---

**Published paper**

Santos, J.; Merat, N.; Mouta, S.; Brookhuis, K.; De Waard, D. (2005) *The interaction between driving and in-vehicle information systems: Comparison of results from laboratory, simulator and real-world studies.* Transportation Research Part F: Traffic Psychology and Behaviour, 8(2), pp.135-146.

---

# THE INTERACTION BETWEEN DRIVING AND IN-VEHICLE INFORMATION SYSTEMS: COMPARISON OF RESULTS FROM LABORATORY, SIMULATOR AND REAL-WORLD STUDIES

Jorge Santos[1]* Natasha Merat[2], Sandra Mouta[1], Karel Brookhuis[3], Dick de Waard[3]

[1]University of Minho, [2]ITS Leeds, [3]University of Groningen

**Keywords:** Driving performance, In-vehicle Information Systems (IVIS), Driving test facilities

Correspondence Address: Jorge A. Santos, Department of Psychology, I.E.P., University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal. Email: jas@iep.uminho.pt

## Abstract

The main objective of this study was to compare a standardised visual performance test in three driving research environments: laboratory, simulator and instrumented vehicle. The effects of a standardised secondary visual search task on the primary task, i.e. aspects of driving performance, were evaluated and compared between the three facilities. Results showed that for gross effects on performance indicators, aspects of lateral position control in the laboratory test gave a sufficient first indication of sizeable influence as soon as visual attention was diverted towards the secondary task. More subtle differences between levels of visual search difficulty were only found in the simulator and in the field. One main purpose of the EU project HASTE, which was the context of the present study, is to produce guidelines for and assess the suitability of each of the test environments for testing the effects of In-Vehicle-Information-Systems on driving performance.

## 1. Introduction

From a driving behaviour research perspective, field studies with instrumented vehicles are often regarded as the ultimate validation stage for assessing behavioural models, safety measures and new designs of road infrastructure or vehicle equipment. However, ethical as well as technical constraints restrict the margin of studies in the “real world”. For example, participants must be protected from hazardous traffic conflicts, the surrounding traffic cannot be controlled, while recording, synchronizing and analysing relevant data from the driver, the vehicle and the traffic environment simultaneously is a hard and often time consuming task. Therefore, driving simulators are usually considered much more convenient and purposeful research tools. Simulators allow the design of experiments with high-risk traffic scenarios where specific chains of events are easily created and repeated and can be equivalent for all participants in the experiment. In addition, almost any kind of road environment can be presented with this tool, while data acquisition is usually complete and straightforward. However, driving simulators vary considerably in sophistication (and cost), while the validity and reliability of driving behaviour data gathered from simulators are common concerns to the research community (Farber, 1999, De Waard, Van der Hulst, Hoedemaeker & Brookhuis, 1999). A widely accepted way to classify simulators is as low, medium and high cost systems (Weir & Clark, 1995). These vary from simple single screen, PC-based laboratory instruments, to advanced graphics, wide-screen, fixed-based mock-ups to a moving base version of the latter that is only affordable for a happy few research institutes.

This paper reports some results from the EU funded FP5 project HASTE, which provided an excellent opportunity to evaluate and compare the power of driving behaviour research tools in three different settings. A number of experiments were carried out in laboratory simulator, advanced simulators and instrumented vehicles. The project’s goals and methodological standards set the stage for a comparative study into the opportunities and limits of the three types of research facilities with respect to studies of existing and newly developed electronic driving aid systems.

Firstly, HASTE was focused on providing guidelines to assess the safety of in-vehicle information systems (IVIS). A standard workload design was implemented in a range of test sites, to investigate the interaction between primary (driving) and secondary (in-vehicle) tasks. One objective of this project was to find out if relatively simple commodity hardware, easily accessible for any IVIS manufacturer, could be used at least for preliminary safety evaluations of in-vehicle information provision prototypes. Such an approach would allow an early inclusion of safety aspects in the design process of an IVIS, while more sophisticated and expensive tests with simulators and instrumented vehicles could be postponed to later stages.

Secondly, a high degree of methodological standardization was achieved by the HASTE consortium, including specifications of road layout, traffic behaviour, as well as precise arrangement of tasks and procedures. This in turn allowed exact matching of empirical data gathered from laboratory tools, simulators and instrumented vehicles with quite disparate levels of technological sophistication. Needless to say that such an approach is likely to provide relevant cues to the management and cost-efficiency assessment of road traffic research facilities.

What are the requirements of a realistic driving simulator, i.e. what technical specifications should such a research tool have in order to be flexible on the one hand while preserving critical dimensions of real traffic scenarios on the other? Even if the scope is narrowed down to very specific research goals and tasks, the answer to this question is far from being trivial and even a technically geared researcher will soon become overloaded with details on angles of the visual field, spatial and temporal resolutions, feedback parameters of the driving interfaces, dynamic variables of the virtual vehicle, etc. Nevertheless, the interest in virtual reality, augmented reality and immersive systems in general is still growing. These systems may be applied in domains such as military training, remote operations in hazardous environments, safety and design assessment, entertainment, e-learning, and psychotherapy. A short review of the research on immersive systems highlights the keys issues related to the specifications of driving surrogate systems and might help the interpretation of some apparently surprising results in the present comparative study.

The strength of immersive systems is often associated with the popular but controversial concept of the “feeling of presence”, i.e., the feeling of being in and part of the environment created by the computer system (Kalawsky, Bee & Nee, 1999). This concept was used for the first time in the field of teleoperations, to designate the operator’s subjective sensation of being in the remote environment of the robot he was controlling, instead of being in his own physical and near environment (Steuer, 1992, Witmer & Singer, 1998, Schuemie, Straaten, Krijn & Mast, 2001). To accomplish this feeling of presence, the user must be involved in the virtual environment and tasks, up to the point of becoming unaware of the mediating technology (Lombard, 2002).

Promoting the feeling of presence by developing increasingly immersive systems would be the ultimate goal (Schuemie et al., 2001). To achieve this goal, stimulation channels of the visual, auditory, tactile, and proprioceptive kind should be as redundant and consistent as possible (Held & Durlach, 1992; Kalawsky, 2000). The visual realism (spatial resolution, deep cues) is also a key factor (Dillon, Keogh, Freeman & Davidoff, 2001), while the feeling of presence would be greater with a wider field of view, i.e. the periphery should be covered by the display system (Witmer & Singer, 1998). The latency or delay between the action of the user and the response of the system should be kept to a minimum and changes in the virtual environment must be smooth by means of anti-aliasing filtering (Freeman, Lessiter & IJsselsteijn, 2001). Finally, the availability of virtual actors to allow the user to interact also promotes the immersive effects (Welch, Blackmon, Liu, Mellers & Stark, 1996).

In short, according to the research of the last decade on virtual systems, one would be tempted to define a demanding list of specifications for a driving simulator. A simulator should include a real vehicle on a sophisticated dynamic platform, surrounded by a very large display system with high spatial and temporal resolutions, a virtual environment fulfilled with autonomous road users and, all these criteria should be accomplished with a very responsive interface and no noticeable delays.

The key question is whether a powerful and high cost simulator as specified, provides empirical data almost as reliable and valid as if the user was driving in the real world? The relationship between the feeling of presence and the performance in a virtual world is a common belief. However, it should be stressed that such an interaction is not obvious nor is it a simple causal relationship (Singer, Ehrlich, Cinq-Mars and Papim, 1995). In fact, even opposite effects have been shown (Ellis, 1996). These authors showed that as soon as redundant information from displays of air traffic control displays was removed, thus reducing the feeling of presence, a decrease in performance of the system operators was found. Therefore, choosing a particular simulator setup should be based on a tentative evaluation of the research goals, the nature of the driving tasks and the expected behavioural outputs. For example, if a high degree of ecological validity is aimed for, then the “physical correspondence” (Blaauw, 1982) between driving performance in the simulator and the real world should be a first priority. This in turn will narrow the choice to high cost systems, which is certainly the case whenever absolute driving performance measures are a goal by their own. However, if the aim is to obtain consistent results, for instance, with relatively obvious performance measures, e.g., on driving impairment by a secondary task, then a low to medium cost system should be adequate.

## 2. Method

Before comparing the results from the three methodologies, cross cultural differences in driving ability and S-IVIS performance were examined in an experiment using British and Portuguese subjects. For this study, 24 Portuguese and 24 British participants performed the experiments in the laboratory context at the University of Minho (see below for a description of this site). All the specifications and conditions of the Minho laboratory site were maintained in the cross-cultural laboratory study. Although some differences in the driving performance were found between the two samples, the effects of the secondary task were manifested in a similar way above the primary task.

### 2.1. Experimental tools

*Laboratory*

The laboratory experiments were performed in the low cost, laboratory driving simulator (DriS) of the Faculty of Engineering of the University of Porto (see Figure 1). The main core of DriS ran on a SGI Onyx Reality Engine 2 graphical workstation. This workstation held the scene database, and performed the simulation and the computer graphics tasks. In these experiments, the driver saw the image in a 21” monitor at a distance of 80 cm. The horizontal visual angle under these conditions was of 27°. Experiments were performed with a spatial resolution of 1280x1024, and a temporal resolution of 18 frames per second. The driver interface was composed of a low cost kit of steering-wheel and pedals (brake and accelerator). Audio and dynamic feedbacks were not provided in these experiments. All the experimental work was recorded by a video camera.

FIGURE 1 ABOUT HERE

*Simulator*

The Leeds Driving Simulator was used for this study. The simulator has no motion system and is based on a complete Rover 216GTi, with all of its driver controls and dashboard instrumentation still fully operational. A real-time, fully textured and anti-aliased, 3-D graphical scene of the virtual world is projected on a 2.5 m radius cylindrical screen in front of the driver. This scene is generated by a SGI Onyx2® Infinite Reality2 graphical workstation. A Roland digital sound sampler creates realistic sounds of engine and other noises via two speakers mounted close to each forward road wheel. The projection system consists of five forward channels, the front three at a resolution of 1280 x 1024 pixels. The images are edge-blended to provide a near seamless total image, and along with two peripheral channels (640 x 480 each), the total horizontal field of view is 230°. The vertical field of view is 39°. A rear view (60°) is back projected onto a screen behind the car to provide an image seen through the vehicle's rear view mirror. For this study, the frame rate was fixed to a constant 60Hz. Although the simulator is fixed-base, torque feedback at the steering wheel is provided via a motor fixed at the end of the steering column and a vacuum motor provides the brake pedal booster assistance. Data are collected at the frame rate.

### *Instrumented vehicle*

The instrumented vehicle of the Department of Psychology, University of Groningen was used for this experiment. This car, a Renault 19, was equipped with dual controls for the test leader to take over control in case of emergency and a computer operated by the experimenter that sampled driving speed and steering wheel position at 10 Hz. The car was also equipped with four video cameras, one directed at the driver’s face, one registering the front view and one the rear view, and one camera pointed at the right hand (edge) line.

## 2.2. Participants

### *Laboratory*

Participants were selected with reference to the following criteria: aged between 23 and 50 years, driving license held for at least five years and at least 10,000 km driven per year.

Two groups of 24 Portuguese participants took part in the laboratory study. Visual and auditory screening was applied to each participant, and results from these tests were used to distribute the participants among the visual and auditory secondary tasks.

### *Simulator*

Twenty-four drivers (12 male, 12 female), aged between 25 and 50 years old (Mean = 31.7 years, SD = 7.2) participated in this experiment. All drivers had at least five years' driving experience and drove an average of 10,000 km per year.

### *Field*

Twenty-four volunteers participated in the field study: 19 (79%) were male, 5 (21%) female. Their average age was 40 years (SD = 13) and all had at least five years' driving experience. All volunteers drove at least 10,000 km per year.

## 2.3. Driving Environment

The laboratory and simulator studies included two sections of rural road, each of which consisted of two 3.65m wide lanes, one in each direction, with no verge or shoulder to the lane. Each rural road section consisted of three levels of driving difficulty, separated by sections of 'filler' road. The layout of these two sections was exactly the same, although, in order to avoid a learning effect, the scenarios implemented were slightly different in visual appearance. The speed limit was 90 km/h and each road had a total length just over 29 km.

The field test rides were performed in the North of the Netherlands in and around the village of Haren (south of Groningen). The route included an eight km rural section, with a speed limit of 80 km/h. Completion of one test ride took around 30 minutes.

### 2.4. Secondary task

The secondary task employed in these studies was the Arrows task, a visual surrogate in-vehicle information system (S-IVIS, for further details of this task and the driving environment, see Jamson and Merat, this issue).

### 2.5. Design and Procedure

All participants were submitted to a learning period of driving and secondary task completion. They were instructed to attend to the road speed limit and to drive naturally. All experiments included two drives, one with the secondary IVIS task ("experimental"), and one with only the driving task ("baseline"). A static version of the S-IVIS (i.e. no driving) was also performed. The order of drives and static S-IVIS was counterbalanced across subjects at each site.

During each drive, subjects were asked to rate their driving performance following completion of a particular driving scenario (with or without secondary task). Driving was rated on scale of 1 (I drove very badly) to 10 (I drove very well).

The variables of the study were (i) level of difficulty for the secondary task (4 - baseline and levels 1, 2 and 3) and (ii) the test methodology (3 - laboratory, simulator and field study). Several measures were collected in the laboratory and simulator allowing a comparison between them. These measures can be grouped by two general driving performance variables: longitudinal and lateral control measures. In the field study, speed related and limited lateral control measures were obtained.

## 3. Results

The analyses examined differences between each of the three methodologies: laboratory, simulator and field. Several repeated measures analyses were carried out using ANOVA. For the between-subjects analysis, a 4 (S-IVIS difficulty level) x 3 (methodology) design was used. An aggregation of the data of the three methodologies allowed the identification of the sensible measures to the S-IVIS effects and the interaction effects between the S-IVIS and methodology factors.

### 3.1. Self reported driving performance

S-IVIS effects and interaction effects between the different methodologies were found in the self-reported driving measure (F (67, 2.416) = 53.952, p < .01 and F (132, .686) = 7.550, p < .01, respectively). Post hoc tests showed a significant difference in self reported driving performance between the simulator and the field (Sidak = -1.02, p < .01, see Figure 2).

A significant decrease of the subjective rating was observed between baseline and S-IVIS level 1 and all the other difficulty levels in the simulator (F (21, 4.520) = 31.641, p < .01), and between baseline and all S-IVIS levels in the laboratory study (F (21, 1.652) = 11.563, p < .01). In the field study, a decrease of the rating of self-performance was observed along the crescent complexity of the secondary task, with reliable differences between all the S-IVIS levels (F (21, 3.226) = 22.584, p < .01).

FIGURE 2 ABOUT HERE

### 3.2. Longitudinal control measures

In absolute terms, the differences between mean speed were found to be reliable between simulator (t (46) = -3.998, p < .01) and laboratory, and simulator and field (t (46) = -5.123, p < .01) – the lowest values for mean speed were obtained in the simulator study.

For speed variation, the highest levels were found in the laboratory study, with reliable differences from simulator (t (46) = -1.045, p < .01) and field (t (46) = 15.110, p < .01) results.

S-IVIS effects were found in mean speed and standard deviation of speed. These effects were seen in all three methodologies, but the direction of these effects varied between the difficulty levels of the task (F (67, .332) = 7.416, p < .01 for mean speed and F (67, .272) = 6.078, p < .01 for standard deviation of speed). Post hoc Sidak tests showed a reliable difference in mean speed between the simulator and the field (Sidak = -9.88, p < .01) and between simulator and laboratory (Sidak = -11.51, 573392, p < .01).

As can be observed in Figure 3, for mean speed, the results in the simulator showed a reliable decrease between baseline and difficulty levels 1, 2 and 3, and the same was observed between levels 1 to 3 (F (21, .899) = 6.290, p < .01). For standard deviation of speed a significant increase was observed between level 3 and all the other S-IVIS difficulty levels (F (21, 1.057) = 7.396, p < .01).

FIGURE 3 ABOUT HERE

In the laboratory, a reliable increase of mean speed was observed between levels 2 and 3 (F (21, .372) = 2.602, p < .05). Standard deviation of speed was found to increase significantly between baseline and difficulty levels 1, 2 and 3 (F (21, .919) = 6.433, p < .01).

In the field, a reliable decrease of mean speed was seen between baseline and S-IVIS difficulty levels 1 and 3, as well as between levels 2 and 3 (F (21, .791) = 5.540, p < .01). For standard deviation of speed, no S-IVIS effects were found (F (21, .039) =. 275, n.s).

For mean distance headway (mn_hwd) main effects of S-IVIS were found in the laboratory and simulator (F (44, 1.385) = 20.317, p < .01). In the simulator, a reliable increase between baseline and the three difficulty levels 1, 2 and 3 was observed (F (21, 2.458) = 17.209, p < .01); while in the laboratory study this increase was significant from baseline to S-IVIS level 3 only (F (21, .386) = 2.700, p < .01). Significant effects of the S-IVIS on all other distance headway related measures were only observed in the simulator. An increase in the variation of distance headway between baseline and levels 1, 2 and 3 can be observed in Figure 4 (F (21, 1.900) = 13.302, p < .01). Results showed a similar pattern for minimum distance headway measures in the simulator (F (21, .753) = 5.270, p < .01).

FIGURE 4 ABOUT HERE

### 3.3. Lateral control measures

Main effects of S-IVIS were found in lateral position related measures (F (44, .278) = 4.078, p < .05). In the laboratory study, an increase in mean lateral position was observed between baseline and S-IVIS levels 1, 2 and 3 (F (21, .479) = 3.350, p < .05). For lateral position variation, a significant increase from baseline to the other difficulty levels was observed in both the laboratory and the simulator, as can be seen in Figure 5 (F (21, .996) = 6.973, p < .01 and F (21, 1.029) = 7.203, p < .01, for laboratory and simulator respectively). In the simulator, this effect could be also observed from the level 1 to levels 2 and 3.

FIGURE 5 ABOUT HERE

In terms of percentage of lane exceedence (lanex) a main effect of S-IVIS was observed (F (44, .428) = 6.273, p < .01), but there was no interaction effects between the laboratory and simulator (F (44, .050) = .729, ns). For the simulator, an increase in lanex was verified between baseline and levels 1, 2 and 3 (F (21, .750) = 5.250, p < .01); while in the laboratory an increase was observed between baseline and levels 1 and 2 of S-IVIS difficulty (F (21, .428) = 2.994, p < .05), as can be seen in Figure 6.

FIGURE 6 ABOUT HERE

Although a main effect of S-IVIS was found for steering reversal rate (rr_st1), these differed between the laboratory and simulator, as indicated by interaction effects (F (44, .403) = 5.904, p < .01). In the simulator, there was an increase in the number of reverses of the steering wheel between the baseline and the levels 1, 2 and 3, and between the level 1 and 2 (F (21, 2.744) = 19.205, p < .01). In the laboratory, this same increase was observed between baseline and S-IVIS difficulty levels 1, 2 and 3 (F (21, 2.150) = 15.053, p < .01).

## 3.4. Secondary Task Performance

S-IVIS complexity level effects during driving were verified through response times, with the presence of interaction effects between the three methodologies (F (134, .925) = 15.491, p < .01). Post hoc tests showed a significant difference in this measures between the three methodologies (Sidak = -.44, p < .01 between simulator and laboratory, Sidak = -.41, p < .01 between simulator and field and Sidak = -.85, p < .01 between laboratory and field). In the simulator, an increase in response time between baseline and levels 1, 2 and 3 was observed (F (22, 2.811) = 30.916, p < .01). The same result was verified for the field study (F (22, 7.980) = 87.780, p < .01). In the laboratory, reliable differences were observed between level 2 and the other two levels of S-IVIS complexity (F (22, .017) = .187, ns).

As shown in Figure 7, response time for the visual S-IVIS task showed a crescent tendency from field to simulator, and then to laboratory. This ranking may be related to the different workload of driving task of for each methodology, and consequently, to the different ways of dealing with simultaneous tasks.

FIGURE 7 ABOUT HERE

# Discussion and conclusions

A few words of caution on the scope of this paper and the generalization of conclusions are in order. The laboratory and simulator studies were carried out within a carefully planned and controlled framework. These studies were more guided by the general experimental standards in fundamental research than the weaker approach found in applied field studies, usually based on balancing and randomising techniques. Needless to say, that the experimental approach had a major role on the robustness of the data. However, all studies were concerned with a specific issue: safety of in-vehicle information systems, within particular road scenarios and events. Given the enormous variability inherent to road traffic scenarios, generalizations from our results to the real world should be considered with caution.

In all three research settings, clear differences were found between baseline conditions and secondary task conditions, with most of the performance parameters. However, differences in task load within the standardised visual attention task were not reflected in the laboratory driving performance. Apparently, the simple laboratory simulator set-up suffices to indicate that an IVIS affects driving performance tentatively, but is not able to give an index for the level of difficulty, i.e. the seriousness of potential effect with respect to traffic safety. This notion is supported by the self-report data indicating that the participants themselves clearly felt a performance decrement in the simulator and instrumented vehicle.

A striking result is the similarity in defensive reactions in all three settings. As soon as participants in any of the settings became aware of driving performance deterioration as a consequence of the secondary task, they chose to adapt their behaviour (see also, Brookhuis, De Waard & Fairclough, 2003). The adoption of lower (i.e. safer) speed, smaller distance to the road shoulder, and a longer margin towards vehicles in front was particularly clear in the simulator and field.

Finally, the comparison of the three research settings contributed to the purpose of the HASTE project in the sense that indeed a simple, low-cost laboratory simulator set-up is able to provide a first-shot test-facility to the automotive industry for assessing the impact of an IVIS under design or development. For more detailed analyses of the nature and seriousness of the influence of IVIS-type systems, a (medium cost) simulator is indicated, whereas some of the earlier established problems with field studies in an instrumented vehicle have been confirmed.

## References

Blaauw, G. J. (1982). Driving experience and task demands in simulator and instrumented car: a validation study. *Human Factors 24* (4), 473-486.

Brookhuis, K.A., De Waard, D., Fairclough, S.H. (2003). Criteria for driver impairment. *Ergonomics, 46,* 433-445.

De Waard, D., Van der Hulst, M., Hoedemaeker, M., & Brookhuis, K.A. (1999). Reply to comments on "Driver behavior in an emergency situation in the Automated Highway System". *Transportation Human Factors, 1*, 87-89.

Dillon, C., Keogh, E., Freeman, J., & Davidoff, J. B. (2001). *Presence: is your heart in it?* Paper presented at The 4th Annual International Workshop on Presence, Philadelphia.

Ellis, S. R. (1996). Presence of mind: A reaction to Thomas Sheridan's further musings on the psychophysics of presence. *Presence: Teleoperators and Virtual Environments, 5*, 247-259.

Farber, E.I. (1999). Comments on "Driver behavior in an emergency situation in the Automated Highway System". *Transportation Human Factors*, *1*, 83-86

Freeman, J., Lessiter, J., & IJsselsteijn, W. A. (2001). An introduction to presence: A sense of being there in a mediated environment. *The Psychologist, 14*, 190-194.

Held, R. M., & Durlach, N. I. (1992). Telepresence. *Presence: Teleoperators and Virtual Environments, 1*(1), 109-112.

Kalawsky, R. S. (2000). *The validity of presence as a reliable human performance metric immersive environments.* Paper presented at the Presence 2000 - 3rd International Workshop on Presence, Delft, The Netherlands.

Kalawsky, R. S., Bee, S. T., & Nee, S. P. (1999). Human factors evaluation techniques to aid understanding of virtual interfaces. *BT Technology Journal*, *17*(1), 128-141.

Lombard, M. A. (2002). *Resources for the study of presence: presence explication,* from http://www.temple.edu/mmc/ ispr/explicat.htm

Schuemie, M. J., Straaten, P., Krijn, M., & Mast, C. A. (2001). Research on presence in VR: a survey. *Cyberpsychology and Behavior, 4*, 183-201.

Singer, M. J., Ehrlich, J., Cinq-Mars, S., & Papin, J. (1995). *Task performance in virtual environments: stereoscopic vs. monoscopic displays and head-coupling* (No. tech. rep. 1034). Alexandria, VA: US. Army Research Institute for the Behavioral and Social Science.

Steuer, J. S. (1992). Defining virtual reality: dimensions determining telepresence. *Journal of Communication, 4*(2), 73-93.

Weir, D. H. & Clark, A. J. (1995). A survey of mid-level driving simulators. *SAE* 950172.

Welch, R. B., Blackmon, T. T., Liu, A., Mellers, B. A., & Stark, L. W. (1996). The effects of pictorial realism, delay of visual feedback and observer interactivity on the subjective sense of presence. *Presence: Teleoperators and Virtual Environments, 5*, 263-273.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: a presence questionnaire. *Presence: Teleoperators and Virtual Environments, 7*(3), 225-240.

Figure 1 – The Minho Driving Simulator (DriS)

Figure 2 – Self reported driving performance (subj_r) for visual S-IVIS in simulator, laboratory and field.

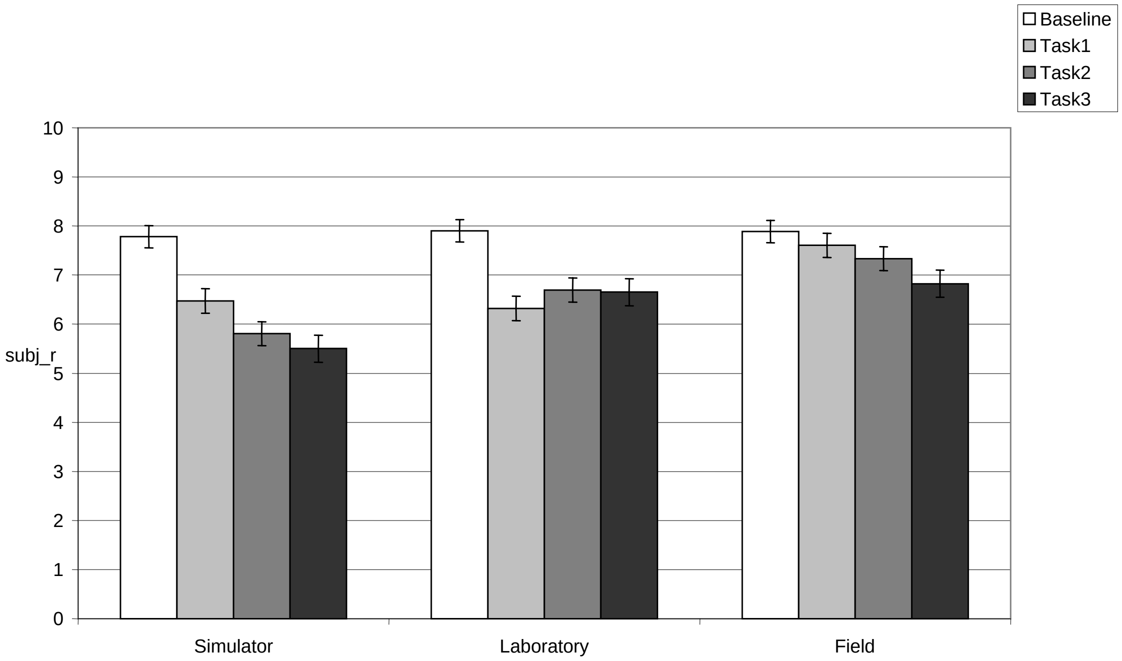

Figure 3 – Mean speed for visual S-IVIS on simulator, laboratory and field.

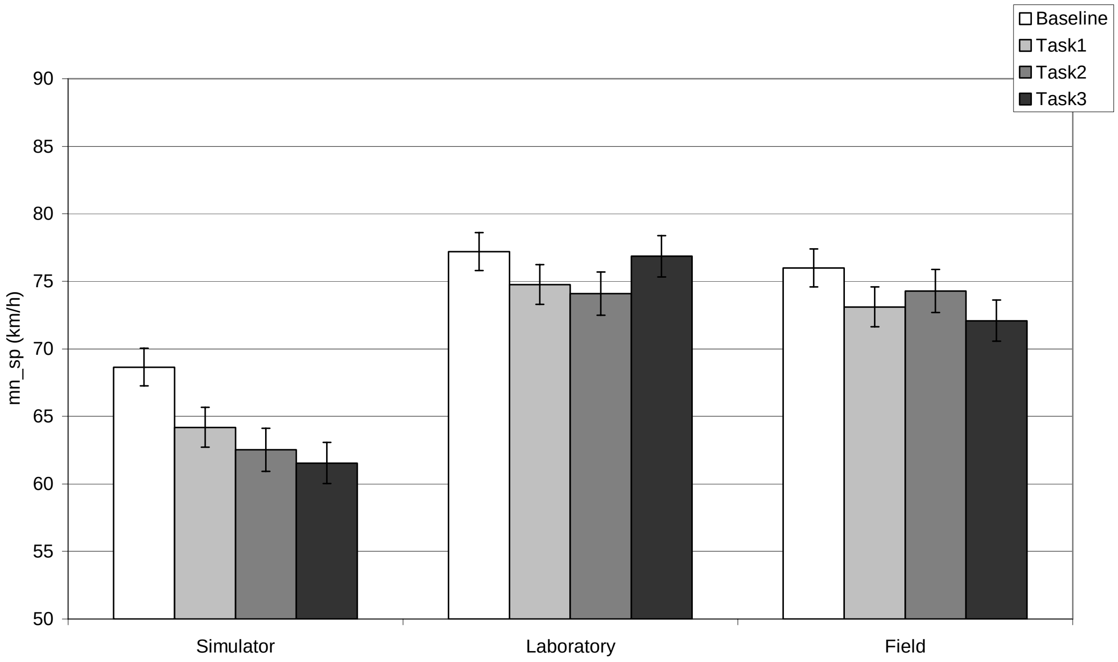

Figure 4 – Distance headway variation for visual S-IVIS on simulator and laboratory.

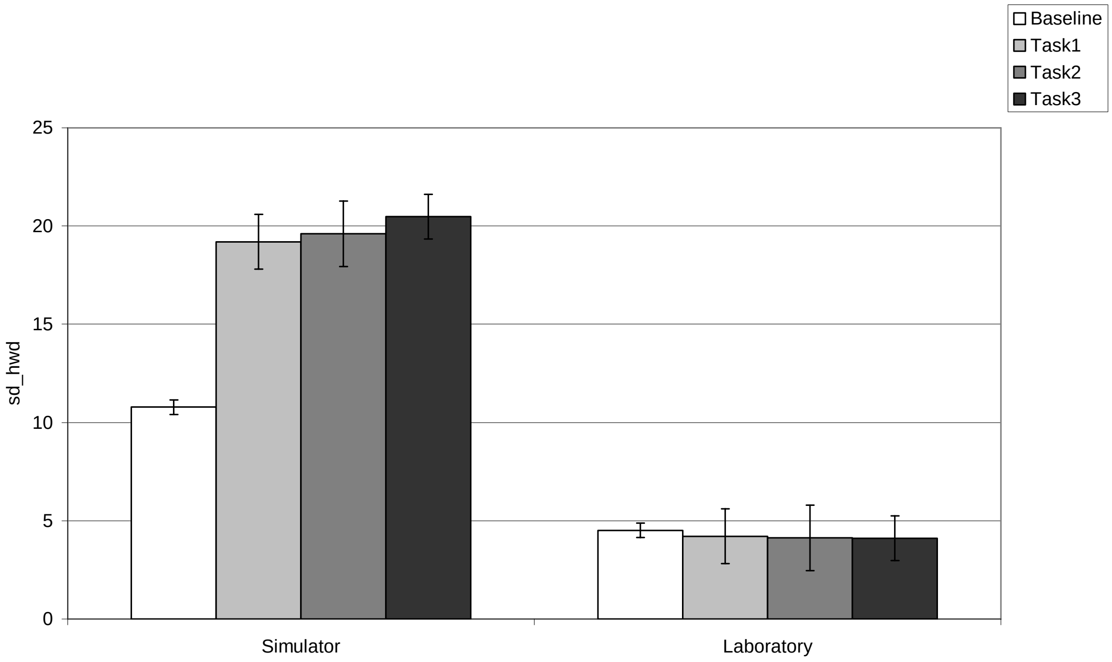

Figure 5 – Mean lateral position variation for visual S-IVIS in simulator and laboratory.

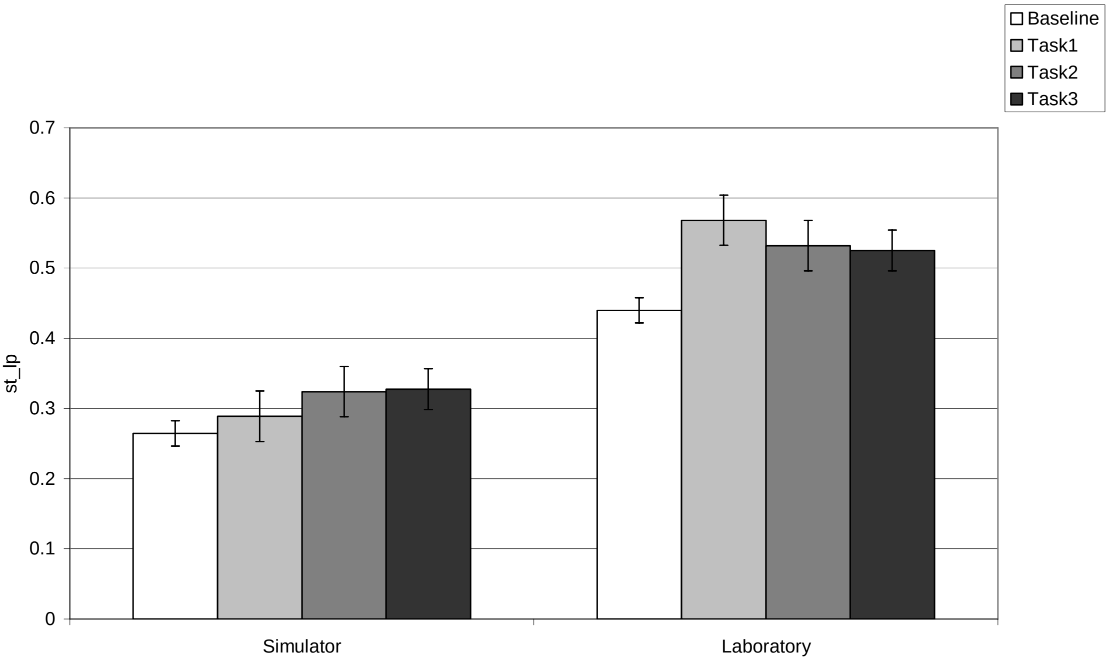

Figure 6 – Lanex for visual S-IVIS on simulator and laboratory

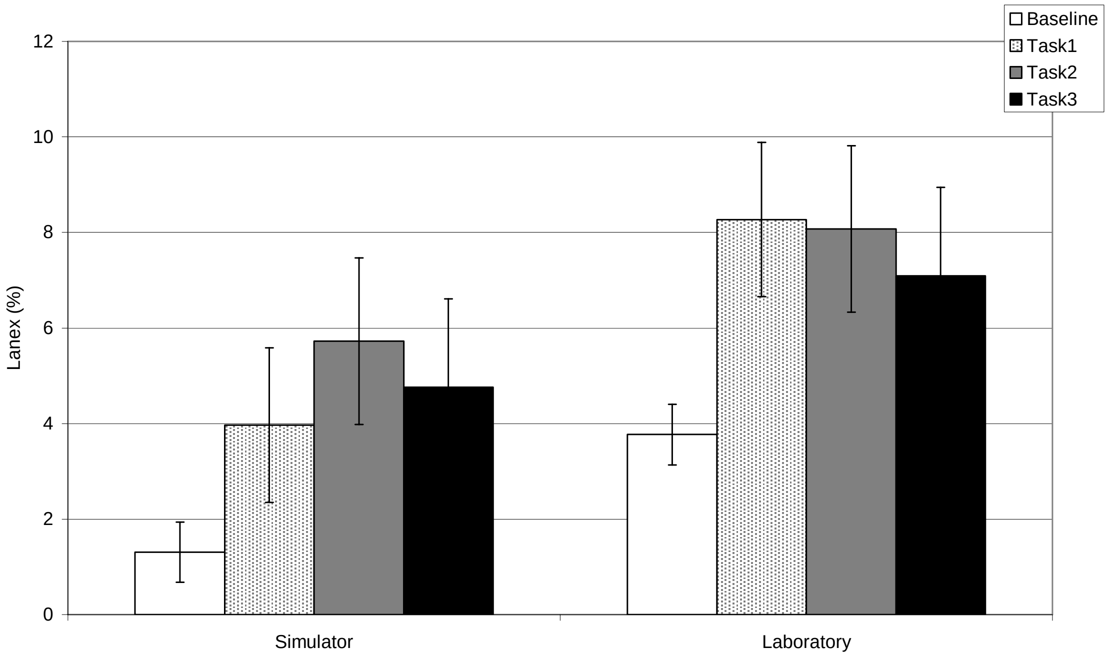

Figure 7 – Response time for visual S-IVIS in simulator, laboratory and field.