Simulator-based Evaluation on the Impact of Visual Complexity and Speed on Driver's Cognitive Load

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ABSTRACT
Assessing the driver's cognitive load has become an increasing research interest. Methods described in literature fall into three categories: self-assessment, physiological measures, and performance-based measures. We claim that cognitive load can also be deducted by environmental factors, such as visual complexity of the context or driving speed. This paper describes an experiment aimed at backing this claim and its first results.

Categories and Subject Descriptors
H.5 [**Information Interfaces and Applications**]: User Interfaces; H1.2 [**User/Machine Systems**]: Human factors—*complexity measures, performance measures*

General Terms
Theory

Keywords
cognitive load, presentation complexity, automotive information systems

1. INTRODUCTION
We claim that environmental factors correlate with the driving performance, e.g. reaction time, and thus also serve as an indicator for the current cognitive load of the driver. Now, we attempt to back this hypothesis with empirical data acquired in a driving simulator test.

Real-life field studies for evaluating driver distraction are often inefficient (e.g. observing accident data) or intricate to accomplish. On the other hand, indirect laboratory methods measuring reaction times independent of the real driving context can be of limited validity. To overcome these shortcomings, [3] introduced the Lane Change Test (LCT) as a measure of the influence of the secondary task on the driving performance in a simple simulator task.
The original LCT consists of a simple driving simulation at a regular consumer PC with steering wheel and foot pedals used for computer games. The subject is driving on a straigh three-lane road with traffic signs indicating which lane to use.These traffic signs are used as stimuli, and the corresponding maneuver of the driver is the response. In between two responses, the subject still has to keep driving and stay on his current lane.
The LCT was subsequentially standardized as an ISO norm in 2008 [2].

The LCT Kit as an implementation is developed since 2009 at the Leibniz Research Centre for Working Environment and Human Factors (IfADo), based on the original Lane Change Test. Its main purpose is to determine reaction times and also the connection between driver reaction times and the placement of the stimulus in the left or right visual half-field, such as [1].
In this simulation, the driver is placed in the middle lane of a straight road with a screen-filling number of lanes to the left and right. Except for seeing his own car interior, there are no visual distractions in the simulation. After a prompt, a short instruction to change lanes (either one or two lanes to left or right) is displayed for 300 milliseconds on one side of the screen. This short time span is sufficiently long to decode the information after a short training but short enough to avoid saccades, which would add noise to the data to be observed. The reaction to the stimulus is measured as the time span between stimulus and a steering wheel angle outside of the ordinary lane keeping range. Furthermore, the task of changing the lane has to be completed in a certain amount of time.

OpenDS[1] is an open source driving simulator software developped in our automotive group at the German Research Center for Artificial Intelligence. It is based completely on open source modules.
OpenDS was developped with the intention to have a flexible driving simulation, which can perform the standard Lane Change Test (LCT), but easily extended to other/similar/new testing tools beyond the possibilities of LCT, since the original LCT is very restricted and not extendable.

2. EXPERIMENT
The experiment described here is based on the IfADo LCT Kit (see figure 1). We reimplemented the task in OpenDS and made some modifications: As the aim is to show the correlation between contextual complexity and cognitive load,

[1]www.gethomesafe-fp7.eu/index.php/menu-opends

AutomotiveUI'12, October 17-19, Portsmouth, NH, USA.
Adjunct Proceedings

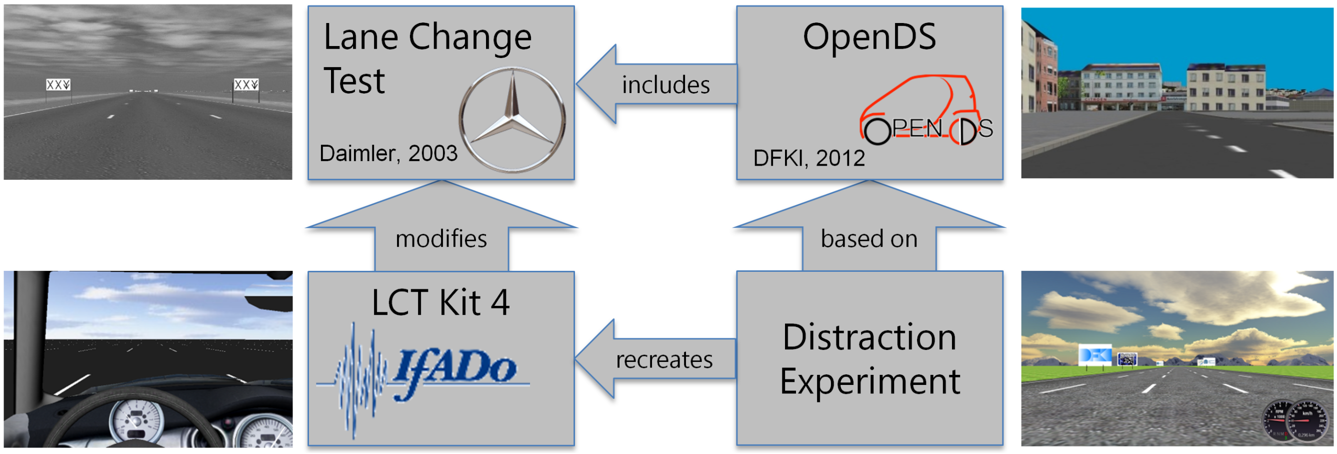

Figure 1: The distraction experiment described here is a reimplementation of the LCT Kit in our OpenDS driving simulator. It is based on the Lane Change Test, but measures reaction time instead of lane deviation.

we change the parameters speed and visual complexity.

Visual complexity
The original experiment uses infinite lanes and offers no visual distraction for the subject. In a first step, we reduce the number of lanes to a necessary minimum of five and fill the remainder of the visible plane with monochrome shading. To avoid predictability (e.g. the subject knows the next instruction must be left because she is on the far right lane), the driver is automatically centered again on the middle of 5 lanes by adding or removing lanes on the respective sides. Now, we introduce visual complexity by adding objects (billboards) to both sides of the street. To keep different experiment runs comparable, all objects are of same size and similar visual complexity, i.e. identical models. The hypothesis to be verified in the experiment is a positive correlation between visible objects in the subjects viewfield and the reaction time during the experiment.

Vehicle speed
The second assumption to be verified here is the correlation between vehicle speed and reaction time. We extend the original experiment and run it in different speeds. This assumption is closely related to the previous assumption, as the higher vehicle speed results in faster change in the visually perceived environment.

In a pre-test before the main study, five subjects drove in the simulation under varying conditions. Their task was to react as fast as possible to lane change commands displayed on the screen. We used three variants of visual complexity (no distractions, some billboards on the side of the road, many billboards on the side of the road) and two different speeds (60-80 km/h and 120-140 km/h). In order to observe whether or not any training effect in getting used to our simulator occurred, three of the subjects were asked to perform the test twice in a row.
As setup, we used a real car positioned in front of three projection walls covering a visual range of 120 degrees.

3. RESULTS

Results of the pre-test clearly confirmed our two hypotheses: (1) The average reaction time increases with increasing speed. (2) The average reaction time increases with the number of distracting objects (billboards) on the roadside. A more detailed look at the data is shown in table 1.
An interesting effect can be found when looking at the reaction time under both varying speed as well as varying number of distractions: While in average and at high speed the reaction time increases with the number of distractions, the exact opposite can be observed at slow speed. Our first assumption that this can be attributed to training could not be confirmed, since the effect prevailed when only considering the three test runs of subjects performing the test for a second time. We will provide more detailed results after the main study on the conference.

	slow driving	fast driving
no distraction	1380 ms	1387 ms
medium distraction	1344 ms	1464 ms
high distraction	1126 ms	1783 ms

Table 1: Average reaction time in ms under varying conditions

4. ACKNOWLEDGMENTS

We would like to thank our colleagues from training science for collaboration and support, especially Professor Stefan Panzer and Peter Leinen.

5. REFERENCES

[1] T. Ellenbuerger, A. Boutin, S. Panzer, Y. Blandin, C. H. Shea, L. Fischer, and J. Schorer. Observational training in visual half-fields and the coding of movement sequences. *Human Movment Science*, 2012.

[2] Road vehicles–Ergonomic aspects of transport information and control systems–Simulated lane change test to assess invehicle secondary task demand. ISO Norm 26022, 2008.

[3] S. Mattes. The Lane-Change-Task as a Tool for Driver Distraction Evaluation. In *Quality of Work and Products in Enterprises of the Future (Proceedings of the GfA/17th Annual Conference of the International Society for Occupational Ergonomics ans Safety, ISOES)*, pages 57–60, 2003.