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Distractions intervention strategies for in-vehicle secondary tasks: An on-road test assessment of driving task demand based on real-time traffic environment

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ABSTRACT

When driving a vehicle, the driver must allocate adequate attention to the demands of driving in order to be safe. Based on analyses of vehicle data, driving environment data, and videos of the road ahead, a driving task demand prediction model based on real-time road traffic data was established in this study. Assessments of driving task demands allowed for the validation of this model. In addition, intervention strategies were proposed for distractions from in-vehicle secondary tasks at different levels of demand. The analysis showed that at a high driving task demand, the control of all in-vehicle information systems (IVIS), except for the playing of radio or CD, should be warned against or forbidden. Meanwhile, distractions from secondary tasks originated from 91% of the in-vehicle foreign objects, and 67% of the in-vehicle facilities can be avoided by formulating precaution strategies. This study provides methods and technical support for the management of driver distraction precaution.

1. Introduction

1.1. Background

The driver of a motor vehicle generally performs a variety of tasks, both those directly involving driving and those that don't. Usually, the primary task is to steer the car and watch out for potential road hazards. Secondary tasks refer to those in-vehicle tasks that ask the driver to divide individual attention to perform. Such tasks include visual-related tasks, such as checking a map, responding to cell phone texts, or looking for items, as well as non-visual-related assignments, such as calling on the phone, listening to a radio programme, drinking a beverage, or thinking. Both types of tasks directly compromise the driver's visual ability, thus causing a driving distraction (Birrell and Young, 2011). A study from the National Highway Traffic Safety Administration (NHTSA, the United States) showed that out of the traffic collisions caused by driver distraction, about 30% (1 million cases) are caused by distractions caused by secondary tasks (Nevile and Haddington, 2010). IVIS are also an important source of distraction (Greenberg et al., 2003). In-Vehicle-tasks will affect the driver's response time to the danger, and the braking time and acceleration will be higher (Nowosielski and Trick, 2018). Reducing driving mistakes and traffic accidents, as well as searching for effective approaches to eliminate the potential hazards in those tasks, are of significant, practical importance for the improvement of road traffic safety and the application of IVIS technology in the car industry (Regan, 2005).

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1.2. The current study

The latest surveys show that among various in-vehicle secondary tasks, using the audio entertainment system is performed by 70% of drivers. Using a cell phone or other wireless devices is the primary cause of accidents (Brodsky and Slor, 2013; Consiglio et al., 2003), followed by talking with passengers, comforting children in backseats, and other passenger-related behaviors are the second most frequent cause of accidents (Arnett et al.,1997; Regan et al., 2005). Using in-vehicle systems to receive and send e-mail greatly weakened driver's distraction and decreased their ability to control the vehicle (Xian and Jin, 2014). In-vehicle Tasks that require many glances and a high proportion of long glances away from the road are of special concern for safety (Tivesten and Dozza, 2014). The driver must allocate attention to the demand of driving tasks in order to drive safely (Engstrom and Johansson, 2005). With real-time assessment of the driving task demand, discouraging or forbidding some secondary tasks when the demand exceeds a pre-defined limit could help reduce distractions.

Driving task demand assessment was first introduced in studies of general in-vehicle driver subsidiary (GM Intelligent Driver Systems, GIDS) and in-vehicle multi-media communication (COMMUNICAR) projects. The GIDS project applies the multi-resource attention allocation theory to assess the workload from driving tasks, such as steering, overtaking, and secondary tasks. Based on information estimation and the assessed workload, the priority of each secondary task is determined(Rantanen and Goldberg, 1999). Multi-resource theory was proposed by Wickens and Knight et al., which assumes that human processing resources are three dimensions of a cubic structure with perceptual channels, coding, and stages. The perceptual channel includes visual and auditory levels. The stage includes three levels of sense, cognition, and response. The coding dimension is divided into two levels: spatial coding and speech coding. In addition, the attention of the visual channel to the information can also be divided into the focal point and the periphery so as to constitute the fourth dimension. If two tasks have a common demand level in one or more dimensions, time sharing will become poor and driving performance levels will decline. The car multimedia communication (COMMUNICAR), using driving data including brake and throttle positions, and Neural Networks Model evaluates the driving workload and judges the driver distraction. The Safety Vehicles Using Adaptive Interface Technology (SAVE-IT) research, subsidized by the NHTSA, seeks to manage vehicle-mounted systems through real-time monitoring of driver behaviors and road conditions (Witt et al., 2004; Zhang et al., 2006). However, the Adaptive Integrated Driver-vehicle Interface (AIDE) developed within the European Commission evaluated the type of driver distractions using different variables such as surface friction, driver predilection, and driver conditions; AIDE can provide warning information for use in newer in-vehicle technology and portable equipment (Peng et al., 2014).

At present, two common methods have been used to reduce the driver distraction issue (Horberry et al., 2006). One of methods adapts to a nonadaptive way, and the second method is adaptive interface technology. Through the first way, the distraction potential of non-driving tasks (such as editing text message) can be evaluated by models, performance index, and simulation procedures, which were based on test trajectory assessment, task analysis, laboratory experiments, and field research (Tango and Botta, 2013; Liang and Lee, 2014). Those three factors can help an experimental designer to better design a less distracting task (for example, designing commonly used text messages). Besides, a threshold line can be drafted to distinguish the tasks that are high-distracting or low-distracting. When the vehicle is moving, some less distracting tasks (such as radio tuning) may be allowed to operate, but high-distracting tasks may be prohibited. Some new principles have been proposed to assist drivers avoid distraction while improving the utility of on-board systems (Jin et al., 2012).

The attention level required by the driver is usually constrained by the driver's own conditions and the influence of different driving environments. Therefore, the non-adaptive method has certain limitations. The second method is adaptive interface technology, also known as workload management method, which can change dynamically with the different driving environment. This method is used to evaluate the attention needs from the driving task and the level of distraction from non-driving tasks through the pre-installing sensors in the vehicle. It tries to ease the driver's distraction by intervening or preventing. Through intervention strategy, when the driver showed more distraction than the driver's threshold, the distraction alert would inform the driver to redirect his attention to the driving task. Through prevention strategy, if the non-driving task has a trend to produce over certain threshold level of distracted driving conditions, the system could prevent the non-driving task, or issue advices to discourage the drivers involved in this non-driving task. In addition, when the adaptive method is adopted, the threshold of distraction depends on the driving condition, and the user interface can be modified.

Currently, there are few reports of studies in China related to in-vehicle secondary tasks. Most researchers focus on distraction sources outside the vehicles when studying driver attention allocation. Although no thorough or systematic studies of the relation between driving tasks and distractions from in-vehicle secondary tasks have been done, existing studies have established an important basis for this work. Based on previous researches, we concentrate on the intervention strategies to mitigate driver distraction, develop and evaluate driving task demand. The demand of driving task is tested by the variables collected by the in-vehicle sensors. Two strategies are discussed to reduce the driving distraction: The intervention strategy can provide the driver with demand-based feedback, while the prevention strategy avoiding certain non-driving tasks and providing need-based advice. Our strategies are aimed at preventing drivers from undertaking in certain non-driving tasks. Considering that many traffic accidents are caused by distractions from in-vehicle secondary tasks, there is an urgent need to study such distractions.

1.3. Aims and objects

On the basis of analyzing the demands of driving tasks and in-vehicle secondary tasks, this paper proposes intervention strategies for secondary task distractions based on the demand of driving tasks. Combining experimental data, the driving task demand is assessed and predicted. A driving task demand prediction model based on real-time traffic data is established. The outcome of the