Title of Paper: How does driving experience affect allocation of attention in complex signaled intersections?


Names, qualifications, positions/affiliations of all authors:
Julie J. Famewo, BSc, MA, Department of Psychology, University of Guelph (principal author)
Lana M. Trick, PhD, Associate Professor, Department of Psychology, University of Guelph
Blair Nonnec

Contact Information:
Email: ltrick@uoguelph.ca
Address:
Department of Psychology
University of Guelph
Guelph, Ontario
N1G 2W1

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HOW DOES DRIVING EXPERIENCE AFFECT ALLOCATION OF ATTENTION IN COMPLEX SIGNALED INTERSECTIONS?

Julie J. Famewo, Lana M. Trick
Department of Psychology
and Blair Nonnecke
Department of Computing and Information Science
University of Guelph, Guelph, Ontario, Canada

A change detection paradigm was used in the University of Guelph driving simulator to study how drivers of different experience levels allocate their attention in complex intersections. Given that it is impossible to attend to everything at once, an important component of driving skill is to know what to attend to and what to ignore (Kirsner, 1995). Change blindness is the failure to detect a change in the environment. Attended elements in a scene are less likely to be missed. Therefore, detected changes provide an index for the allocation of attention (Rensink, O'Regan & Clark, 1997). To examine whether experienced drivers attend differently to the environment compared to less experienced drivers, detection of two types of changes across the three directions (left, center and right) of a complex intersection were examined. Changes included the appearance of a new vehicle (safety-related change) or a colour change (safety-unrelated). As predicted, experienced drivers detected more new vehicles than did less experienced drivers. All drivers detected more changes to the right of the intersection, with experience differences only being revealed to the left, where experienced drivers detected more changes than inexperienced drivers. Results suggest that greater experience assists drivers in selectively attending to more safety related aspects of the driving scene and in increasing their range of attended directions in intersections.

INTRODUCTION

Inexperienced drivers are at an increased crash risk compared to more experienced drivers (Cooper, Pinili & Chen, 1995). A number of factors are involved in this heightened risk including insufficient understanding of the rules of the road, poor operation of the vehicle and risk taking behaviour (Laapotti, Keskinen, Hatakka, & Katila, 2001). Overcoming these factors, however, is not enough to make a good driver. Part of becoming an experienced driver is knowing where to attend and what to attend to. Attention is often thought of as a spotlight that moves around the environment to select elements of the scene for further processing (Wright & Ward, 1998; Yantis, 1998). As attention cannot be in all places at once, it is necessary to attend to the most meaningful or safety-related aspects of the driving scene. It is possible that inexperienced drivers have not developed these abilities to the same degree as experienced drivers and therefore do not acquire as much relevant information from the environment.

Eye tracking techniques that examine the length or number of visual fixations made during a task have been used to evaluate where drivers look. These methods have shown that visual scan patterns differ between drivers of different experience levels. Inexperienced drivers tend not to fixate as far ahead of their vehicle as experienced drivers, and they have a narrower horizontal spread of fixations (Falkmer and Gregersen, 2005). Despite these observations, eye-tracking methods do not fully explain how attention is used in the environment. Wright & Ward (1999) explain that people do not necessarily attend to the same location where their eyes are focused. In fact, Underwood, Chapman, Berger and Crundall (2003) found that drivers are able
to recall information about items in the driving environment that they did not fixate on. To more thoroughly examine what and where drivers attend, this study applied a dynamic change blindness paradigm in a high-fidelity fixed-based driving simulator.

Change blindness is the failure to detect changes in a visual scene (Rensink, O’Regan & Clark, 1997). In everyday life, a distraction that directs vision away from the roadway, or even an eye blink or saccade can cause one to miss a change such as a traffic light change or sudden appearance of a vehicle or cyclist. Similar disruptions can be simulated in the laboratory by blanking the screen where the scene is presented (Rensink et al., 1997; Tse, 2004). Aspects of the scene that received attention prior to the change are less likely to be missed. Therefore, examining the position and types of changes detected most often can provide information about where and what was selectively attended (Rensink et al., 1997; Bahrami, 2003; Tse, 2004).

Experience in specific domains provides an advantage in change detection tasks indicating that meaning and familiarity increase the selective power of visual attention. For example, Werner and Thies (2000) found that coaches, players and referees of American football detected more changes that occurred across static football scenes than did novices to the game. Experts were also faster at detecting the changes. This was especially true when the changes were meaningful to the football formation or game play.

The purpose of this study is to find out whether experienced and inexperienced drivers differ in terms of what and where they attend in complex intersections by making use of the change blindness technique. Complex intersections were chosen because of the increased complexity of the driving scene in these regions, which was expected to heighten differences between drivers of varying experience levels. As well, intersections are a common location for collisions. It was hypothesized that experienced drivers would be more likely to detect safety related changes, such as the presence of a new vehicle, compared to less experienced drivers. As well, we predicted that experienced drivers would distribute their attention more equally across the portions of the intersections. Inexperienced drivers, on the other hand, would have reduced attention to the left and right, in support of their narrow horizontal spread of fixations suggested by eye track monitors.

**METHOD**

**Participants**

Forty-eight students from the University of Guelph completed the experiment. Each student was prescreened with questionnaires for susceptibility to simulator adaptation syndrome and for colour vision deficits. All participants had a minimum of a beginner’s driver’s license (G1 level of the Ontario Graduated Licensing Program). In the past, research on the effects of driving experience have typically relied on single criterion to divide participants into groups, with different studies using different criterion to decide whether the given driver was experienced or inexperienced. In the present study, we used both the number of kilometers and days driven during the most recent year. Participants provided these values for the spring, winter and summer seasons. The characteristics of these two groups are presented in Table 1. Five participants could not be placed in either group because their answers to the criterion questions yielded inconsistent results. Participants were paid $15 or course credit. All had normal or corrected-to-normal vision.
<table>
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<th>Inexperienced (n = 22)</th>
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Table 1. Selection of results from the Driving Experience Questionnaire. Kilometers/year and days/year were used to determine the driving experience category.

Driving Simulator Hardware and Software

The experiment was conducted using a fixed-based, high-fidelity, 6-channel DriveSafety driving simulator. Two hundred fifty degrees of frontal and side view projection screens curved about a four-door Saturn sedan. A virtual environment was projected onto the screens at a resolution of 1024 x 768 pixels per screen.

Change Blindness Paradigm

A dynamic change blindness paradigm was used to determine what and where drivers selectively attended in complex intersections (Zheng, Tai & McConkie, 2004). Participants drove through a series of simulated suburban environments. Change blindness was induced by blanking the projection screens for 100 milliseconds when participants were 50 meters (about 3 seconds when traveling at 60 km/h) from the center of each intersection encountered in the virtual environment. The 100 millisecond blanking was chosen to be similar to the length of an eye blink, known to cause change blindness (O’Regan, Deubel, Clark & Rensink, 2000). During the blanking, a change could take place in the front row of cars to the left, center or right of the intersection being approached (see Figure 1). When a change occurred, it could be a colour change or a new vehicle could appear. On one third of the trials there was no change. These no-change catch trials were used to discourage guessing.

![Figure 1. Aerial-view schematic of a complex intersection. Changes could occur in the circled regions to the left, center or right of the intersection. The dark shaded circle and arrow represent the participant.](image)

Driving Scenarios and Procedure

Participants drove at approximately 60 km/h through a practice session and three experimental scenarios. Each scenario consisted of a straight four-lane suburban road with a parking lane on each side and a number of complex signaled intersections occurring every 400 meters. Before the arrival at most intersections, the traffic lights (including the left advance light) turned green for the participant and red to all other directions. This created a situation where vehicles in the change detection zones were stationary, unless making a right turn on a red
light. Drivers drove in the left lane in order not to have their vision occluded by ambient traffic that primarily drove in the right lane. When participants detected a change, they pulled the high-beam lever as quickly as possible and told the experimenter seated in the passenger seat, where (left, center or right) and what (colour or new vehicle) change they observed. The experimenter recorded this manually and with a button-box. The proportion of correct detections was used to determine what and where drivers had attended. The high-beam lever pull was used to calculate reaction times, which were informative for determining the time needed for decision-making.

The reaction time was calculated from the moment the blanking of the screens occurred to the time the driver pulled the lever. This is the time drivers’ required to scan the intersection and determine that something was different from the scene prior to the blanking.

Despite the blanking of the screens at all intersections, there was not always a change. Besides the no-change catch trials, red light and hazard catch trials were also incorporated into the scenarios. These additional trials were used to verify that participants were driving normally, despite the secondary change detection task. Red light catch trials occurred when the traffic lights failed to change green prior to the participant arriving at the intersection. This required participants to inform the experimenter of the red light. These catch trials encouraged drivers to attend to the traffic lights as in normal driving. On hazard trials, a vehicle would run a red light from the left, center or right. Participants had to identify these dangerous behaviours, showing that they were alert to the actions of other drivers.

**Practice Session**

In the practice session, participants first learned how to control the vehicle and how to maintain a 60 km/h velocity. The change detection task and presence of red lights and hazards were explained to the drivers. For the first four intersections, the experimenter told the participant where and what kind of change would happen so that the driver could attend to that specific region of the environment. Therefore, the participant had an opportunity to practice rapidly pulling the high beam lever after observing the change. Participants drove through an additional 9 intersections where they experienced each type of change several times, as well as the red lights and hazard trials. They received feedback after each intersection to determine if they correctly identified a change. After completing the practice session participants were told that during the experimental scenarios a change may or may not occur and that they should be careful not to guess. Participants were not provided with feedback during the experiment, except for on hazard and red light catch trials.

**Experimental Session**

Each of the three experimental scenarios had 36 intersections. In total, ten of each type of change (new vehicle and colour change) occurred in each of the three directions (left, center or right). Therefore, there were 30 colour changes and 30 new vehicle changes, accounting for 20 changes in each of three directions. There were also 30 no-change catch trials. These trials were distributed randomly across each of the three scenarios, but identically across participants. In addition, each scenario had one hazard trial and five red light catch trials. Three additional intersections where no blanking occurred were distributed throughout each scenario as designated break times. Break times were included to provide some variety to the drive allowing participants to experience unique events (pedestrians, pack of dogs, making right turns).

Between scenarios participants worked on the driving experience questionnaire. The entire study required approximately 1 hour and 30 minutes.
RESULTS AND DISCUSSION

To answer the questions of what and where drivers of different experience levels attend in complex intersections, the detection of the within-subjects independent variables, type of change (colour and new vehicle) and direction of change (left, center and right) were evaluated for accuracy. For type of change detection, if the colour change or new vehicle was accurately identified, regardless of whether the direction was correct, this counted as a correct detection. For the direction detection, a correct detection included all trials where the direction of the change was correctly identified, even if the type of change was incorrect. The dependent variable, proportion of correct detections, was calculated by dividing these totals by the actual number of changes. Reaction times, another dependent variable, were evaluated for the correct detections to examine differences in the decision processes for determining that a change had occurred. Proportions and reaction times were averaged for each correct type of change detection and direction detection for the experienced and inexperienced drivers separately.

A preliminary analysis was performed to verify that participants were driving normally by examining the percentages of correct responses made to red light and hazard trials. Then, no-change catch trial responses were examined to make sure that drivers were not randomly guessing. The main analysis examined both what and where drivers attended.

Preliminary Results

Did participants drive normally? Detection of red light and hazard catch trials.

On average, experienced drivers detected 89% of the hazards and inexperienced drivers detected 91%. Red lights were detected at similar levels with experienced drivers detecting 94% and inexperienced drivers detecting 92%. These high percentages indicate that drivers did not neglect normal driving behaviours to perform the change detection task.

Did participants guess? Responses to no-change catch trials.

False alarms were defined as trials in which drivers claimed that there was a change in the intersection when there was no change. Experienced and inexperienced drivers had comparable numbers of false alarms (34% and 31% respectively). Although these percentages are high, the values were consistent across drivers despite being asked not to guess. It is possible that the high number of objects in the intersections may have hindered deep processing of much of the driving scene, resulting in many false alarms, despite confidence in their responses. Interestingly, false alarms were approximately 0.5 seconds slower than overall detections (p<0.001), suggesting hesitancy in these responses.

Main Results

What did drivers attend to? Type of change detection.

Overall, the presence of new vehicles and colour changes were detected at the same rate (p = 0.38). However, a MANOVA performed to determine the simple effects revealed that experienced drivers detected marginally more new vehicles than did inexperienced drivers (F(1,41) = 2.88, p < 0.1). As well, experienced drivers approached significance at detecting more new vehicles than colour changes (p = 0.13), as shown in Figure 2. These results suggest that similar to our predictions, those with more experience selectively attend to safety-related aspects of the scene, such as the presence of a new vehicle. This selective processing associated with greater experience supports the concept that attention may be an important contributor to the development of driving skills.
Drivers of different experience levels did not differ in how quickly they made their decision that a specific type of change had occurred in the intersection. However, colour changes were detected more rapidly than new vehicles ($F(1,41) = 5.52, p < 0.05$). It may have taken longer to decide that a new vehicle had appeared because participants had to confirm two pieces of information - that the colour that had appeared wasn’t just a new colour, but was also on a vehicle that was not present prior to the blanking of the screen.

Where did drivers attend? Direction detection.

Experienced drivers detected marginally more changes to the left than did inexperienced drivers ($F(1,41) = 3.68, p < 0.1$) (refer to Figure 3). There were no experience differences for the center or the right. This supports our expectation that inexperienced drivers would be unable to selectively attend to all directions of the intersection. However, this limitation was only to one direction, instead of to both the left and right.

However, even experienced drivers did not attend to all directions equally. There was a main effect of direction ($F(2,82) = 11.45, p < 0.001$). Bonferroni pairwise comparisons showed that more changes were detected to the right than to the left or center of the intersections ($p<0.01$). Similarly, there was a main effect of the direction reaction times ($F(2,80) = 34.14, p < 0.001$). Each direction differed from the other ($p < 0.05$ for each comparison). Drivers were slowest at deciding a change occurred to the left, followed by the center. Detections to the right were decided the fastest. These results suggest that regardless of experience level, attention is selective to the right portion of the intersection, allowing for more correct change detections and more rapid decision-making.

Several factors may explain this increased attention to the right. First, vehicles made right turns on red lights from the right portion of the intersection. This extra motion in the vicinity of the driver may have captured participants’ attention to the right, enhancing detections of changes to this direction and hindering detection to other directions. Second, the higher proportion of detections to the right may have been due to a greater difficulty with the left direction. Some drivers explained that the frame between the windshield and car door window was obstructing their view of the left portion of the intersection causing a more difficult scan. The greater reaction times necessary to correctly decide that a change happened to the left offer some support for this possibility. The inexperienced drivers’ lower proportion of correct
detections to the left suggest that they may have focused their attention primarily on directions that were more easily viewed.

![Proportion Correct vs Reaction Time](image)

Figure 3. Average proportions (left) and reaction times (right) of the correct direction detection (+/- SE). Experienced drivers detected more changes to the left than did inexperienced drivers.

Surprisingly, participants were only correct on their decisions about what type of change took place and where the change occurred 41%-65% of the time. This was despite intentionally searching for the changes. These results coincide with the high percentage of false alarms, suggesting that drivers are only moderately aware of the presence and appearance of vehicles stopped at complex intersections. It is likely that moving vehicles would have received a greater response because of the higher safety risk. However, the observation that an interruption the length of an eye blink can so severely affect change detection suggests an even higher importance to being able to attend and process meaningful parts of the driving scene.

**CONCLUSION**

The dynamic change blindness paradigm was able to differentiate drivers of different experience levels. Experienced drivers selectively attend to the presence of new vehicles, a safety-related concern, more readily than do less experienced drivers, though there is no significant difference in ability to notice colour changes, a non-safety related concern. As well, experienced drivers were able to attend to the left portion of the intersection with greater ease than were inexperienced drivers. The results support that with increased experience, particularly greater kilometers and days driven, drivers develop skills in knowing what and where to attend. This improved allocation of attention may be an important factor in the development of safe driving skills.

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