Driver interaction with different in-vehicle navigation system input devices: a validation study comparing simulation and on-road testing

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ABSTRACT

In-vehicle information systems are rapidly moving from novelty to becoming a common feature of both consumer and fleet vehicles. Driving simulation has been advanced as a method of evaluating the functional design, ergonomics, cognitive demands and safety of in-vehicle information system interfaces. Simulation is appealing since it provides a safe environment for conducting such testing. However, relatively little research has addressed the extent to which interactions with in-vehicle information systems in the simulator provides an accurate model of behavior in the real world. In this study, we assess the validity of driving simulation for assessing the demands of various methods of interacting with in-vehicle systems. A surrogate destination entry task was developed based upon a typical interaction with modern text messaging system. In our surrogate task, we required drivers to enter the first two letters of a road name, city, and state with the system automatically completing the remainder of the entry. Three interfaces were evaluated: two parallel-mapping methodologies used by various automobile manufacturers (touch screen and distributed rotational controller) and a third based upon a cellular phone keypad. Results from an overall study were compared with those obtained from a criterion single screen driving simulator to assess the validity of measures of visual attention, driving performance, and task performance. Two independent sets of participants took part in the study, S1 in the driving simulator and S2 in the field study. Participants were between the ages of 22 and 28. During the destination entry task, mean visual attention measures and destination entry task performance indices, such as glance frequency, total glance duration, and mean task response time, mapped almost identically from simulation to field. The driving performance measures, including standard deviation of velocity and lateral offset, appeared somewhat less consistent for discriminating between devices; however, there were no meaningful differences between the two experimental conditions except for mean standard deviation of lane position in simulation vs. on-road. In conclusion, we found that visual attention, task performance and impact on driving performance mapped well between simulation and the field. In conclusion, fixed-based driving simulation appears to be a very effective method of evaluating task interaction, performance, and modeling of field behavior of in-vehicle device interfaces.

RESULTS

Apparatus

1. Test vehicle: MIT AgeLab “Aurora Car” – a 2003 series Volvo SV-90 SUV instrumented vehicle with eye tracker, CAN (Controller Area Network), lane tracker and on-board computer.
2. Simulator: MIT AgeLab driving simulator “Miss Dior”, a fixed-base simulator comprised of a full scale 2001 Volkswagen Beetle running STDSim Build 2.1 (Stevens 2001).
3. Eye Tracking System: Seeing Machines FaceLab 4.2, with cameras mounted on both the test vehicle and the simulator.
4. Surrogate in-vehicle information systems (S-IVIS): three integrated input devices consisting of a NUMARIC 880-3SV touch screen, a USB number stick keypad, and a PC-based Griffin Technology USB scrolling wheel (drive). Destination Entry Task (DET)

Event timing: only the first two letters of each word were required.

Three destination entry tasks were carried out with each device.

Experimental Design

1. Independent variables
   - Device
   - Field vs. Simulator (between subject comparison).

2. Dependent variables
   - Visual attention: Glance Frequency, Total Glance Duration
   - Driving performance: Standard Deviation of Longitudinal Velocity, Standard Deviation of Lane Position

Data Analysis

General Linear Models with Repeated Measures (SPSS 11.5) with p < .05 used for establishing significance. A Bonferroni-Greenhouse correction was applied in cases where the assumption of sphericity was not met.

Analysis of Validity

CONCLUSION

In conclusion, fixed-based driving simulation is a safe method of assessing task interaction and performance that provides valid estimates of on-road behavior for the type of in-vehicle interface the interaction examined in this study. Visual attention and task response time measures derived from the simulation appear particularly promising for modeling field behavior.

• Both relative and absolute validity hold for the visual attention measures.
• Both relative and absolute validity hold for the standard deviation of velocity measures of driving performance; relative validity is evident for standard deviation of lane position.
• Both relative and absolute validity holds for the mean destination entry task response time; relative validity is evident for the mean destination entry task duration while absolute validity is impacted due to slight but concurrently higher task durations in the simulator. It could be argued that for purposes of comparing devices, a perfect, if not absolute validity, was established for task duration.

Participants

62 subjects between the ages of 22-28 were enrolled in the two independent samples. One simulator subject and 3 field subjects were dropped from analysis due to technical difficulties in the simulation and three in the field sample and 30 in the simulator sample. Gender representation was relatively balanced in each group.

Subjects were required to hold a valid driver’s license for at least 5 years, a clean driving record for the previous year, and no prior experience in a driving simulation study. Subjects also were required to have no neurological problems. The risk of a mental disorder or a major medical condition such as cancer, or be on medication for hypertension, has no medication that causes disinclination, and not require prescription glasses to drive.

Attempts were made to match subject age, gender and driving experience as closely as possible.

In this study, a surrogate destination entry task was used to test the validity of simulated driving in assessing the demands of various methods of interacting with in-vehicle systems.

In summary, we found that visual attention, task performance and impact on driving performance mapped well between simulation and the field. In conclusion, fixed-based driving simulation appears to be a very effective method of evaluating task interaction, performance, and modeling of field behavior of in-vehicle device interfaces.