The Netherlands
Research School for
Transport, Infrastructure
and Logistics
TRAIL

11th TRAIL Congress
November 2010

DRIVING WITH VARYING SECONDARY TASK LEVELS

Mental workload, behavioural effects, and task prioritization

Drs. Nina Schaap[1], Prof. dr. ir. Bart van Arem[2], Dr. ir. Richard van der Horst[3], Prof. dr. Karel Brookhuis[2, 4]

[1]Faculty of Civil Engineering and Management, Centre for Transport Studies, Knowledge Centre 'Applications of Integrated Driver Assistance' (AIDA), University of Twente, the Netherlands

[2]Faculty of Civil Engineering and Geosciences, Department of Transport and Planning, Delft University of Technology, the Netherlands

[3] TNO Defence, Security and Safety, Soesterberg, the Netherlands

[4] Faculty of Behavioural and Social Sciences, Department Clinical & Developmental Neuropsychology, University of Groningen, the Netherlands

ABSTRACT

Advanced Driver Assistance (ADA) Systems may provide a solution for safety-critical traffic situations. But these systems are new additions into the vehicle that might increase drivers' mental workload. How do drivers behave in situations with high mental workload, and do they actively prioritize safe driving? We conducted two driving simulator experiments, investigating the effects of increased mental workload on driving behaviour and task prioritization. Increased secondary task difficulty raised the level of mental workload. This had effects on driving behaviour, upto a certain threshold of task difficulty. Above that threshold, drivers gave priority to safe driving and gave up on the secondary task.

KEYWORDS

Driving behaviour, mental workload, task prioritization, driving simulator experiment, secondary tasks

INTRODUCTION

Advanced Driver Assistance (ADA) Systems may provide a solution for unsafe or difficult traffic situations. But these systems are new additions into the vehicle that might increase drivers' mental workload. It is therefore relevant for ADA development to have an understanding of the behavioural effects of increasing mental workload and drivers' task prioritization. Do drivers still pay as much attention to safe driving when they concurrently do

something else? Do they actively prioritize safe driving at the expense of the secondary (non-driving) task? Or could driving with increased mental workload turn out to be detrimental to safety? We describe two driving simulator experiments aimed at studying the effects of mental workload on driving behaviour and task prioritization. We hypothesize that with a rise in difficulty of secondary non-driving tasks, safe driving performance (anticipating to upcoming situations and maintaining an appropriate distance and speed) will decrease.

TWO DRIVING SIMULATOR EXPERIMENTS

We conducted two driving simulator experiments. Experiment 1 was performed in TNO's low-cost driving simulator with manual transmission; 39 drivers participated in this experiment. Experiment 2 took place in TNO's moving-based driving simulator with automatic transmission, with 36 participants. All drivers had their driving license for over 5 years and drove at least 8,000 kilometres annually. In order to study the effects of mental workload on driving and task prioritization, participants were asked to perform secondary tasks of varying difficulty while driving. The secondary task conditions were varied either between participants (Experiment 1) or between blocks of road sections (Experiment 2). Participants furthermore performed the head-mounted Peripheral Detection Task (PDT; Van der Horst and Martens, in press) as another additional task, as a measurement of their mental workload levels. They were instructed to prioritize driving and arithmetic tasks over the PDT, which was thus labelled the tertiary task. The PDT has been shown to be unobtrusive and sensitive to workload changes (Jahn et. al, 2005). The average reaction time to PDT stimuli and the percentage of missed stimuli in different conditions are compared to assess the (relative) mental workload situation.

Mental workload conditions

Experiment 1: Mental workload condition, a between-subjects variable, was defined by the presence or absence of a difficult arithmetic task. Half of the participants were in the 'driving only' group, the other group was asked to perform a difficult arithmetic task during driving (e.g., subtract 8 from 791 iteratively). This was related to a higher mental workload than 'driving only' (Table 1).

Table 1: Effects of task difficulty on mental workload measurements - Experiment 1

Measure	*Driving only*	*Driving with difficult arithmetic task*	*Effect*
Reaction time to PDT (ms)	M= 571.19 SD=40.30	M= 798.59 SD= 49.92	F(1,29)= 54.725, p<.001
% of missed PDT stimuli	M= 9.67 SD= 10.34	M= 24.18 SD= 16.28	F(1,33)= 34.873, p<.001

Experiment 2: Mental workload, a within-subjects factor, had three variations: driving only, driving with an easy arithmetic task (e.g., 400-6 iteratively), and with a difficult arithmetic task (e.g., 406-13 iteratively). The average reaction time to the PDT stimuli and the percentage of missed PDT stimuli show that adding an additional task to the driving task increased mental workload, and that an increase in difficulty of this task led to a further increase in mental workload (Table 2).

Table 2: Effects of task difficulty on mental workload measurements - Experiment 2

Measure	*Driving only*	*Driving with easy arithmetic task*	*Driving with difficult arithmetic task*	*Effect*
Reaction time to PDT (ms)	M=495.75 SD=16.95	M=695.75 SD=22.20	M=747.73 SD=25.16	F(2,66)= 116.122, p<.001
% of missed PDT stimuli	M=9.38 SD=1.78	M=31.24 SD=3.51	M=41.21 SD=3.63	F(1.726. 58.628) = 62.181, p<.001

Furthermore, we determined participants' performance on the arithmetic tasks. When driving while performing the easy arithmetic task, participants on average gave 102.5 answers, and made 2.6 mistakes (2.9%). In the difficult arithmetic task, 47.3 answers were given and 4.8 mistakes were made (12.5%). As can be seen from Tables 1 and 2, the difficult arithmetic task increased mental workload more than the easy arithmetic task.

EFFECTS ON DRIVING BEHAVIOUR

In the following sections, E1 denotes a result found in Experiment 1, and E2 in Experiment 2.

Speed

E2: Driving speed, averaged over the complete road sections, did not change when mental workload was elevated to any of the two higher levels, F(2,70)=0.361, p=.698. However, the speed approach pattern did change significantly with mental workload level (interaction effect of mental workload condition and location at road section), F(16.667,58.336)=1.699, p=.040.

Headway (m) and time headway (s)

E1: The difficult arithmetic task (high mental workload) did not affect headway.
E2: The average headway in the easy task condition (M=15.37, SD=1.64) was significantly smaller than when driving only (M=18.20, SD=1.58), but there was no difference between these two conditions and the difficult task condition (M=16.50, SD=1.78), F(2,68)=5.586, p=.006. The headway approach pattern was significantly different for the three conditions, F(2,68)=5.887, p=.004. Figure 1 shows average headway for the three conditions over complete road sections (left) and per 10-metre cell (right).

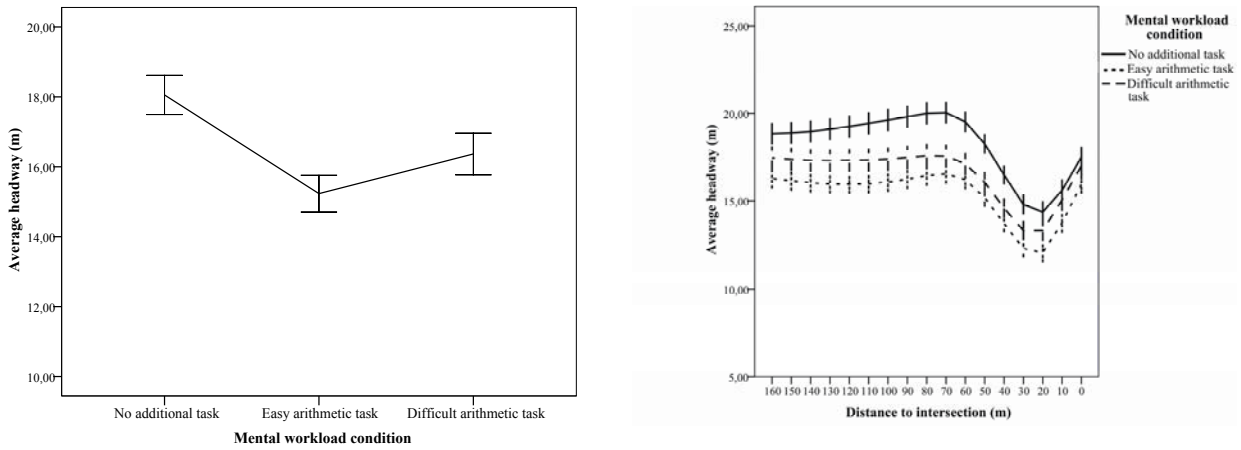

Figure 1: Headway per road section and per 10 metres for all secondary tasks (E2)

E2 (continued): Average time headway in the driving only condition (M=1.40, SD=0.14) was significantly larger than in the easy task condition (M=1.17, SD=0.13), but there was no difference between these two conditions and the difficult task condition (M=1.27, SD=0.09); the difference between the three conditions was significant with F(1.810,66.960)=6.371, p=.004. In other words, participants drove closer to their predecessor when driving with an easy task, but the dificult task did not increase this effect; in fact, it dimished. This is a similar effect as found in headway measurements. It appears as though participants gave up on the difficult secondary task and did not allow this to interfere with safe driving, but did spend attention critical for safe distance keeping on the easy task.

Lateral position

E1: Drivers without an additional task stayed more to the right of their lane than their counterparts driving with an additional task, F(1,33)=7.591, p=.009.
E2: Lateral position did not change significantly as a result of varying mental workload. However, a trend was seen, although its effect was very small: with increasing mental workload, participants drove more to the left side of their lane, F(2,68)=2.830, p=.066, Figure 2. The standard deviation of the lateral position (a measure of swerving) was not affected by the level of mental workload. This result contradicted with results from Experiment 1.

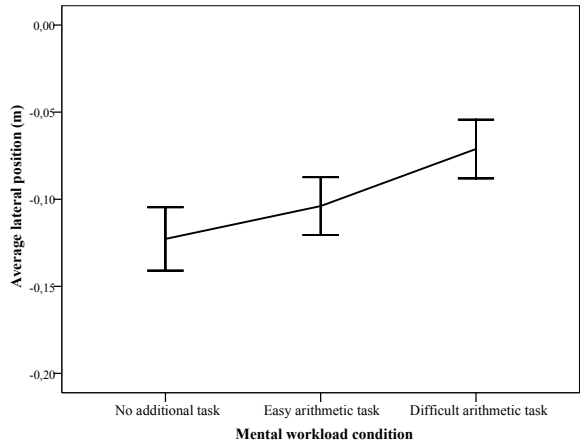

Figure 2: Average lateral position for each mental workload condition (E2)

DISCUSSION AND CONCLUSIONS

Both experiments revealed that an increase in drivers' mental workload changes their driving behaviour. Drivers pay less attention to their speed and speed approach pattern and maintain a shorter (time) headway when engaged in secondary tasks. Participants performed much better on the easy than the difficult version of the task, with 2.4 times more answers and only one third of the proportion of wrong answers. This ratio could suggest that participants gave up on the difficult arithmetic task in order to focus on the primary task of safe and attentive driving. This indicates prioritization of safe driving above a certain threshold of secondary task difficulty. Prioritization of safe driving over certain secondary task levels was also indicated by the larger behavioural effects for the easy arithmetic task than the difficult task: apparently drivers paid more attention to driving when they were asked to perform a difficult secondary task. In Experiment 1, where no easy task was given to the participants, similar results were found for driving with the difficult arithmetic task.

REFERENCES

Jahn, G., A. Oehme, J. Krems, and C. Gelau (2005) Peripheral detection as a workload measure in driving: effects of traffic complexity and route guidance system use in a driving study, in: *Transportation Research part F (8)*, pp. 255-275.

Van der Horst, A.R.A. and M. Martens (2010) The Peripheral Detection Task (PDT): On-line measurement of drivers' cognitive workload and selective attention, *SAE Special Issue 2008 Driver Metrics Workshop (in press).*