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Response interference under near-concurrent presentation of safety and non-safety information

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ABSTRACT

The growing advent of Connected Vehicle Systems (CVS) is changing the information environment within the vehicle cab. As vehicles add the capability to receive data from the road infrastructure or share data with other vehicles, there is an expanding amount of safety and non-safety information from these systems with which the driver must contend. The information processing demands for the driver may become more complex, especially under conditions that present multiple information signals to the driver at the same time. To manage this complexity, the design of CVS \will need to incorporate information management functions to prioritize information so as to be compatible with the processing capacity of the driver. The objective of this research was to examine the potential interference effect of non-safety critical information on driver responses to near concurrent, critical safety warnings. The study design was based on theory and evidence that there is a "bottle neck" in a human's central processing of information, such that the processing of early signals (S1) in the environment may delay the response to a later signal (S2) until such time as the response to the first stimulus has been initiated. The results of the study suggest that there is the possibility that near concurrent presentation of safety and non-safety critical information may generate interference effects, but the combination of signal parameters (modality, timing) that are most likely to create this interference may be infrequent in most real world conditions. Future research should focus on the specific parameters that increase the probability of such interference. Such research would then provide a better estimate of the potential frequency of this interference and also guide the formulation of design guidelines to minimize this potential.

1. Introduction

Recently, there has been much attention to driver distraction, both within the scientific community and among the general public (Oprah.com, 2012). Much of this attention has focused on the effect of cell phones on the ability of drivers to safely manage the primary driving task. The challenge for the driver is to integrate the cognitive (and physical) demands of processing information from a single communication device (cell phone) with dynamic information embedded within the driving environment. The growing advent of Connected Vehicle Systems (CVS) is changing the information environment within the vehicle cab. As vehicles add the capability to receive data from the road infrastructure or share data with other vehicles, there is an expanding amount of safety and non-safety information from these systems that the driver will need to

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manage. The information processing demands under these multiple system conditions make the integration task considerably more complex for the driver, especially under conditions that present multiple information signals to the driver at the same time.

In designing and evaluating interfaces for CVS subsystems – especially in the context of multiple, concurrent, or competing signals – it is necessary to consider the human factor of our cognitive limitations in terms of processing and integrating information from multiple sources within our environment. Such considerations need to be applied to the design of CVS interfaces. One design choice relates to the signal modality presented by the interface. Signal modality can affect both saliency and processing capacity. For example, Multiple Resource Theory (MRT) describes the implications of limited amounts of cognitive resources. For example, under conditions of two signals transmitted in the same modality, coded in the same format, or requiring the same form of response, performance toward one of the signals (speed or accuracy) will be impaired as each signal competes for limited quantity resources specific to that modality (Wickens & Hollands, 2000). The trade-off in performance for such dual-task conditions is evident from Performance Operator Curves with the prioritization of either task influenced by such factors as instruction, salience, priming, and incentives (Proctor & Van Zandt, 2008).

MRT has been used to understand cognitive workload in the driving task with the practical implication of providing guidelines for selecting in-vehicle interface modalities that do not compete for resources typically required for the primary driving task: namely, visual processing, spatial coding, and manual responses (see Horrey & Wickens, 2003). For example, Maciej and Vollrath (2009) found that lane change behavior was superior while using speech based rather than manual entry methods for interacting with phone and route guidance systems. According to MRT, the worse performance with the manual entry methods would be attributed to the fact that the secondary task (e.g., manually entering a phone number) and the primary driving task (e.g., manually turning the steering wheel for the lane change) competed for the same limited resource necessary for manual control.

Another choice that is perhaps overlooked in the design of an interface is signal timing amongst multiple systems. Signal timing affects both processing and integration capacity. For example, single channel capacity theories are relevant in describing the structural limitations for human information processing of signals occurring near concurrently in time (Proctor & Van Zandt, 2008). This limitation is based on the assumption that there is a processing "bottleneck" due to a single channel capacity for processing information (Pashler, 1998). As shown in Fig. 1, the first signal (S_1) is perceived and its selected response is made. However, the single channel remains occupied (e.g., response selection) until the response to the first signal is initiated (R_1). The period during which the single channel remains blocked to other signals is called the "Psychological Refractory Period" (PRP). Specifically, whereas the second signal may be perceived (S_2), the PRP delays the processing of the response selection for the second signal response (R_2). The PRP produces a slower reaction time for the second signal response in combination with the first signal (RT_{2+1}) compared to the response time to the second signal appearing alone (RT_2). The duration of the PRP increases as the interval between the first and second signal decreases (Pashler, 1998). Generally, there is no delay if the second signal occurs after the first signal response has been initiated (Pashler, 1998; Wickens & Hollands, 2000).

Single channel capacity theories that advocate for a Psychological Refractory Period (PRP) have been used to model driver distraction in terms of the temporal sequence on (competing) signals from multiple signals. Such theories have implications for the design of information management strategies to prioritize concurrent signals from multiple in-vehicle systems. However, evidence for the PRP effect attributed to the single channel bottleneck has mostly been derived from an experimental paradigm with large numbers of trials and tight control over error variance, using rigidly timed stimuli and simple responses. For example, the stimuli used in these traditional experiments are deliberately designed to ensure that the first signal ends before the second signal finishes with specific instructions to respond to both signals as quickly as possible (speeded response), such that the natural priority is to respond in the same serial order as the signals. Such stimulus and response conditions do not necessarily represent the complex and dynamic conditions of integrating both safety critical and safety non-critical vehicle systems under the dynamic variation of naturalistic signals within the driving environment.

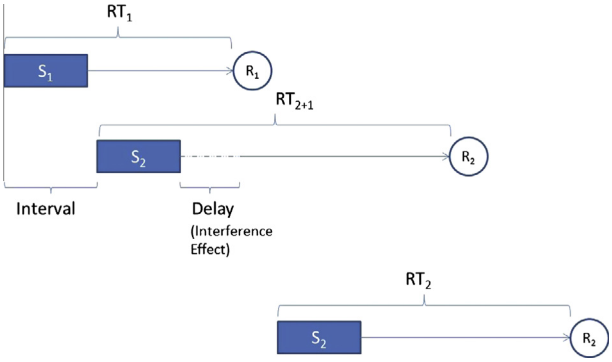

Fig. 1. Illustration of response delay due to signal channel capacity of information processing model (based on Wickens & Hollands, 2000).