Lenné et al., 2008; Fitch et al., 2014). Moreover, driver aids together with nomadic devices are investigated (Mohebbi et al., 2009; Zhang et al., 2014). The common part of these studies is using a driving simulator to investigate the effects of nomadic devices and driver aids on driver's performance. Even though, simulators are very effective, building and using them is generally expensive and timely. On the other hand, using a simulation model to represent and analyze the vehicle interface system is one way to better understand the interactions of all of the interfaces present in the vehicle with the human driver. The simulation model can help investigating various interfaces rapidly and in an inexpensive way (Ozsoy et al., 2015). Once the interactions and problems found distraction mitigation strategies can be applied and tested (Donmez et al., 2016).

The Improved Performance Research Integration Tool (IMPRINT), which is employed in this study, is a human performance modeling tool developed by the US Army Research Laboratory (ARL). IMPRINT is a stochastic, task-network simulation environment designed to help assess the interaction of users and system interfaces. Task time and accuracy requirements are collected and workload profiles are generated so that user-workload distribution and user-system task allocation can be examined. Data are entered through model interfaces and task-network diagrams. Human performance algorithms are then employed to perform simulations.

IMPRINT can be used to predict the mental workload of a user interacting with a system through an interface; the amount of mental workload required to use a system has a significant effect on user task performance (Mitchell, 2000). For example, a system interface requiring more button pushes or scanning of a cluttered display will increase both workload and performance time. Wickens (2002) Multiple Resource Theory (MRT) is the basis for the IMPRINT Visual, Auditory, Cognitive and Psychomotor (VACP) workload algorithm. According to MRT, human mental resources for handling tasks are limited. When an individual is required to perform multiple tasks at the same time, the user is using the same limited resources for the concurrent tasks. With the VACP method, the resources that the operator expected to use for any task can be entered for the selected resources (visual, auditory, cognitive, psychomotor, or a combination of any of these four) using scales developed by McCracken and Aldrich (1984) and improved by Bierbaum et al. (1989). The scale for each resource is based on a 7-point interval and contains verbal anchors that describe the behaviors expected for each interval. This combination of resource limits and multiple task demands may result in high workload that in turn, may lead to a greater number of errors, increased task time, or both.

Various application of the IMPRINT model has been used by the US Army to evaluate human interface design and operator configuration (Colombi et al., 2012; Hunn et al., 2008; Mitchell and Brennan, 2009; Mitchell et al., 2004). Brennan and Mitchell (2013, 2009); Mitchell et al. (2012); Wojciechowski (2004) applied this approach particularly to evaluate the displays of military vehicles. Because IMPRINT captures the interactions between system design, mental workload, situation awareness, and task performance, it is an appropriate tool to use to evaluate the interaction of the operator, the driving environment, and the vehicle interface to determine the impact on driver workload.

The objective of this current work was to create a simulation model of driving tasks that can be configured to represent different driving scenarios for commercial truck drivers and evaluate its potential to assist in interface design. One of the advantages of modeling is that it leads to a well formulated understanding of the various sequences of tasks the operator completes as well as the interfaces with which the operator interacts. By creating an IMPRINT model of a driving scenario and varying the number and type of interfaces that the driver must manage, the impact on driver workload can be calculated and presented to designers as an evaluation parameter. While our prototype model has not yet been externally validated through other methods (such as observational studies), by using workload data from previous studies using large military vehicles applied to the commercial truck driving domain, the model provides a medium for initial assessment and identification of problematic areas that warrant further investigation. The simulation output can be used to determine ways to reduce the