

DRIVER REACTION TIME IN CRASH AVOIDANCE RESEARCH: VALIDATION OF A DRIVING SIMULATOR STUDY ON A TEST TRACK

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A series of experiments was conducted on the Iowa Driving Simulator to examine driver reaction and performance in an intersection incursion crash scenario. To validate these simulator trials, a second study was run on a test track using a similar intersection incursion scenario to examine driver reaction and vehicle performance. Results showed that there was statistical equivalence between important driver reaction times with both studies.

INTRODUCTION

Validating data from driving simulator studies is important to any research program that intends to carry forward conclusions based on the data collected. Direct validation is often difficult as driving simulators frequently are used to put drivers in conditions too dangerous to test on-road. This is particularly the case when it comes to conducting crash avoidance research. While numerous crash avoidance studies have been conducted both in simulators and on-road (Broen and Chaing (1996); Lerner et al (1993); McGehee et al 1997, 1998; Lee et al (1998)), no crash avoidance simulator studies have been designed with a specific validation study on-road.

This study was designed so that an unexpected intersection incursion scenario could be safely implemented on a test track. Comparisons were made between primary reaction times across both simulator and test track studies.

The overall purpose of this study was to increase the body of scientific data on driver behavior and performance using Antilock Brake Systems (ABS) and conventional brakes. The goal was to determine the cause(s) of the apparent increase in single-vehicle run-off-road crashes and the decrease in multi-vehicle on-road crashes as vehicles transition from conventional brakes to ABS. As part of this program, the National Highway Traffic Safety Administration (NHTSA) conducted research examining driver crash avoidance behavior and the effects of ABS on drivers' ability to avoid a collision in a crash-imminent situation.

METHODS

Experiment 1: Iowa Driving Simulator

The first study was conducted at the University of Iowa on the Iowa Driving Simulator (IDS). The IDS uses four multi-synch projectors to create a 190-degree forward field-of-view and a 60-degree rear-view. The IDS is comprised of a 1993 Saturn mounted inside a dome on top of a six-degree-of-freedom motion base.

Sixty females and 60 males between the ages of 25 and 55 participated in this study. The study used a 2x2x2x2 experimental design. The between-subjects factors were brake type (ABS or conventional), speed limit (45 or 55 mph), time to intersection (TTI) (2.5 or 3.0 seconds), and instruction (ABS-specific or safety-only video).

To help ensure that subjects would not anticipate the intersection-incursion event, participants were informed that they would be driving for approximately 30 minutes. Subjects were told that their task was to assess the look and feel of the simulator, and that they would be given a questionnaire to collect their impressions after their drive. In actuality, the drive was approximately 15 minutes in length on a rural two-lane highway, ending with the intersection-incursion.

Experiment 2 : Test Track

This study involved 192 subjects between 25 and 55 years of age. Gender was balanced per condition. The study used a 2x2x2x2x2 experimental design. The between-subjects factors included type of brake system, ABS brake pedal feedback level, ABS instruction, braking practice, time-to-intersection, and vehicle.

The actual test drive took approximately 15 minutes and required each subject to complete 3.5 laps of a large, two-lane “figure 8” course at 45 mph on dry pavement. Subjects followed a confederate vehicle and were asked to maintain a headway of two seconds (as indicated on a dashboard display). Each lap contained an intersection with real vehicles and drivers. On the last lap, a full size foam core photograph mock-up of a GM Saturn was substituted for one of the vehicles. As the subject passed over a tape switch on the pavement on the fourth lap, the foam core vehicle was propelled 6 feet into the subject's lane of travel by a cable hooked to another vehicle. The tape switch turned a light that cued a test driver to pull the incurring vehicle out in front of the subject.

RESULTS

The data analysis for the comparison was achieved by combining like factors between the two experiments. The results produced several important findings that indicate the test track and IDS driver performances were statistically equivalent (Snow et al, 1999).

Hypothesis testing is usually done to determine whether two groups are statistically different. The use of an ANOVA with non-significant results is not by itself strong enough to conclude there is no difference in driver reaction time. A 95th percentile confidence interval in addition to the ANOVA confirms the lack of difference in this case (Snow et al., 1999).

Overall brake reaction and time to initial steering input were compared between the two studies. In addition, we examined the maximum lateral and longitudinal acceleration of both the IDS and the instrumented vehicle used in the test track study. Table 1 presents the means and

standard deviations between the IDS and test track studies. Confidence intervals at the 95th percentile also confirmed that these results were equivalent.

	IDS	Test Track
Initial Accel Release	0.96 sec. 0.21 SD	1.28 sec. 0.29 SD
Total Brake RT (to max brake)	2.2 sec. SD 0.44	2.3 sec. SD 0.46
Time to Initial Steering	1.64 sec. SD 0.49	1.67 sec. SD 0.46

Table 1. Means and standard deviations of primary dependent measures

As can be seen in Figures 1 and 2, total brake reaction time (defined as the period between the point at which the driver began to release the accelerator pedal up to the maximum brake application point) was 2.2 seconds for the IDS and 2.3 seconds on the test track. Time to initial steering (defined as the point at which the driver first began to use steering to avoid the crash) was 1.64 seconds on the IDS and 1.67 seconds on the test track.

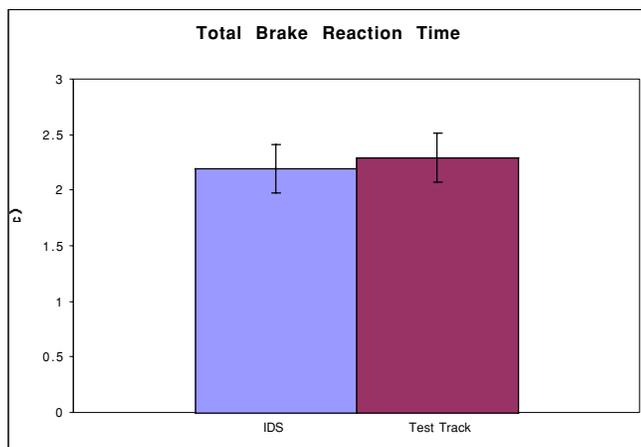


Figure 1. Mean total brake reaction time between IDS and test track

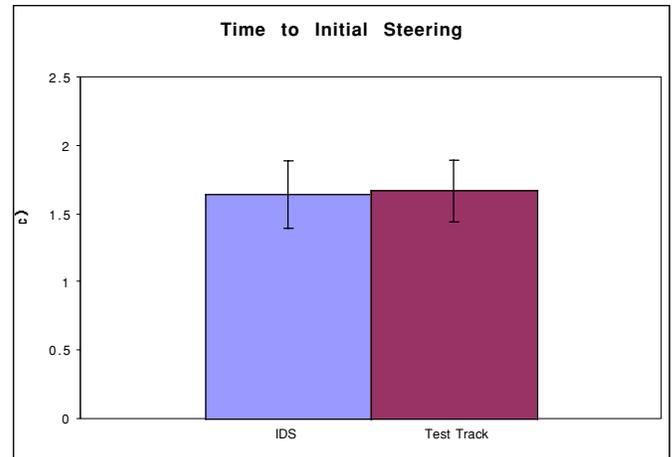


Figure 2. Mean time to initial steering between IDS and test track

Time to throttle release was also compared between the two studies. Mean time from incursion start to throttle release was 0.96 seconds for the IDS study and 1.28 seconds for the test track study. These results were not statistically equivalent. However, a number of methodological differences between the two studies may explain this difference. First, subjects in the test track study saw the intersection with the incursion vehicle in place three times prior to the actual incursion on their fourth lap. Thus, it is reasonable that subjects in the test track study would respond later due to the fact that in their prior three passes through the intersection, the car on the intersecting roadway had not moved. Second, subjects in the test track study were given the secondary task of monitoring a visual display to maintain a certain headway to a forward vehicle. Subjects in the IDS study had no secondary task. Finally, since the time from incursion start to throttle release included the reaction time of the tow vehicle driver pulling the foam car (which was consistently less than 200 milliseconds), this could have caused an increase in the values for the test track study.

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These differences may have affected the time it took subjects to realize the threat presented by the incursion vehicle. If you assume that release of the throttle indicated the time at which subjects perceived a threat that required intervention, then dependent measures which address the subjects' reactions subsequent to throttle release should be comparable between the two studies. In other words, these methodological differences would affect their time-to-throttle release, but should not affect the timing of their response subsequent to their perception of the threat. In addition, these reactions subsequent to throttle release are those considered to be more functionally important for this type of crash avoidance scenario than time-to-throttle release.

In addition to reaction time measures, lateral and longitudinal acceleration was also examined. Maximum lateral acceleration was 1.24 g on the IDS and 1.17 g on the test track; maximum longitudinal acceleration was 0.65 g on the test track and 0.8 g on the IDS.

DISCUSSION

As simulators become more commonplace because of reduced cost and increased fidelity, results such as these have important implications for how crash avoidance data can be used toward the design of crash avoidance systems. Driver reaction time is one of the most important measurement components in crash avoidance research. Driver reaction time data can then be incorporated into baseline crash avoidance algorithms. Based on the measures examined in this paper, such baseline data can be brought forward to prototype form for true field-testing.

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References

- Broen, N. and Chaing, D. (1996). Braking response time for 100 drivers in the avoidance of an unexpected obstacle as measured in a driving simulator. Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting, pp. 900-904.
- Lechner, D., & Malaterre, G. (1991). Emergency maneuver experimentation using a driving simulator (SAE Report No 910016). Presented at Autotechnologies 5th Conference and Exposition, Monte Carlo, Monaco.
- Lee, J., D.V. McGehee, T.A. Dingus, and T. Wilson (1998). Collision avoidance behavior of unalerted drivers' using a front-to-rear-end collision warning display on the Iowa Driving Simulator. Transportation Research Record. National Research Council.
- Lerner, N.D. (1993). Brake Reaction Times of Older and Younger Drivers. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting.
- McGehee, D. V., Brown, T. Wilson, T. B., & Burns, M. (1998). *Examination of driver's collision avoidance behavior in a lead vehicle stopped scenario using a front-to-rear-end collision warning system*. NHTSA Tech. Report.
- Snow, M.P., Reising, J.M., Barry, TP and Hartstock, D.C. (1999). Comparing New Design with Baselines. Ergonomics in Design. October 1999; pp 28-33).