DISTRACTION AND WORKLOAD
DRIVING ON THE A10 RING ROAD AROUND AMSTERDAM

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ABSTRACT

A simulator study was performed to establish the effects of motorway environment complexity on driver distraction and workload.
We compared two situations that represented the extremes regarding environment complexity (empty versus full) of the A10 ring road around Amsterdam, which has been modelled in the simulator based on a photographic realistic representation. We concluded that the minimum and maximum version of the A10 ring road differed a lot in environment complexity, but objective secondary task measures showed no workload effects. It appeared that participants were able to neglect distraction by the visual complex environment and that environmental complexity does not directly influence workload.

KEYWORDS
Driving simulator, environment complexity, distraction, workload

INTRODUCTION

There are many external factors that influence the workload of a driver (see [1]):

- Macro traffic circumstances, like traffic density, intensity and speed.
- Micro traffic circumstances, like maneuvering (e.g. overtaking), regulating (e.g. time headway). These factors are influenced by the driver, but are also forced by the other traffic participants.
- Weather, sight and road surface circumstances.
- Features of the road, like number and width of driving lanes, road markings and road environment.

The factor environment complexity (simple versus complex environment) was also studied by [2]. They reported that subjective workload did not differ between simple and complex environments. Only elderly drivers (> 60 years) showed effects in their driving behavior. They decreased their speed when driving through a complex environment.
In [3] the effect of route complexity was studied by using the Peripheral Detection task. The used classification of route complexity was based on task demand in terms of information processing and vehicle handling. Besides complexity, the influence of driving experience was studied. A higher complexity was found to be related to longer reaction times. Inexperienced drivers did not show differences between average and high complexity, while experienced drivers did not show differences between low and average complexity.

The current study focuses on the effects of environment complexity by comparing a maximum and a minimum version of the same road in terms of driver workload. Performance on secondary tasks will be the main measure of workload.

METHOD

In this driving simulator study, two variants of the same part of the A10 ring road around Amsterdam were compared.

1. A maximum variant, in which all traffic signs, variable message signs (VMS), road furniture, and buildings were realistically modeled based on real life photography. Also road geometry, lane markings, guard rail and connecting roads were modeled (see Figure 1).
2. A minimal variant, in which all the above was taken away except for the road geometry, lane markings and connecting roads (see Figure 2).

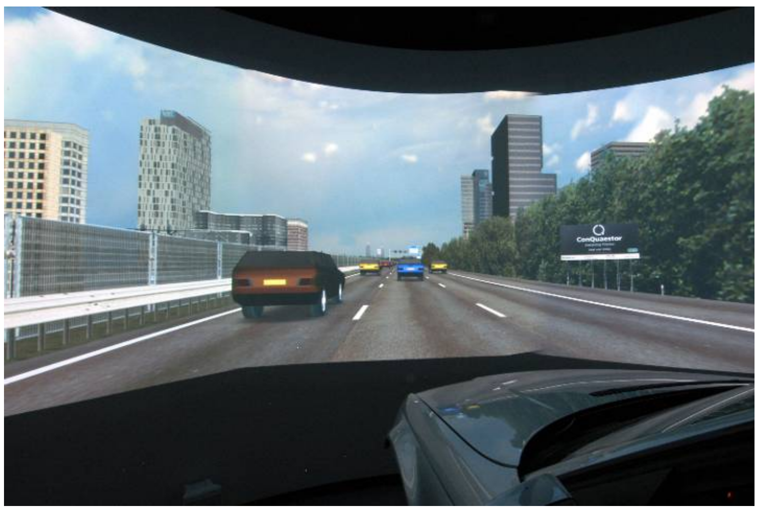

Figure 1 Impression of the maximum variant of the A10 in the TNO driving simulator.

Figure 2 Impression of the minimum variant of the A10 in the TNO driving simulator.

In the second part of the maximum variant Work In Progress situation was added to further increase the workload of the traffic environment (see Figure 3).

Figure 3 . Work In Progress in the maximum variant in the TNO driving simulator.

During the experiment the other traffic was driving with an average speed of 100 km/h, with slight fluctuations and with a high traffic density (all lanes were occupied). The goal of the other traffic was to give the participants hardly any chance to increase their speed above 100 km/h or to change lanes. The vehicles of the other traffic kept a headway of 1 second to the participant and to each other. Only in the kilometer before the Work In Progress, where all traffic had to merge into the right lane, the speed decreased to 90 km/h. The experiment was performed in the high fidelity moving base driving simulator of TNO Human Factors (see Figure 4).

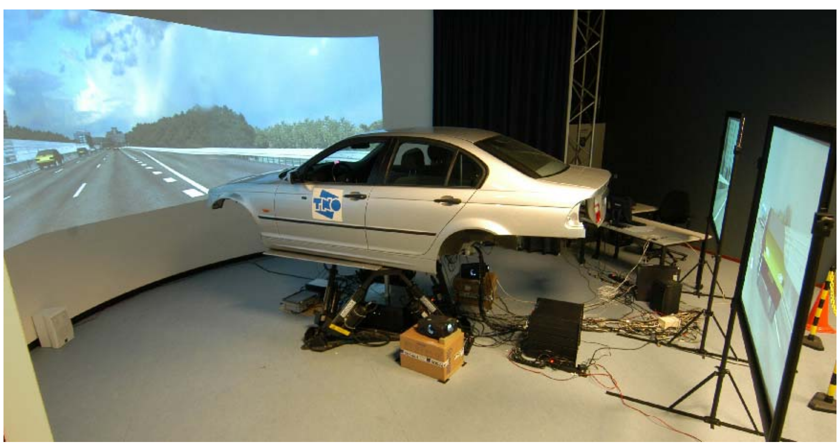

Figure 4 The TNO driving simulator.

In this driving simulator the participant was seated in a BMW 318i mock-up with automatic transmission, which was placed on a motion base with six degrees of freedom. The participant watched a large radial screen in front of the mock-up and two flat screens behind the mock-up on which the road and traffic environment was projected. An additional 34” LCD display was mounted in the rear of the mock-up to display the rear view. The original mirrors were used to let the subject look at the rear projection. The front projection had a field of view of 180^o horizontal and 35^o vertical. Also the sound of traffic in the environment and the sound of the car the participant was driving were presented.

Workload of the participants was measured with secondary task measures, subjective measures and driving behavior measures.

1. Secondary task measures:

- Peripheral Detection Task (PDT).
  This task is developed by TNO [4] [5]. The method has shown to be very sensitive for variations in workload caused by different driving situations. The task hardly interferes with the performance of the primary driving task. The task works as follows: Participants wear a headband with a small led light in the upper left corner not obstructing their view on the road. The stimulus (onset of the red led light) has an interval time of 3 to 5 seconds. The stimulus is presented for 1 second maximum and disappears as soon as the participant presses a small finger switch.
- Digit task.
  This is a visual detection task based on [6]. A neutral stimulus ‘00’ is presented on a display. Participants have to detect the target stimulus ‘99’. The number on the display were 18mm high and 11 mm wide. The stimulus has an interval time of 3 to 8 seconds from the start of the previous stimulus. The stimulus is presented for 2 seconds maximum and disappears as soon the participant presses a small finger switch. The display was positioned such that the participants had to take their eyes off the road to be able to see what was on the display. To this end the display was placed on the ground of the car in front of the passenger seat, which is about 50^0 to the right and 45^0 down from the viewing (straight ahead) direction of the driver.

The PDT as well as the digit task are visual detection task. The important difference between the tasks is that the PDT stimulus is always visible, while the stimulus of the digit task can only be detected when the participant is actually looking (i.e. taking his eyes off the road). The digit task could be more suitable to measure ‘rest capacity’ because of the necessity to look away. This digit task is at the same time more interfering with the primary driving task.

2. Subjective measures

The Rating Scale Mental Effort (RSME) [7] is a one dimensional scale ranging from 0 to 150. Participants give their rating by putting a cross on this scale indicating how effortful their task was. Compared to other techniques of measuring mental workload the RSME has been shown to be one of the more sensitive measures [8].

3. Behavioral measures.

These measures give an indication of the amount of objective risk that is taken during different driving situations. Behavioral measures also provide insight in the way drivers might compensate for experienced workload (for instance because of performing a secondary task). Driving behavior is therefore the *result* of a certain level of workload than the workload itself.

45 drivers participated in the experiment. They all drove for at least 5 years with more than 20.000 kilometers per year. Their ages varied between 25 and 60.

The following factors were analyzed:

- Complexity with two levels: minimum and maximum as a within subjects variable.
- Segment with two levels: part 1 without road works and part 2 with road works as a within subjects variable (Note that road works are only present in the maximum complexity).
- Secondary task with two levels: with and without secondary task as within subjects variable.
- Type of task with two levels: PDT and digit task as a between subjects variable.

RESULTS

In the analysis of only samples of headways below 5 seconds were included. Larger headway indicate that participants were not in a following situation, which means that they decreased their speed considerably not following the original instructions of speeding up and decreasing secondary task performance when workload gets too high. 2% of all the runs were considered as missing data, because the subjects had not performed a proper car following task, i.e. time headways larger than 5 seconds. The analysis of the time headway is described in the following subsection.

The speed choice was not a proper behavioral measure when participants followed the instruction of speeding up correctly. This is because speeding up was restricted to the speed of the car in front (set to 100 km/h). Therefore, the speed choice was not taken into account in the statistical analysis as a behavioral measure.

Time Headway

A significant effect of Complexity was found on average time headway. For the minimum complexity, the time headway was lower (1.18 s) than for the maximum complexity (1.63 s) [$F(1,43)=28.9$, $p<0.001$].

Also a significant effect of van segment was found: average headway was larger for segment 1 (1.16 s) than for segment 2 (1.65 s) [$F(1,43)=41.3$, $p<0.001$].

Also the interaction between Complexity and Segment was found [$F(1,43)=40.6$, $p<0.001$]. See figure 5. Tukey post hoc tests showed the following:

- Within minimum complexity no difference was found between the segments
- Within maximum complexity thw is larger in segment 2 [$p<0.001$], which is the road works zone.

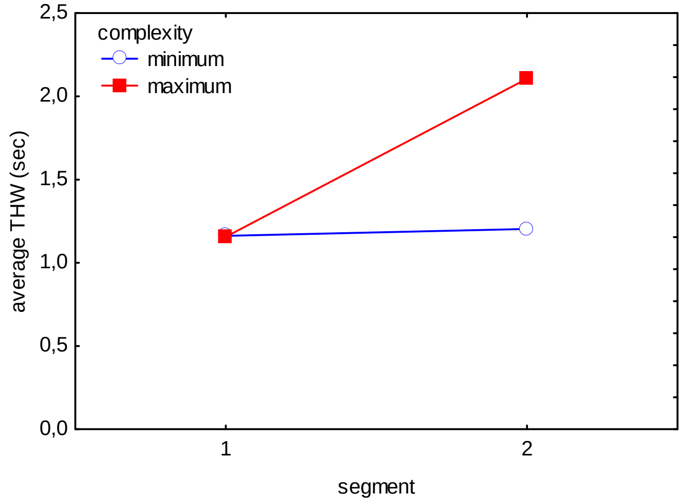

Figure 5 Average headway for Complexity and Segment.

Standard deviation lateral position (SDLP)

Standard deviation lateral position was significantly different between complexities [F(1, 43)=5.8; p<0.05]. SDLP was larger in the maximum complexity (0.28 m) compared to the minimum complexity (0.26 m). Also a main effect of segment was found [F(1,43)=58.2; p<0.001]. SDLP was larger in segment 2 (0.31 m) compared to segment 1 (0.23 m). Both effects are shown in Figure 6. Although the interaction between segment and complexity was not significant [p<0.12], it was shown by a post hoc Tukey that segment 2 in the maximum complexity had a larger SDLP compared to the minimum complexity [p<0.05].

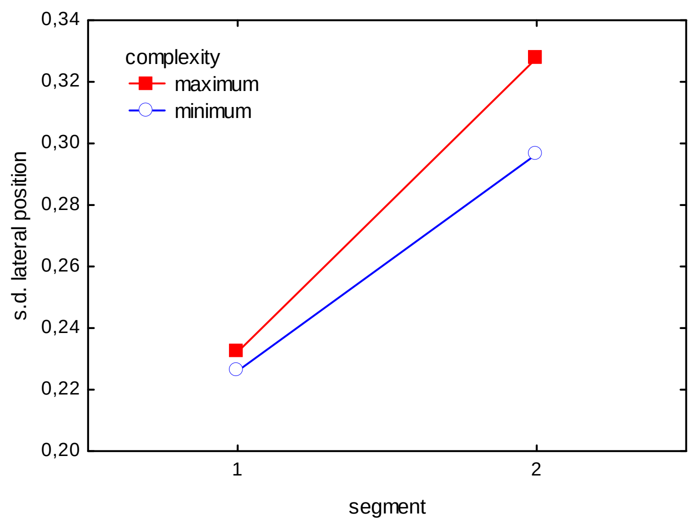

Figure 6 Standard deviation lateral position as a function of segment and complexity.

The strong increase in SDLP in the maximum complexity can be attributed to the change in lateral position to the right lane because of the road works. Although this lane change was meant to take place before segment 2, it turned out that part of it still took place during segment 2. Furthermore, the SDLP was also larger in the minimum complexity in segment 2 compared to segment 1. It turned out that this was caused by a long gentle curve in the road in segment 2.

Performance on secondary tasks

Reaction time

Average reaction time showed a significant effect of baseline versus driving [$F(1,43)=265.5$, $p<0.001$]. Averages: 368 ms baseline and 753 ms driving. Also a significant effect of type of task was found [$F(1,43)=70.2$, $p<0.001$]. Averages: 430 ms PDT and 691 ms digit task. The interaction between both independent variables was also significant [$F(1,43)=102.9$, $p<0.001$]. See Figure 7. A Tukey test on this interaction showed the following:
In the baseline condition no difference was found between PDT and digit task (averages 358 ms versus 378 ms). During driving a significant difference was found between PDT (503 ms) and digit task (1003 ms) [$p<0.001$]. For both task types the increase because of driving compared to baseline was significant [both $p<0.001$].

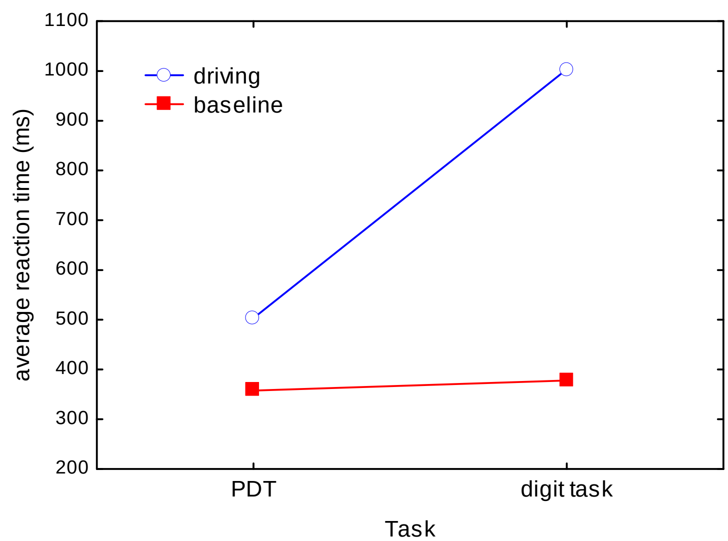

Figure 7 Average reaction time per task type.

Percentage missed stimuli

The average percentage missed stimuli for driving and for baseline with both secondary tasks are shown in Figure 8. The data of this variable did not show a normal distribution: in the baseline-condition average and standard deviation were almost zero. That is why these data were analyzed using a Wilcoxon-test to establish the main effect of driving of type of task. The results show that the percentage missed stimuli was lower when performing the PDT during baseline compared to driving [$p<0.001$]. The same is true for the digit task [$p<0.001$].

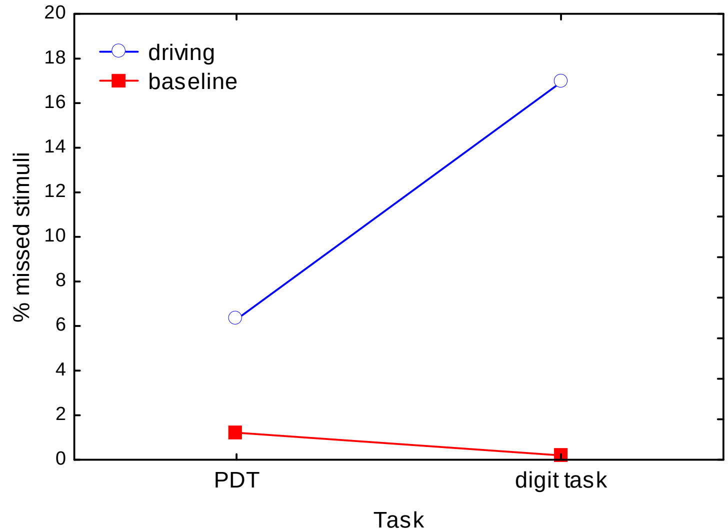

Figure 8 Percentage missed stimuli per task type: driving versus baseline.

Hence, the pattern is the same for the reaction time as for the percentage missed stimuli: In the baseline measurements, there is no difference between the task types, while the effect of driving in the simulator shows a larger impact on the digit task than the PDT.

The effects on the secondary task performance were analyzed further with an analysis of variance with the independent measures the complexity (minimum, maximum), the task type (digit, PDT: between-subject design) and the road segment (1, 2 with only in the maximum complexity on segment 2 a Work In Progress)

The number of stimuli (averaged over all subjects, with a 5s time-tracking criterion applied) is shown in Table 1.

Table 1 Average number of stimuli for the secondary task divided into task type and segment.

Task type	segment 1	segment 2
PDT	33.4	11.5
Digit task	24.3	7.5

The number of stimuli for the PDT was approximately a factor 1.4 larger than for the digit task. This factor was in line with the average inter-stimulus period for both tasks (4s for the PDT versus 5.5s for the digit task). In segment 2 the number of stimuli was smaller than in segment 1 (in accordance with the differences in length of both segments).

The results for the average reaction time per task type and segment for the minimum and maximum complexity are shown in Figure 9.

There was a significant effect for task type: For the PDT the average reaction time was smaller than for the digit task [F(1,43)=106, p<0.001]. The reaction time was for driving with the PDT smaller than the reaction time for driving with the digit task, respectively 497 versus 962 ms.
There was a borderline significant effect for segment [F(1,43)=3.5, p<0.1]; The average reaction time for segment 2 was smaller than for segment 1, respectively 706 versus 753 ms.

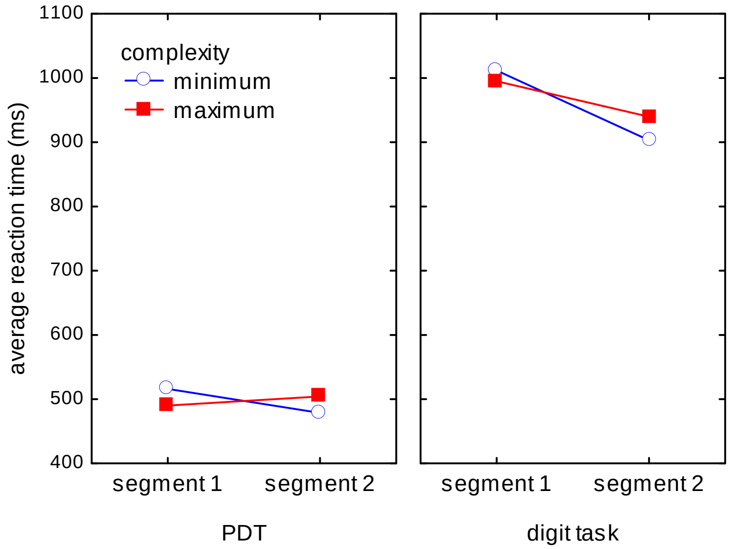

Figure 9 Reaction time per task type and segment for both complexities.

There was a significant effect for task type with respect to the percentage missed stimuli (see Figure 10) [F(1,43)=10.8, p<0.01]: The percentage missed stimuli was larger for the digit task than for the PDT, respectively 15% versus 5%. There were no other effects found.

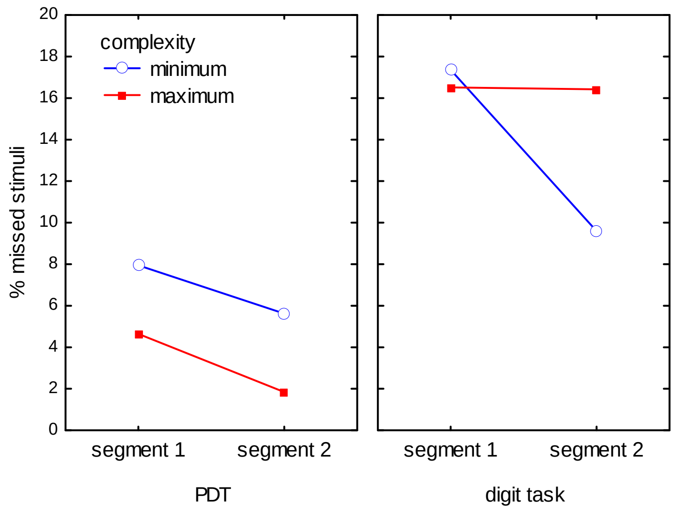

Figure 10 Percentage missed stimuli per task type and segments for both complexities.

Summarizing, the results show that there is a difference between the secondary tasks PDT and the digit task. Effects of complexity of the environment or the Work In Progress were not found.

Subjective workload

The ANOVA on the subjective measures, i.e. the RSME data, showed that there was a main effect of complexity on the experienced workload [$F(1, 43)=21.8$; $p<0.001$] (see Figure 11). The mean workload was smaller for the minimum complexity than for the maximum, respectively 39.3 versus 48.3. Furthermore, there was an effect for secondary task [$F(1, 43)=93.1$; $p<0.001$]. Without a secondary task the experienced workload was smaller than with a secondary task, respectively 33.2 versus 54.9.
There was an effect of the 2-way interaction between the secondary task and the task type [$F(1, 43)=10.4$; $p<0.01$]. The post hoc Tukey test showed that the increase of the workload was larger for driving with the digit task than for driving with the PDT [$p<0.001$], the means on the RSME scale were respectively 46.8 and 63.1.

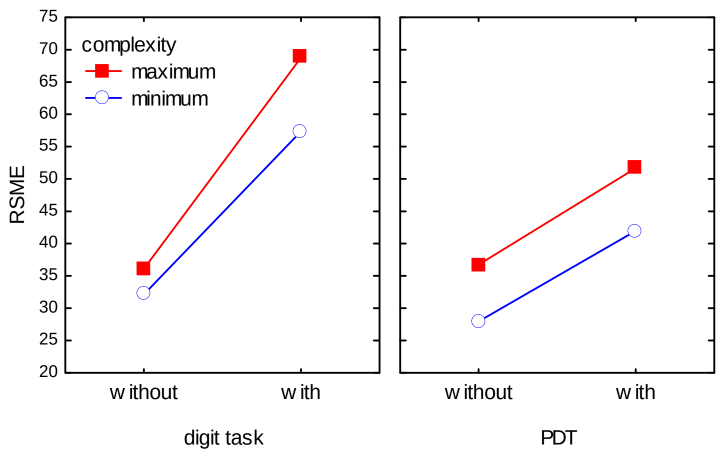

Figure 11 RSME for complexity, task and task type.

The subject experienced a larger workload when driving the maximum complexity than when driving the minimum complexity. Because the RSME was completed after the total run, i.e. segment 1 and 2 together, the subjective workload of maximum complexity of the different segments, i.e. with and without Work In Progress, can not be distinguished. Furthermore, driving with a secondary task resulted in a larger subjective workload than driving without the secondary task. This effect was larger for the digit task than for the PDT.

Discussion and conclusions

There are different factors that could influence the driver workload. In this research we focussed on motorway environment complexity, which contained several elements: driving task related, e.g. traffic signs, and non-driving task related, e.g. advertisements and buildings.
The minimum and maximum version differed a lot in environment complexity. In spite of this, the secondary task measured showed no workload effects. The subjective workload was higher in the maximum version, but the cause of this effect (environment complexity or Work In Progress) is not known.
In the experimental setting as applied here (with specific instructions to hurry, and in addition to that conduct a secondary task), it appears that subjects were able to neglect distraction by the visual complex environment. Considering both secondary tasks, the digit task resulted in larger reaction times and larger percentages of missed stimuli than the PDT, but a larger sensitivity of one of the tasks was not concluded. Altogether, the secondary task methods have not shown workload effects of the environment complexity of the motorway.

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