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Distraction and task engagement: How interesting and boring information impact driving performance and subjective and physiological responses

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ABSTRACT

As more devices and services are integrated into vehicles, drivers face new opportunities to perform additional tasks while driving. While many studies have explored the detrimental effects of varying task demands on driving performance, there has been little attention devoted to tasks that vary in terms of personal interest or investment—a quality we liken to the concept of task engagement. The purpose of this study was to explore the impact of task engagement on driving performance, subjective appraisals of performance and workload, and various physiological measurements. In this study, 31 participants (M = 37 yrs) completed three driving conditions in a driving simulator: listening to boring auditory material; listening to interesting material; and driving with no auditory material. Drivers were simultaneously monitored using near-infrared spectroscopy, heart monitoring and eye tracking systems. Drivers exhibited less variability in lane keeping and headway maintenance for both auditory conditions; however, response times to critical braking events were longer in the interesting audio condition. Drivers also perceived the interesting material to be less demanding and less complex, although the material was objectively matched for difficulty. Drivers showed a reduced concentration of cerebral oxygenated hemoglobin when listening to interesting material, compared to baseline and boring conditions, yet they exhibited superior recognition for this material. The practical implications, from a safety standpoint, are discussed.

1. Introduction

Today, drivers have access to more in-vehicle activities as new embedded and portable technologies become available and as more products and services are introduced that expand the connectivity of drivers and vehicles. While these devices and related activities afford drivers enhanced convenience and productivity, there are obvious safety concerns to the extent that they detract attention from the driving task, resulting in driver distraction (e.g., Regan et al., 2009).

Performance of a task, such as driving, is generally demanding of attentional resources and successful performance depends in part on the amount of resources demanded (e.g., difficulty) and the availability of resources to meet those needs (i.e., capacity; e.g., Wickens and Hollands, 2000). For very difficult tasks, there may be insufficient resources to accomplish the task and performance may suffer as a consequence. Likewise, when multiple tasks are performed concurrently, available resources will deplete more rapidly. Several studies in the driving context have shown that more demanding secondary tasks result in greater performance decrements in driving-related tasks (e.g., Briem and Hedman, 1995; Patten et al., 2004; Angell et al., 2006).

Tasks employed in experimental dual-task situations mobilize a similar set of underlying cognitive mechanisms as more naturalistic tasks (e.g., perception and information processing; use of working memory). However, they often fail to capture any semblance of personal investment or interest on the part of the participant. For example, performing mental arithmetic is an effective means of mobilizing cognitive resources; however, it does not constitute an activity that people would willfully engage in under normal

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circumstances. That is, motivation and interest in the to-be-performed tasks, irrespective of task difficulty, are likely to influence the individual's attentional allocation policy when performing concurrent activities. We refer to this as the quality of task *engagement*.

2. What is engagement?

The definition of engagement varies as a function of domain. Some refer to it as the overt or covert allocation of attention (Tops and Boksem, 2010), whereas others describe engagement by its propensity to attract and hold our attention (Chapman, 1997, 2003; Pintrich and De Groot, 1990) or even as a state in which an individual is so involved in an activity that all competing influences are blocked out (e.g., Csikszentmihalyi, 1990). While these approaches focus more on the outcome of engagement, O'Brien and Toms (2008) proposed a model of task engagement that focused on the properties of a task that would compel more or less engagement, including the degree to which tasks are challenging, interactive, rich in feedback, aesthetically pleasing, enduring, and varied or novel. With respect to tasks involving spoken auditory material, engagement can also be driven by many factors related to the gender, prosody and emotional tone of the speaker, among other factors (Nass and Brave, 2005). Interest in a particular task is assumed to be underscored by a positive affective response to the material and intrinsic motivation to perform the task. In the area of knowledge acquisition and skill development, level of interest is considered a central determinant of how we select and persist in processing certain types of information to the exclusion of others (e.g., Hidi, 1990). In the driving context, many of these factors likely influence users' willingness to perform potentially distracting tasks while driving (e.g., Lerner and Boyd, 2005).

2.1. Multitasking, engagement, and driving

Level of engagement can be influenced by a number of factors, regardless of task difficulty. As such, engagement may be an important factor in determining the driver's resource allocation policy over and above what might be required for successful task performance. Drivers may devote more attentional resources to activities that are considered engaging over ones that are less so and this could yield more detrimental implications for performance. Many studies of multitasking while driving have employed tasks that vary in terms of difficulty, but few have paid any attention to the individual's level of engagement or interest in the tasks.

For example, Dula et al. (2011) found that drivers in an emotional conversation engaged in more dangerous driving behaviors than drivers in a mundane conversation or a no-conversation condition. While these authors did not control for task difficulty (it was not a focus of their study), the study is intriguing because it underscores the potential for tasks that have certain attributes, such as those noted above, to impart different performance outcomes.

In earlier work, Horrey et al. (2009) examined two tasks that differed on many of the criteria for engagement (per O'Brien and Toms, 2008). The results suggested that a task that was considered to be more engaging (a twenty questions guessing game) led to worse performance outcomes than a less-engaging mental arithmetic task, although drivers rated their driving performance as superior with the engaging task. Although this dissociation was intriguing, the two tasks employed were quite different, in spite of attempts to model them after the criteria for task engagement, such that the observed pattern of results could have been influenced by differences in task structure, difficulty, and/or complexity (as seen in other experiments).

There have been no efforts to delineate the role and influence of task engagement on driving performance while controlling for task difficulty and task structure (e.g., modality, response demands). The current study purports to address this knowledge gap, with the specific aims of examining (1) performance implications of, and (2) physiological and subjective responses to, auditory material that was more interesting or engaging than mundane information of comparable difficulty.

2.2. Current study

Drivers in a driving simulator were exposed to boring (low engagement) auditory material, interesting (high engagement) material, or no auditory material (baseline). We examined driving performance along several dimensions of vehicle control and subjective responses. For the latter, we examined subjective ratings of workload and performance, self-reported interest in the material as well as post-trial recognition for presented material (as a potential index of the depth of processing; e.g., Craik and Lockhart, 1972). To the extent that more engaging material incurred more attention from drivers, we expected that performance would more adversely impacted and workload would be rated higher compared to boring material and baseline conditions.

In addition to performance implications, we were also interested in examining the physiological response to material of varying levels of engagement. We employed several physiological measurements. First, measures of cerebral hemoglobin oxygenation were monitored and assessed using an optical technique called near-infrared spectroscopy (NIRS). Previous research has also demonstrated that mental workload associated with visual, motor, and auditory stimuli evokes changes in regional oxidative metabolism of the brain (e.g., Roland, 1993; Derosière et al., 2013). The influence of mental workload on optical spectroscopy-derived responses during driving has increasingly being investigated (Harada et al., 2007; Li et al., 2009; Liu et al., 2012; Yoshino et al., 2013). For example, Harada et al. (2007) found that the concentration of oxygenated hemoglobin (O_2Hb) increased, with a concomitant decline in deoxygenated hemoglobin, when driving was compared to resting conditions (i.e., with increased workload). Similarly, Liu et al. (2012) demonstrated the sensitivity of NIRS-derived O_2Hb in the frontal lobe while driving under intrinsic and extrinsic cognitive load. However, none of the studies investigated the influence of listening to boring vs engaging material on cerebral responses while driving. To the extent that more engaging material could elicit the willful allocation of more cognitive resources (i.e., attention), we expected that the NIRS outcomes would reveal a greater mobilization of oxygenated hemoglobin than boring material, which would be more likely to be disregarded.

Additionally, we employed valid and reliable physiological measures of workload, including various pupil and heart rate parameters (e.g., O'Donnell and Eggemeier, 1986; Kramer, 1991; Sakamoto et al., 2009; Recarte et al., 2008; Beatty, 1982). For example, Mehler et al. (2012) found that heart rate increased with level of cognitive demand in drivers engaged in a concurrent working memory task. Similarly, Kun et al. (2013) found that pupil diameter was sensitive to variations in cognitive load associated with different aspects of dialogue.

3. Method

3.1. Participants

Thirty one drivers (aged 25 to 55, M = 37.0 yrs, SD = 8.5), 18 men and 13 women, participated in the study. They were screened for fluency in English, absence of self-reported hearing difficulties,