How does night-time driving and engagement in a cognitive distraction task affect detection of peripheral targets?

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Abstract: Driver distraction is known to be a potential risk factor for traffic safety. Previous studies have shown that increased cognitive load can affect many driving outcomes, and lab-based studies have commonly used the detection-response task (DRT) to quantify the level of cognitive load from in-vehicle systems during driving. The aim of the present study is to examine the effects of varying levels of cognitive distraction (two levels of n-back task) on performance in the detection-response task, in day- and night-time driving conditions. A total of 60 drivers (30 younger: 21-25 years, and older: 60-75 years old) are recruited for this driving simulator study, which is conducted as part of the EPSRC-funded HAROLD (HAzards, ROad Lighting and Driving) project. Response time and hit rate data for the DRT, the percentage of correct responses for the n-back task, as well as lateral and longitudinal vehicle metrics are collected, to understand how different lighting conditions affect stimulus detection, and how this is affected by engagement in a demanding cognitive distraction task. Results will be discussed in terms of the implications of such non-visually distracting tasks on driving performance, and road safety. The ultimate aim of the project is to understand how/if pedestrian detection at night is affected by driver engagement in cognitively demanding, non-visual, tasks, to contribute to state of the art on distraction and lighting research, together with policy and countermeasure development.

1. Introduction

1.1 Driver Distraction

Despite a continued and sustained effort to prevent the adverse effects of distraction while driving in recent years, distracted driving still appears to be a critical contributor to crash involvement (e.g. Lym & Chen, 2021; Olsson et al., 2020), perhaps due to the plethora of activities now possible on our mobile devices in the vehicle, as well as the general pressures of life, taking our minds off the main driving task. During the past 20 years, numerous studies have examined the effects of engagement in distracting vehicle-based activities on driving performance, such as how they divert our attention away from the driving task, and increase our brake response, and crash involvement (e.g. Li et al., 2019; Papantoniou et al., 2017).

Such distracting activities can be broadly categorised into those that require visual, visual-manual, auditory, and cognitive resources, or a combination of the above (NHTSA, 2010; Ranney et al., 2000). "Cognitive distraction", which is associated with increased cognitive activity, includes thinking about something other than driving, taking attention and mind off the road (NHTSA, 2010). One lab-based task that has been used extensively to study the effect of cognitive distraction on driving performance, is the n-back task (Mehler et al., 2011; Stojmenova & Sodnik, 2018). Increased n-back difficulty is associated with increased cognitive load (Čegovnik et al., 2018), and a reliable measure for studying the effects of varying levels of cognitive load on driving outcomes (von Janczewski et al., 2021).

1.2 Night-Time Driving

The time of day is an important factor that might directly or indirectly affect driving outcomes through environmental factors such as visibility (Wood, 2020), and exposure to different levels of risk (Åkerstedt et al., 2001). Driving at night is perceived to be riskier and more difficult compared to daytime driving, due to decreased visibility of the environment (Evans et al., 2020), as well as the likelihood of driving while sleepy (Chipman & Jin, 2009). In the UK, night-time driving is shown to be particularly problematic for young and middle-aged drivers, with a higher proportion of accidents with fatal injuries occurring at night, when compared to day-time driving (Regev et al., 2018).

1.3 Aim of the Present Study

The detection-response task is a standard measurement adopted by the International Organization for Standardization (ISO 17488:2016) to determine the attentional demands due to the cognitive load of a secondary task (ISO, 2016; Stojmenova & Sodnik, 2018). Changes in cognitive load can be assessed with DRT performance, in terms of both response time and hit rate (ISO, 2016). Drivers' DRT performance is known to be affected by engagement in secondary tasks (Bowden et al., 2019), and influenced by driver- and environment-related factors (e.g. Engström et al., 2005; van Winsum, 2018). However, to the best of our knowledge, very little research is done on how the detection of objects in the driving scene is affected by different lighting conditions. In light of this research gap, the present study focuses on how young and older drivers' DRT is affected by a cognitive distraction task, and whether different lighting conditions influence this performance.

2. Method

2.1 Participants

The data collection for this study is currently underway. A total of 60 drivers are signed up for participation, with the sample being equally distributed across two age

groups: young drivers (21-25 years old), and older drivers (60-75 years old). Gender is also balanced for each age group.

2.2 Materials and Tasks

Driving environment and lighting level: The study will be conducted in the University of Leeds Driving Simulator (UoLDS). The scenario contains a two-lane, contraflow, rural road, with a 60 mph speed limit, consisting of straight and curved road sections. The lighting of the driving simulator environment is presented at two levels (daylight and night-time).

The n-back task: An auditory version of the n-back task, first used Mehler et al., (2011), will be used to provide two levels of difficulty in cognitive distraction: 1-back (repeating the digit one before) and 2-back (repeating the digit two before) the last digit heard. Participants will be required to respond to an auditory stimulus, presented via the driving simulator speakers, and response is provided verbally, and recorded by the experimenter, and via a voice recorder. Each trial will include a set of randomly generated ten digits. The percentage of correct responses to the task will be used as an indication of n-back performance.

Detection-response task: The effect of the n-back task on cognitive load will be examined by using the visual DRT. Each trial will include the presentation of a red circle with a visual angle of about 1°, presented in the driving scene, at a horizontal angle of 11° to 23°, and a vertical angle of 2° to 4° above the horizon, on either the right or left side of the road used for the driving environment. Based on the ISO recommendations, these visual stimuli will be presented at a random rate of every three to five seconds. Participants will be asked to respond to the stimuli as quickly and accurately as possible by pressing a micro-switch button, which will be attached to the index finger of their dominant hand, against the steering wheel. Response time and hit rate will be calculated to evaluate performance (ISO, 2016).

2.3 Procedure

The study is approved by the ethics committee of the School of Business, Environment and Social Services, University of Leeds (AREA 21-108). After receiving informed consent and instructions, participants will first complete a practice drive, followed by practicing both the n-back and DRT, separately. They will then complete practice of driving with the n-back task, driving with the DRT, and driving with the n-back and DRT together. Following this practice drive, participants will complete two experimental drives, which will be exactly the same as the practice drive, and identical in terms of road geometry and presentation of the non-driving related tasks, but counterbalanced across participants, in terms of night- and day-time driving environment. Each of the non-driving related tasks are programmed to start in the straight sections of the road, and last around 30 seconds each. The total experiment duration, including familiarisation, briefing and subjective feedback takes approximately 60 minutes to complete, and participants will be compensated £20 for taking part in the study.

3. Results

Data collection is currently underway and results will be reported in the next version of this paper. Response time and the number of hits and misses to the DRT will be calculated for the free (baseline) driving sessions with no n-back task, and compared to sections which require performance of the 1- and 2-back tasks. The effect of lighting conditions on detection of the stimuli will be studied and response from older and younger drivers will be compared, using mixed model ANOVAs.

4. Discussion

The findings of this study will be discussed, and the potential implications on road safety research and design practices will be outlined. The implications of these results on detection of pedestrians at night by distracted drivers will also be considered.

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