DRIVING PERFORMANCE OF NOVICE AND EXPERIENCED DRIVERS IN LANE-CHANGE SCENARIOS

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Using a virtual reality driving simulator, the behavior of 12 novice and 12 experienced drivers was recorded during three right-to-left lane-change scenarios. The first scenario had no vehicles in the left lane, the second had one rear-approaching vehicle in the left lane, and the third had three vehicles approaching from the rear left lane. Each lane-change maneuver was composed of 1) a preparatory period, 2) the actual steering initiative from the right lane to the left lane, and 3) a post-lane change period and was to be accomplished while maintaining a specified highway velocity. Lane deviation data showed that novice drivers had significantly more variance in lane position during the preparatory and post-lane change periods than experienced drivers. Novice drivers also spend significantly less time looking at the vehicle's speedometer and mirrors. This study suggests that virtual reality driving simulators may be useful in helping novice drivers acquire the skills necessary for safe lane change maneuvers.

INTRODUCTION

An important element in becoming a safe yet efficient "experienced" driver is to be able to master lane-change techniques. The process of making a roadway lane change requires major skill elements to be simultaneously undertaken and coordinated. These fundamental skills include scanning the vehicle's surroundings in the rear-view and side-view mirrors at appropriate times and controlling both the direction and speed of the vehicle. Recarte and Nunes (2000) studied the effects of verbal and spatial-imagery tasks on eye fixations while driving. They found that glance frequency to mirrors and to the speedometer decreased during the spatial-imagery tasks. These findings were also confirmed the research of Zheng, Tai, and McConkie (2003). This is of significance since adequate mirror-sampling activity is an essential component of safe driving when making lane changes.

Mourant and Rockwell (1972) found that novice drivers' frequency of mirror sampling was much less than that of experienced drivers. They hypothesized that skill in utilizing a vehicle's mirrors does not develop during the early stages of learning to drive. Mourant and Ge (1997) found that novice drivers (with little experience) tend to focus almost all of their visual attention on maintaining proper lane position, and had little "spare visual capacity" to use for mirror glances.

This study was designed to advance the understanding of the process of attaining driving skills when making lane changes, and to contribute to the content of driver training and education material (Allen, Park, Cook, & Rosenthal, 2003).

METHOD

The experiment was conducted using a fixed-base virtual reality driving simulator. The simulator configuration included the front half of a minivan equipped with adjustable seats, a steering wheel with force feedback, accelerator and brake pedals, original mirrors, two projectors (resolution 1024 x 768), and two screens (8' high x 7' wide). The speedometer was a functioning LED display located on the instrument panel in front of the driver. Potentiometers were attached to the accelerator and brake pedals and connected to the computer via a National Instruments PCI 1200 card.

The forward view (horizontal field of view of 57°) was projected onto the front screen. The rear view (horizontal field of view of 57°), with its software camera rotated 180 degrees, was projected onto the back screen. A modern graphics card with 128MB of memory resulted in frame rates of 60 per second.

The participants were 12 novice and 12 experienced drivers. The novice drivers ranged from 16 to 32 years of age (mean = 24.4 years) and had less than 5 hours of total real-world driving experience, with visual acuity of 20/30 or better (possibly corrected). The experienced drivers ranged from 21 to 45 years of age (mean = 30.4 years), had more than 5 years of driving experience, and had driven more than 5,000 miles in the past year, with visual acuity of 20/30 or better (possibly corrected).

A three-factor (2x3x3) factorial design was used in this study. The first factor (subject type) had two levels (novice and experienced). The second factor (scenario type) had three levels (no-cars, one-car approaching form the rear in the left lane, and three-cars approaching form the rear in the left lane). The third factor (maneuver periods) also had three levels (preparatory, during, and post-lane change intervals).

To screen for the minimum vision requirements, a preliminary vision test was conducted using a Snellen Eye Chart when a participant arrived at the laboratory. The experimenter then helped the subject adjust the mirrors and seat for comfortable driving posture and proper views of the mirrors. A practice run was conducted to familiarize subjects with the handling characteristics of the driving simulator. For the two data collection runs, a participant drove for approximately 4 minutes to complete the three lane-change scenarios. Immediately following the second run, each subject filled out a SSQ (Simulator Sickness Questionnaire) Post-Exposure Symptom Checklist to indicate how they were feeling subsequent to the simulator activities.

Three different roadway scenarios were designed and implemented in the test runs. In the first scenario (no car) no autonomous vehicles were present in the scene for the lane-change maneuver. The second scenario (one car) was configured with a single autonomous vehicle approaching from the rear in the left lane. The third scenario had three autonomous vehicles traveling in the left lane and approaching from the rear, without an adequate gap for the subject to insert between them. The subject's vehicle was traveling in the right-hand lane at the start of each run. The subject was instructed to drive straight forward following the road until a beep was sounded indicating that s/he should try to change to the left lane.

Depending upon the scenario, there would be times when the traffic in the left lane would make it unsafe to immediately initiate the requested lane-change maneuver. The subject was instructed to change lanes only after determining it was safe to do so. After a successful shift to the left lane, another beep indicated that the driver should change back to the right lane. Subjects were requested to maintain a velocity between 50–55 mph at all times.

RESULTS

ANOVA was used to determine if the main effects and any related interactions were statistically significant. The Scheffé method was used for post-hoc testing.

Throughout each of the driving tasks, measurements were taken on vehicle velocity and lane position. For changing from the right lane to the left lane, an ANOVA of lane position variance revealed a significant effect for subject type. The variance of novice drivers' lane position was significantly greater than that of experienced drivers during the pre-lane change period ($p < .01$, $F = 27.8$, $df = 1,22$) and the post-lane change period ($p < .025$, F=6.9, df= 1,22). This can be seen in Figure 1, entitled Lane Deviation During Right-to-Left Lane Change. Here, lane deviation is measured as the distance from the middle of the road (roadway center) to the driving vehicle in meters. Figure 1 also illustrates that the variance of novice drivers' lane position was significantly greater for the three-car scenario than for the no-car or single-car scenarios. Analysis of variance confirmed this ($p < .025$, F=3.8, df= 2, 36).

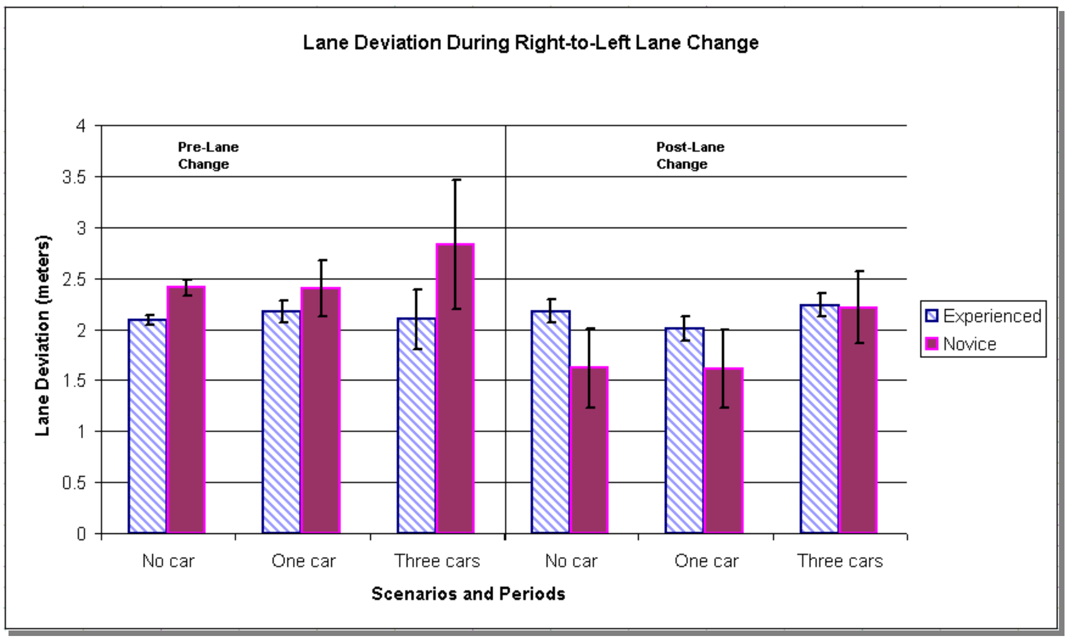

Figure 1. Lane deviation during the right-to-left lane change scenarios.

Also during the driving activities, eye movements were recorded using video that was synchronized with the timing of vehicle measures noted above. Figure 2 presents the percentage of time during each of the three lane-change periods that the drivers spend looking at the vehicle's speedometer. The time percentage spent on viewing the speedometer during each period was obtained from the time (measured in milliseconds) the drivers spent looking at the speedometer divided by the total driving time (also measured in milliseconds) of that period. For all periods, the pre-lane change, during-lane change, and post-lane change, the novice drivers spent a significantly lower percentage of time referring to the speedometer than experience drivers ($p < .025$, F=7.2, df= 2,36).

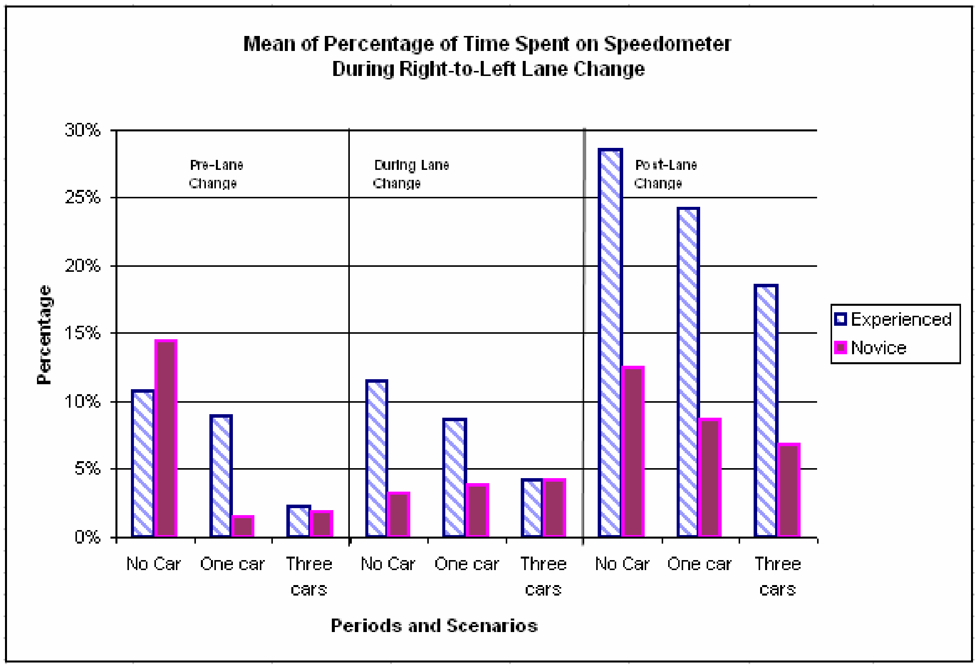

Figure 2. Percent of time spent looking at the speedometer during the right-to-left lane change scenarios.

Figure 3 presents the mean total glance times to the inside rear-view mirror for the three lane change periods. It can be seen that the novice drivers spend less time looking at the inside mirror than experienced drivers for all scenarios during the actual lane change period and the post-lane change period ($p < .05$, F=3.7, df= 2,36).

The results of the SSQ indicated that no subjects exhibited significant evidence of simulator sickness. Only one experienced driver and three novice drivers reported very minor symptoms of visual flashback, headache, or dizziness.

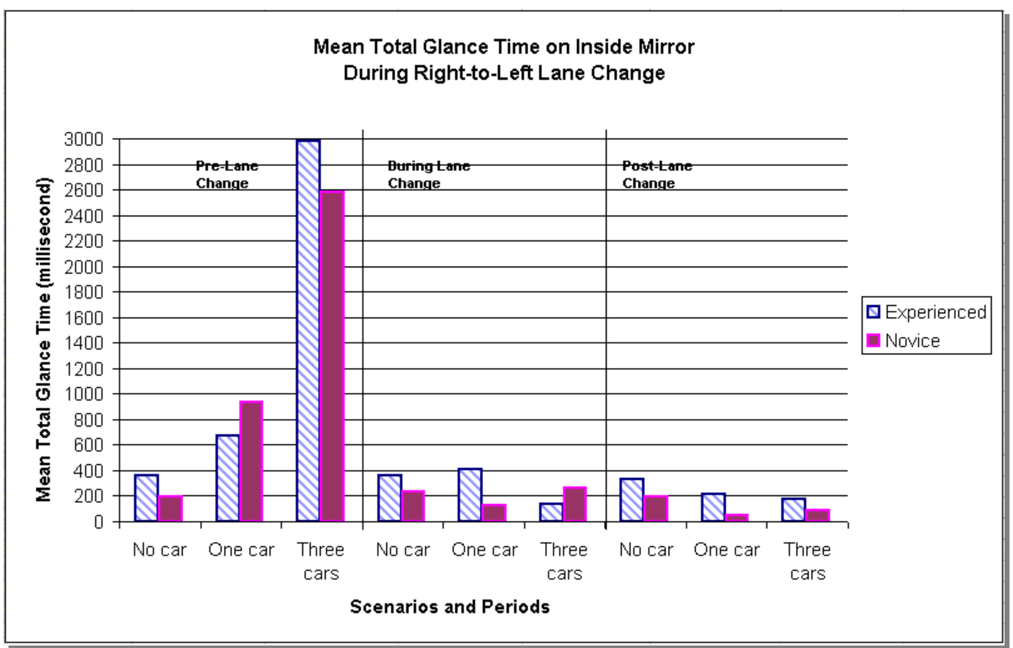

Figure 3. Mean total glance time to the inside mirror in milliseconds for all 3 periods.

DISCUSSION

The results of this work suggest that when the workload of novice drivers is increased, as when executing a lane-change maneuver, their general driving performance deteriorates. This can be seen by the increase in the variance of lane position during the pre-lane change period. During this period, a driver must determine if it is safe to make a lane change. Here, the novice drivers spent about the same amount of time glancing in the vehicle's inside mirror, but were not able to maintain the same degree of control of their vehicles that experienced drivers did.

When executing the actual maneuver, i.e., when the vehicle was moving from the right lane to the left lane, the novice drivers made a smaller number of glances to the vehicle's mirrors and speedometer than the experienced drivers. This may be interpreted as novice drivers needing to pay more attention to steering control than experience drivers when changing lanes.

During the post-lane change period, the variance of novice drivers' lane position was again greater than that of experienced drivers, indicating difficulty in resuming and maintaining a straight course after performing a lane change. During this post-lane change period, novice drivers made fewer mirror and speedometer glances than experienced drivers.

The findings from this research indicate some of the behavioral and multi-tasking distinctions between novice and experienced drivers. A safe lane-change maneuver requires the driver to adequately make a visual sampling of the vehicle's mirrors. For novice drivers, this interval of not visually monitoring the direction of travel resulted in less precise steering behavior as indicated by an increase in the variance of their vehicle's lane position.

To apply the results of simulation to real driving tasks, some facts need to be considered, such as some novice drivers' racing game experience and the lack of a blind spot in the driving simulator. First, some novice drivers, who had lots of racing game experience, performed quite well in the experiments. Second, when executing a left-lane change during actual driving, there is typically a "blind spot" on the left side of the vehicle. Most drivers learn to turn their heads to check this blind spot before beginning a left-lane change. However, most simulators, including ours, do not duplicate this blind spot; our simulator provided only a front view and a rear view, with no side-view images. Since our subjects did not need to check for a blind spot, the time and scanning actions in preparing for a left turn may be less than that of real-world driving. A bigger screen with a larger field-of-view could provide a solution regarding the blind spot.

Finally, a future area of research is to determine if virtual reality driving simulators could be used to train novice drivers in how to execute lane changes, particularly with regard to visually sampling roadway conditions using the vehicle's mirrors.

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