Development of a New Low Cost Driving Simulation for Assessing Multidimensional Task Loads Caused by Mobile ICT at Drivers' Workplaces. – *Objective-Fidelity Beats Equipment-Fidelity?*

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Abstract. Digitization of the world of work has led to drivers' workplaces frequently being equipped with information and communications technology (ICT) [1]. These workplaces often involve the use of several such digital systems. Owing to these systems' potential to distract the driver, they must be integrated into users' workplaces with appropriate attention to ergonomics, and tested by risk-free methods under laboratory conditions. A driving simulator designed and constructed for this purpose at the IFA forms the subject of this paper. Particular aspects of this simulator are its design, which is low-cost and assumed to deliver low fidelity, but which enables good overall simulation quality results to be achieved owing to a special software environment. Third parties are expressly invited to copy the simulator and pool their experiences.

Keywords: Driving simulation · Measurement of distraction · Mobile information and communications technology

1 Problem

The diverse uses of mobile information and communications technology at drivers' workplaces give rise to an increasing risk of distraction. This applies both to the vehicle manufacturers' factory-fitted systems and to aftermarket systems. The particular issue however concerns the combining of multiple aftermarket systems – often without careful consideration – that have never been tested by a (vehicle) manufacturer with regard to the task load associated with them. The systems in question are used for example for job assignment, scheduling and navigation, and for access to information on the move. Equipment typically includes tablet PCs, satellite navigation devices, laptops integrated into the driver's workplace for use in mobile technical services, telematics applications in logistics, etc. Whether the design of a workplace employing mobile IT is free of hazards must also be determined at company level by way of a risk assessment. Awareness of the problem is however fairly limited within companies. A driving simulator was to be created that can be used flexibly and under mobile conditions to test the

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applications that are actually encountered in company operations. The purpose was to improve awareness of the issue and to permit objective study of it.

The IFA's driving simulator was developed for the purpose of analyzing the impact upon drivers' performance of multidimensional task loads in actual practical application scenarios, and for illustrating to users the hazards posed by distraction.

2 Design

The base frame was designed such that a driver's and a passenger's seat can be fitted to it. A passenger's seat is relevant because the equipment used for the secondary tasks to be tested is frequently secured to the seat or seat mounting rail (for example by means of a laptop console). A Logitech G27 steering wheel (with haptic force-feedback characteristic) and an H-pattern manual gearshift gate were located on a hight-adjustable base. A pedal mounting surface was provided on the floor frame (see Fig. 1).

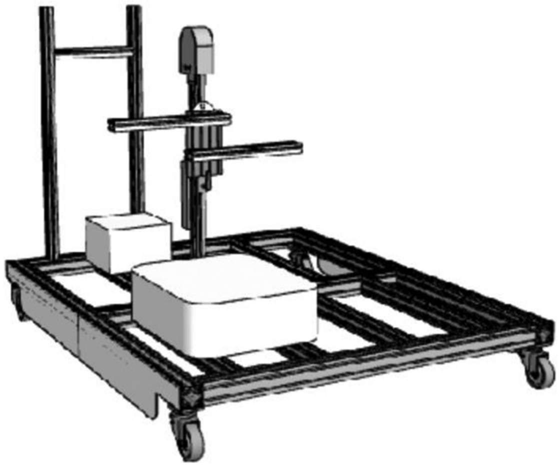

Fig. 1. Design sketch of the mobile IFA simulator, constructed from aluminum profiled sections

The frame was manufactured from standard aluminum profiled sections.

The items of equipment were selected with the aim of achieving the greatest possible realism. The force-feedback feature and the facility for simulation to be controlled by means of a conventional H-pattern manual gearshift gate and standard pedals (gas, brake, clutch) was intended to minimize the reactivity of the test arrangement, i.e. the confounding influence of unrealistic laboratory conditions upon the study result.

The compact dimensions and low weight of the simulator enable it to be used without difficulty at different locations for demonstration purposes. It can be used during company events such as safety training courses for the purposes of education and prevention (Fig. 2).

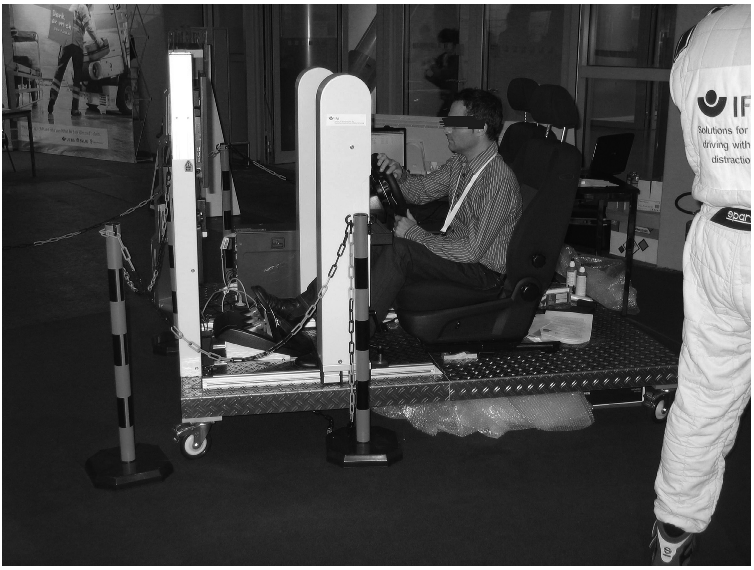

Fig. 2. The simulator in action at the World Congress for Safety and Health at Work 2014 in Frankfurt

3 Software Environment

The powerful but low-cost rFactor software application was used as the simulation environment. rFactor has its origins in the sim racing scene. This project enabled it to be used for the first time in a research application. For this purpose, a custom plugin was developed for the export of log files containing the essential performance parameters (see Fig. 3). Attainment of a high level of overall *simulator fidelity* is therefore claimed, despite relatively low *equipment fidelity* – for example, the driving simulator does not include a replica vehicle body. (In simple terms, the overall simulator fidelity refers to the overall realism attained by the simulation, together with the scope for extrapolation of the results to reality.) The *objective fidelity* (such as realistic dynamic vehicle behavior) and the *perceptual fidelity* (the degree to which the test subject perceives simulation to be realistic, following acclimatization) were attained to an extent often not reached by conventional simulation environments in the research sphere; for fidelity aspects, refer to [2]. A further benefit is the facility for the unrestricted creation of custom routes, together with a Google Maps interface, and the networking capability of the software used.

3.1 rFactor and IFA Plugin

The simulation environment enables any conceivable vehicle type to be used. This in turn enables the simulator to be adapted realistically to specific test subject collectives (such as use of the vehicle type in the company fleet, up to and including detailed design of the instrumentation – see Fig. 3).

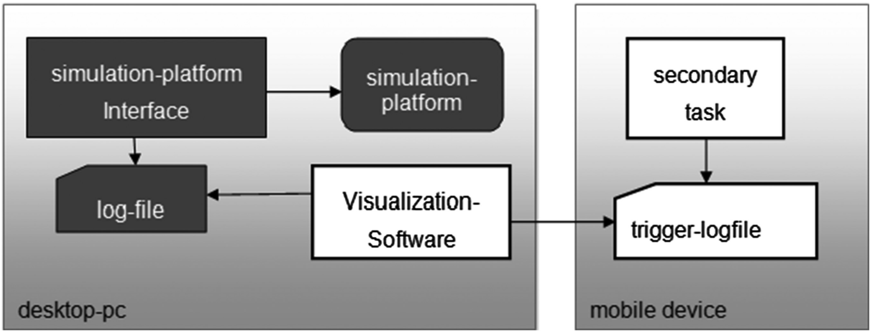

Fig. 3. Logical structure of the software components

The realism of the driving characteristics can be varied. Test runs showed that transfer of existing driving skills was better when the test subject was presented with the driving task in simplified form in the first instance (automatic transmission, steering assist, etc.).

The courses to be completed can be selected from a library of existing layouts, or created by users themselves (see Sect. 3.2). Preference was given to a user-generated layout in the interests of standardized driving tasks.

A plugin created by the IFA enables a number of driving parameters to be accessed. These are essentially the speed, the frequency of lane departures, and the braking behavior.

3.2 Bob's Track Builder

Bob's Track Builder is an add-on application by which courses can be designed freely and thereby adapted ideally to the objectives of the study. An interface to Google Maps enables real-life courses to be imported. The road surface and the landscape can also be adapted without difficulty.

4 Method

The usual test scenario provides each test subject with an acclimatization phase (unstructured driving practice) of adequate length. This is supplemented by standardized test runs. The test proper consists of a baseline run (driving over a standardized course without distraction) and a test run (driving with distraction/secondary task; the distraction task can be a 1:1 simulation of the actual applications within company operations). If applicable, a further run is performed in which a standardized reference task is used as the distraction. The form taken by the test scenario is determined by the specific objective of the study.

Statistical analysis of the data obtained with test subject collectives of adequate size enables the global task load of a secondary task to be determined in relative terms. Variants of the tasks can be retested and developed further as needed.

Fig. 4. View of the instruments in the r-Factor simulation

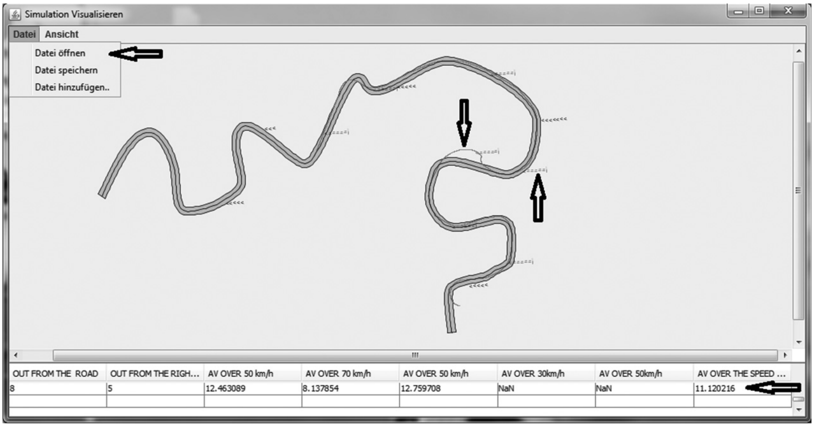

Fig. 5. Visual analysis of the course followed and the incidence of distractions (marked by arrows)

This purely quantitative approach can be supplemented by a qualitative analysis. The USB link between the tablet PC on which the distraction task is presented and the simulation PC enables the respective log files to be merged and processed for presentation in visual form (see Fig. 4). An analysis tool was programmed for this purpose. The exact driving line of a baseline run and that of a test run can be presented in a graph together with the point in time of the distraction. This provides the test subject with very rapid and informative feedback on his or her driving performance (Fig. 5).

For further extension of application and for reference purposes, existing, established standard simulations and test methods such as the Lane Change Task (LCT) in accordance with ISO 26022 [3] can easily be performed by means of the simulator in its current form. The hardware is fully compatible for this purpose.

5 First Impressions and Results

Visitors passing a trade-fair stand were spontaneously invited to take a test drive. 50 test subjects were recruited in this way; 44 of them were documented in full.

The test subjects were provided with verbal instructions on use of the simulator and on the subsequent procedure. Performance of a test drive, which under laboratory conditions would be indispensable, was unfortunately not possible under the given conditions. As a result, the unfiltered adaptation effect limited the suitability of the results for exploitation.

Each test subject completed one baseline run and one test run with distraction tasks on a standard course. Each run involved driving on a twisty country road for approximately three minutes. Oncoming traffic was not presented. The course was divided into five speed zones (30–70 km/h), marked by standard traffic signs.

Each test subject was instructed *to keep to the right-hand carriageway at the speed indicated by the signs*.

Following the baseline run, the distraction task was explained. This consisted of a scheduling message in the context of company operations, and was presented on a laptop. The task entailed reading the text and hitting a function key ("*OK*"). For part of the tasks, the test subjects were prompted by the text of the task to say a certain signal word out loud. The purpose of this was to increase the validity of the data ("*blind clicking*" can be detected and filtered in this way).

The following parameters were read out and documented.

For the driving performance:

- Lane departure: "*shoulder line*"
- Lane departure: "*center line*"
- Speed limit violation

For the distraction tasks:

- *Motor performance* of task completed: "yes/no"
- *Cognitive/acoustic performance* of task completed: "yes/no"

For the checklist:

- Duration of completion of the task

A constant deterioration in driving performance from the baseline run to the test run is evident for all sub-groups.

Lane departures are more frequent. Both the center line and the shoulder line were crossed inadvertently an average of once more often per run. Highway curve entry points were repeatedly missed owing to aversion of the gaze.

Speed limit violations were also more frequent. The average speed limit violation over the entire course was 0.5 km/h higher in the test runs than in the baseline runs.

- Observation 1: Speed limit signs were often missed.
- Observation 2: The test subject first eased off the gas, then attempted to "*make up*" time after completing the task (distraction).

Analysis of the data set filtered following successful completion of the task (distraction) yielded somewhat surprising results. It revealed no significant deviation in driving performance between the sub-groups (filtered for successful/unsuccessful completion of the distraction task). Based upon the observations, the conclusion at this stage is as follows:

- An individual who is already fully occupied does not even address the task, or ignores it and simply drives on.
- The test subject conducts "*information management*", i.e. he or she waits until a straight stretch of highway before addressing the distraction task.

Hardly any test subjects managed to address all the "*speaking tasks*" during the distraction task. 18 out of 44 test subjects completed at least 1 out of 3 "*speaking tasks*". Only 2 persons completed all *speaking tasks*, and these individuals indicated that they had a background in this area of research and had considerable experience with simulators.

6 Discussion

The driving simulator method outlined here is still at an early stage of development. The test runs described nevertheless demonstrated that the method discriminates, at least coarsely, despite the adaptation effects. This must be examined further under adequate laboratory conditions. The validity of the method is to be tested in the future by means of crossover trials employing established methods.

The advantage of this method, which is already evident, lies in the high simulation quality of the driving characteristics. The driving task is highly realistic. The suitability of the driving task and also of the distraction tasks for adaptation leads to a high level of acceptance at company level and thus contributes to the raising of awareness among the target group.

The facility for data to be analyzed qualitatively and presented visually is particularly useful for applications in prevention activity. Test subjects are frequently not aware of how negatively a distraction task has impacted upon their driving performance. Statistical analysis has proved to be of little benefit for prevention activity, the purposes of which are primarily educational. By contrast, visual analysis provides the test subjects with a quick and simple impression of the effect of distraction.

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