INTRUSIVENESS OF VISUAL DETECTION TASK ON SECONDARY AND DRIVING TASK PERFORMANCES

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ABSTRACT

A driving simulator study was conducted to investigate intrusiveness of the visual detection task (VDT) on driving and secondary task performances. A within-subject design was used for assessing both objective and subjective data on 16 participants. In terms of objective measures, the results indicate that VDT had a significant effect on secondary task performance with increased task completion time and a non-significant effect on driving related measures. Subjective estimations showed that the participants perceived a higher level of time pressure, mental load and stress when using the VDT. Hence, the study showed that VDT was intrusive while performing secondary tasks, based on both objective and subjective data.

KEYWORDS: Visual detection task (VDT), Secondary task performance, Driving performance, and Cognitive load.

INTRODUCTION

The number of in-vehicle systems with which the driver can interact increases rapidly. This includes in-vehicle infotainment and telematics systems as well as portable systems, like navigational systems, mobile phones etc. These systems induce secondary tasks to be performed concurrently with the primary driving task, and thus there is a growing concern over their potential negative effects. It has been estimated that secondary-task distraction contributes to over 22 percent of all crashes and near-crashes [11]. Visual distraction caused by the interaction with in-vehicle systems has primarily been the concern. Any glance inside the vehicle, i.e. away from the road scene, reduces the driver's opportunity to detect hazards and handle them safely. For example, a study by Shen et al. [14] revealed that drivers using a touch screen CRT while driving tended to increase their lane deviations. However, today increasing mobile phone conversations and introduction of voice-based solutions for various in-vehicle infotainment functions has generated much interest also in the effects created by cognitive load [15]. The main safety-degrading effects of cognitive demand while driving are; reduced detection performance and impaired cognitive abilities such as decision-making and goal setting [12]. Several studies have revealed degrading effects of purely cognitively loading tasks in terms of reduced event detection performance. For example, a study performed by Horrey and Wickens [3], gave overwhelming evidence that drivers' reaction times were significantly increased by phone conversation. Different metrics have been used as tools to measure the cognitive demand of driver [4] [3]. Measurements can be done, by collecting data related to lateral and longitudinal performance (steering wheel reversal rate, lane position, mean speed etc.). As these metrics are collected from the driving simulator or the test vehicle, they are not intrusive on the driving or secondary tasks performed by the driver. Another approach is to add an artificial detection task that are performed concurrently with the orimary and the secondary task. In a study by Rydström et al. [13] it was observed that the drivers changed their secondary task strategy due to the artificial detection task, which in this case was Visual Detection Task (VDT). Based on these observations it was hypothesized that VDT many affect the experimental results. VDT as a measurement method was developed from the peripheral detection task (PDT), as PDT was subject to a number of limitations, i.e. it is sensitive to lighting conditions, unclear how to combine the reaction time (RT) and hit rate metrics [4]. In the VDT, a single red colored LED is positioned in the central field of view rather than in the periphery, by which the limitations such as sensitivity to light, eccentricity effect of PDT can be minimized. When using VDT compared to PDT, the number of misses may be reduced due to the intensity of the LED light and makes it possible to use response time as a single performance metric [4].

In order to determine if the VDT method itself has an impact on other metrics, a study on a fixed-base driving simulator was conducted. Hence, the purpose of this study was to determine whether the VDT is intrusive on driving and secondary tasks.

METHOD

Participants

The test group consisted of 16 students recruited at Chalmers University of Technology. The test group comprised nine women and nine men aged between 23 to 27 years (M = 24.3, SD = 1.19**)**. The requirements for participation in the study were: possession of a valid driving license and computer or video gaming experience. The later criterion was set to gather a group with experience of virtual environments, since it has been shown that video games have

positive effects on some abilities like attention and spatial cognition [5]. Most participants drove on a non-regular basis. The participants were compensated with a movie ticket for their participation.

Apparatus

The experiment was conducted using a fixed base Volvo XC90 driving simulator. The simulator had an automatic transmission and was equipped with sensors and logging equipment for the collection of data on driving, secondary task and VDT performances. A 2.1 meter wide and 1.6 meter high driving scene was projected on a screen about 2.5 meters in front of the driver. The road type used in the study was a curving rural road with meeting traffic in the left lane, but no traffic was present in the right lane. The radius of both the left and right curvatures was 1000 meters and each lane was 3.2 meters wide. The vehicle speed was limited to 90km/h. The participant needed to accelerate to 90km/h and the vehicle then remained on that speed unless the brakes were applied, similar to that of a cruise control. A 7" TFT-LCD touch screen display (Deltaco, Sweden) was mounted on the simulator (Fig 1). The secondary task interface shown in the display was implemented in Macromedia Director MX (Adobe systems Inc, USA). The VDT led was attached to the dashboard in front of the driver (fig 1). The visual stimuli of the VDT were presented with a random temporal variation between 1 and 3 seconds. The time interval between 1 and 3 was selected, so that the participants would have to respond to a number of stimuli during an experimental task. The participants responded by pressing a button attached to their index finger of left hand (Fig 2).

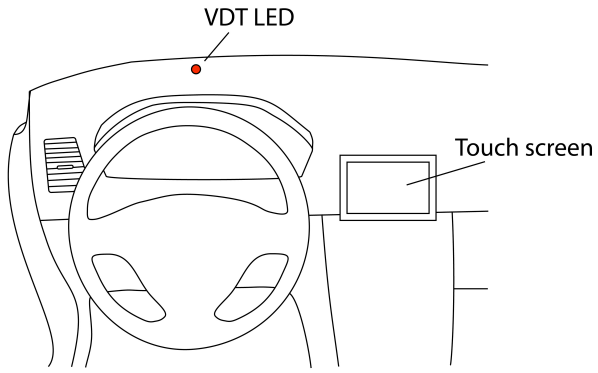

Fig 1 - Illustration of the Volvo XC90 simulator showing the position of the touch screen display and VDT LED.

Fig 2 - The VDT response button attached to the index finger of the left hand.

Secondary task

The secondary task applied in the study was to enter the city name Stockholm in a navigation system shown at the touch screen display (fig 3). Both ABC and QWERTY keyboards are available in cars today. An 'ABC' keyboard was used for the navigational entry in this study. In a navigation system, a user must often go down several layers in the menu structure before reaching the intended function. To make the interaction realistic, the secondary task interface therefore included three levels - a main menu, a middle menu and the destination entry menu. However, only the destination entry is included in the analysis in this paper. A beep indicated that a new task was initiated and the task "Enter Stockholm as destination" was shown at the display. The participant accepted to perform the task by pressing *'OK'*. When the participant

had entered *'STOCKHOLM'* and pressed the *'Guide'* option the task was completed. If the participant verified by pressing 'Guide' when the destination was spelled incorrectly a view was shown in the display in which the task description was repeated. The only option in this view was 'BACK', which returned the participant to the previous view, and the participant then continued the task.

Fig 3 - The interface shown at the touch screen display.

Dependent measures

The experiment consisted of a primary task (driving), a secondary task (destination input) and a tertiary task (VDT). The performance of the driving task was measured in terms of lateral control performance and steering wheel activity, i.e. standard deviation of lane position (SDLP), and steering wheel reversal rate (SWRR). The SWRR metric was defined as the number of steering wheel reversals larger than 0.1° of angular value per minute [2] [10] [9]. Secondary task performance was measured in terms of task completion time (TCT). The visual stimuli (VDT) were measured in terms of reaction time (RT). The simplified subjective workload assessment technique (SWAT) was used in this experiment [8]. In the simplified version of SWAT, the participants are asked to choose between 1) Low 2) Medium and 3) High, for each column of time pressure, mental load and stress as shown (Table 1).

Table 1 – Simplified subjective workload assessment technique (SWAT). The participant is instructed to pick Low, Medium or High for each column.

Time pressure	Mental load	Stress
1. Low	1. Low	1. Low
2. Medium	2. Medium	2. Medium
3. High	3. High	3. High

Procedure

The experiment had a within-subject design and nine participants started with an experimental condition in which VDT was included and nine started in a condition without VDT. Latin square design was implemented to counterbalance potential order effects and learning effects.

Each participant was given a brief description about the experiment and its procedure before starting. They were given the opportunity to ask questions and were asked to fill in background information form and a consent form. The participants were instructed about the driving, the secondary task and the VDT. The subjects were asked to prioritize driving by

maintaining the driving performance at their best. At first, the participants practiced just driving the simulator. Before conducting each experimental condition the participants trained at driving, interacting with the secondary task interface and, in the condition including VDT responding to the VDT light all together. One full loop of training session consisted of 10 secondary tasks, where the destination was not Stockholm.

In the present experiment, 60 second long baseline-driving segments were collected three times for each experimental condition. Baseline driving involved primary task (driving) and VDT while the second condition only incorporated primary task (driving). Each experimental condition incorporated ten navigational input tasks, where the destination name was *'STOCKHOLM'* every time. A new task started 15 seconds after the previous one was completed. After each experimental condition the subjects filled in a simplified SWAT sheet. A short semi-structured interview was conducted at the end of the complete experiment. The full session, took a total of an hour approximately.

RESULTS

To compare the experimental condition between, not including VDT (No VDT) and the one including VDT (VDT), two-tailed independent samples *t*-tests were used. An alpha level of 0.05 was used for all statistical tests. The error bars representing 95% confidence intervals for the means have been adjusted in the figures to suit within-subject comparisons [7].

Task completion time

In terms of task completion time (TCT), there was a significant difference between the No VDT and VDT conditions, $t(15) = -2.217$, $p<.05$, $r = .042$. This indicates that, on an average, participants took more time to perform the secondary task in the VDT condition than in the No VDT condition (Fig 4)

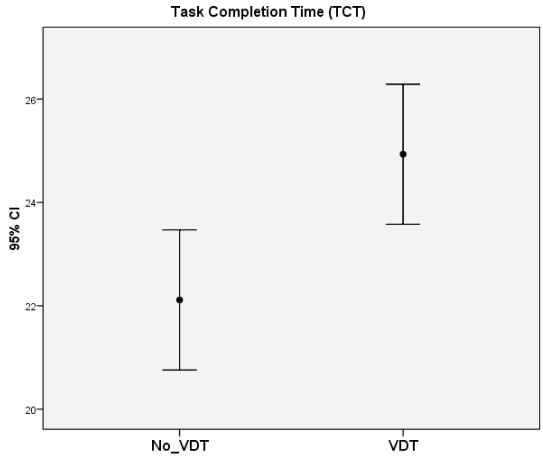

Fig 4 – Task completion time for the No VDT and VDT conditions.

Steering wheel reversal rate

In terms of steering wheel reversal rate (SWRR), there was no significant difference between No VDT and VDT conditions, t(15) = -1.538, $p<.05$, $r = .145$. This indicates that, on an average, the number of times the steering wheel was reversed did not differ between the conditions (Fig 5).

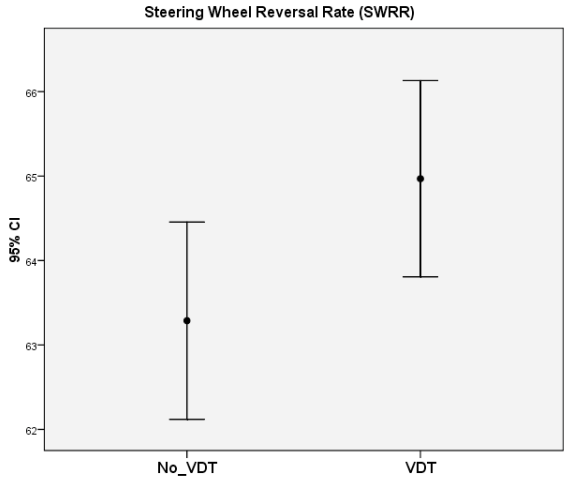

Fig 5 – Steering wheel reversal rate for the No VDT and VDT conditions.

Standard deviation lane position

In terms of standard deviation lane positioning (SDLP), there was no significant difference between the No VDT and VDT conditions, t(15) = -.656, $p<.05$, $r = .522$. This indicates that, on an average, the variation in lateral position did not differ between the conditions (Fig 6).

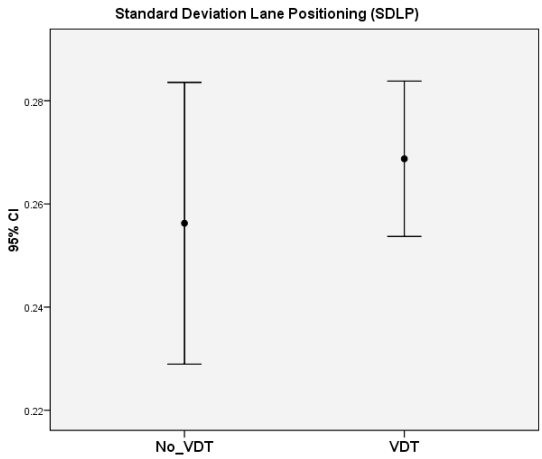

Fig 6 – Standard deviation of lane position for the No VDT and VDT condition.

SWAT

In terms of time pressure, there was a significant difference between No VDT and VDT conditions, $t(15) = -2.782$, $p<.05$, $r = .014$. In terms of mental load, there was a significant difference between the No VDT and VDT conditions, $t(15) = -3.748$, $p<.05$, $r = .002$. In terms of stress, there was a significant difference between the No VDT and VDT conditions, $t(15) = -3.478$, $p<.05$, $r = .003$. This indicates that, on an average, the participants felt an increase in time pressure, mental load and stress due to VDT (Fig 7)

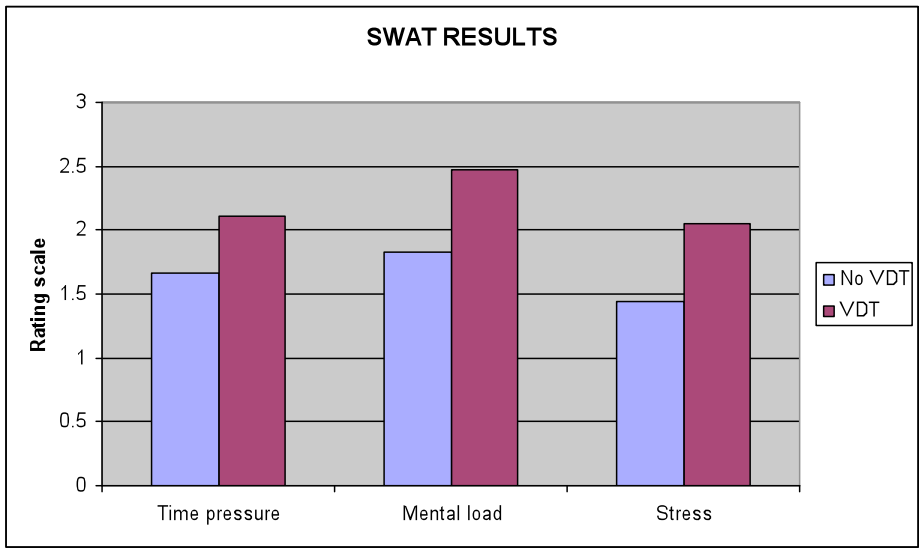

Fig 7 – Comparison of SWAT analysis for time pressure, mental load & stress for No VDT and VDT conditions.

Interview

The majority of participants felt that their driving performance was affected due to secondary task and VDT. Almost all the participants felt that VDT had an effect on driving, but its effect was felt most while performing the secondary task. The participants expressed that VDT had more effect on secondary task due to its demand of visual attention away from the road scene. As, the VDT was present in the periphery of the road scene; participants did not feel the influence of it.

In the beginning of the experiment, all the participants were instructed to maintain driving as their first priority by performing the driving task at their best and other tasks (secondary & VDT) to the best of their ability. In spite of these instructions, most of the participants reported that secondary task became their first priority when it appeared.

DISCUSSION

The purpose of this study was to determine whether the Visual Detection Task (VDT) had an intrusive effect on driving and secondary tasks.

The results show, that VDT has an influence on secondary task performance but not on driving performance. Evidence from the simulator study demonstrated that VDT had significant influence on task completion time (TCT) as it increased in the VDT condition. Even though the driving performance (SDLP; SWRR) worsened, there was no significant influence

revealed. Significant effect on secondary task time (TCT) by the intrusiveness of VDT can be related to time-sharing and task management aspects, it explains high mental effort of one activity degrades the ability to carry out a second activity at the same time, as the resources necessary to support one are limited and are therefore less available to the other [1]. Moreover, from observations during experiment, the participants seem to implement different strategies to perform the secondary task by maintaining driving performance; like, quick glances to the road scene were increased, waiting for a straight road to perform the secondary task, and as there was on-coming traffic in the opposite lane, participants were finding a gap between vehicles to perform the secondary task. These strategies could be a reason for increased secondary task time.

VDT had no significant effect on the driving task even though the speed was cruise controlled at 90 km/h. In the study by Engström [3] it was observed that drivers lowered their speed, as they perceived an increased risk in multitasking. On the other hand, change of behavior due to additional tasks may affect situational awareness. In a study conducted by Hao [6] it was found that an increased mental load deteriorated the participants' situation awareness.

From the SWAT results, we can see a difference in 'No VDT' and 'VDT' conditions. The difference in time pressure, mental workload and stress of SWAT scale is significant and support the results on task completion time. Time pressure, mental workload and stress may be caused by the interruptions caused during task management and time-sharing between concurrent tasks. We can conclude that VDT has added more work in an already existing dual task situation that included driving and destination input. This result is in-line with the conclusions provided by many studies [3] [6] [1].

From the experiment conducted in this study, the following conclusions can be derived:

- Visual detection task (VDT) is intrusive while performing secondary task, e.g. destination input on a touch screen while driving. A significant difference in task completion time (TCT) is found by using VDT as a cognitive tool in a within-subject design.
- Visual detection task (VDT) is not intrusive for driving task. Though, difference in driving performance is evident between the VDT and No-VDT conditions, a significant value could not be found.
- Visual detection task (VDT) has shown increase in time pressure, mental load and stress at a significant level subjectively, which was assessed through subjective measures (SWAT & interviews).

FURTHER WORK

In the experiment performed in this thesis, the tasks performed by the participants were comparatively easy for both primary and secondary task conditions, as driving task was performed on a country road with moderate amount of on-coming traffic only and the secondary task was to input the destination name, which was same *(STOCKHOLM)* for all the tasks. Increasing the complexity of both primary and secondary tasks may affect the result and is therefore an interesting subject for further studies. The participant sample was selected from university students and thus represents young and novice drivers on road. The age span was narrow, ranging from 23 to 27 years. A study done by Feng [6] declares that older adults, whose higher level of cognitive skills is generally inferior to those of young adults, perform poorly on tasks that require attention [6]. So, we could infer that difference between secondary task completion times might be much higher if older drivers were used as test participants, a further research based on age related performances would therefore be interesting. As, the present study was conducted on a fixed-base driving simulator, it would be interesting to look at secondary tasks performed on real world testing conditions. Hence, cognition and its effects towards road safety could be a focus for further research.

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