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DETECTION OF ROAD HAZARDS BY NOVICE TEEN AND EXPERIENCED ADULT DRIVERS

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Abstract

Previous laboratory and simulator research has indicated that hazard detection skills and abilities are less developed among novice drivers compared with experienced adult drivers. Novices tend to miss some relevant cues and may be less able to process important elements in the environment while driving. As was found with other research methods, it was hypothesized that novices would have lower hazard detection skills and will react less appropriately to hazards than older and more experienced drivers.

Three hazard perception scenarios were simulated on a test track and data were collected on newly licensed teen drivers (within 2 weeks of licensure) and a comparison group of adults. The scenarios included a hidden stop sign, hidden pedestrian, and hidden pedestrian with lane closure (this last included a text-messaging task). Discrete quantitative performance metrics were evaluated for this analysis, including: 1) Did the participant glance at the potential hazard (e.g., stop sign, pedestrian)? 2) Did the participant stop (for the stop sign scenario)? 3) Did the participant show signs of indecision, caution, or awareness (for all hazards)?

Significant differences between teen drivers and more experienced adult drivers were found in a combined hazard detection analysis. Results indicate that the adult drivers observed hazards and demonstrated overt recognition of hazards more frequently than the teen drivers. Results indicated that a large portion of teen drivers failed to disengage from peripheral task engagement in the presence of hazards. The results will later be compared to naturalistic data for the same set of drivers to see whether these test track results are predictive of real-world behavior.

INTRODUCTION

Previous research has revealed that novice drivers are overrepresented in crashes compared to experienced drivers (1,2,3,4). One potential reason teen drivers crash at a higher rate than other age groups may be due to perception of fewer hazards. Teen drivers may still be learning how to assess the driving environment efficiently and safely and, thus may be less likely than experienced drivers to react appropriately to road hazards (5,6,7,8,9,10,11).

The early research of Mourant and Rockwell (12,13,14,15) was the first to reveal differences between novices and experienced drivers in terms of the visual acquisition process (scanning forward and to the mirrors) and the frequency of lane-line sampling while driving on the open road. Additional efforts have recently begun using a test-track to evaluate differences between adult and novice drivers (16,17,18,19), during which differences were found in terms of stopping behavior (at an intersection) and scanning behavior. For example, adults have been found to be more likely to stop at a changing traffic light than youth, and teens tend to have fewer mirror glances than adults. However, to our knowledge, no test-track studies have been reported investigating how teen drivers and adults respond to hazard detection scenarios while driving.

BACKGROUND

Roadway hazards, if not attended to properly, could result in a crash (20). Paying proper attention assumes that the driver: 1) is looking at and perceiving the potential hazard, and 2) knows that the situation at hand may be hazardous. In other words, the driver has developed a complete “mental model” of the situation and is able to recognize the situation as potentially hazardous. This concept was discussed by Underwood and colleagues (20) who suggested that less experienced drivers making lane changes may not understand the need for increased scanning and may not recognize and respond to evident hazards.

Both early and recent research found that when the road situation is complex, novice drivers tend to stare at the road directly ahead of them as compared to experienced drivers (11,12,13, 14,15). Mourant and Rockwell (12,13,14,15) also reported that new drivers compared to experienced drivers spend less time scanning the mirrors. Underwood and colleagues (20) indicated that novice drivers look around the vehicle less frequently than experienced drivers, both to search for potential hazards and to maintain a general awareness of the locations of the neighboring vehicles.

Research using driving simulators has also shown similar results in terms of driver behaviors and eyeglance scanning. For example, Greenberg and colleagues (21) reported that there were significant performance differences between teens and adults for hand-held cell phone tasks in a driving simulator. Drivers were instructed to drive while following a compact Sport Utility Vehicle (SUV). A sub-compact vehicle was traveling in front of the lead SUV and was obscured by the lead SUV. During the front detection events the sub-compact appeared to swerve suddenly out of its lane either onto the right shoulder or into the left lane. The teen drivers missed 53.8% of the front events when dialing a hand-held phone, as compared to adults who only missed only 13.6% of these events.

Similarly, work by Fisher and colleagues on driving simulators (7–10,22–24) over the past six years has indicated differences between novice and experienced drivers. An early study (7) showed that novice drivers could be trained to respond to hazardous situations in a similar manner to that of more experienced drivers. Subsequent studies reiterated these findings, and also provided new insight into the hazard detection patterns of the untrained novice drivers (8–10,22–24). Eyeglance patterns were studied in later driving-simulator research comparing novice drivers to experienced drivers (8). Novices were much less likely than experienced drivers to look to the right when passing a truck parked adjacent to a crosswalk. In a related study, Garay-Vega and colleagues (10) found that the majority of novice drivers who saw a pedestrian step out from behind a parked truck before the vehicle reached the simulated crosswalk failed to look to the right when they actually traveled over the crosswalk.

In addition, amongst the studies conducted on the road, Underwood and colleagues (11) have studied novice and experienced drivers in the United Kingdom and have also found that experienced drivers demonstrated more varied fixation sequences, demonstrating the ability of more experienced drivers to actively anticipate hazards.

To our knowledge, the current paper is the first to report findings comparing key components of hazard detection and behaviors between novices and other drivers on a test track. This study is part of a larger study, referred to as the “40 Teen Study,” involving a multidisciplinary evaluation of novice teenage drivers, including two test-track sessions one year apart and 18 months of naturalistic on-road data collection. In this paper, three hazard detection scenarios from the baseline test-track evaluation are discussed.

PURPOSE

The goal of this study was to compare the hazard detection skills and behaviors of novice and older, more experienced drivers in demanding driving situations on a test track. As found with other research methods, it is hypothesized that novice will have lower hazard detection skills and will react less appropriately to hazards than older and more experienced drivers.

METHOD

Participants

A sample size of 84 participants was tested in this study. This includes 42 recently licensed teen drivers ($M = 16.5$ years old) and their parents, 42 experienced adult drivers used as the comparison group ($M = 47.2$ years old). All participants completed the baseline test-track assessment. Gender was approximately equally divided among teens (51% males and 49% females) and primarily female (68%) among the adults. Participants were recruited through driving schools and newspaper advertisements. All participants were licensed to drive in the Commonwealth of Virginia and had at least 20/40 corrected vision. Written parental consent, teen assent, and adult consent were obtained. The entire session took approximately 1.5 hours, including approximately one hour of driving during which participants encountered 15 scenarios. Participants received \$20 per hour for participation in this part of the study.

Apparatus

Test Track—The session was conducted at the Virginia Tech Transportation Institute (VTTI) on the Virginia Smart Road, a 3.5 km (2.2 mi) controlled-access test track with a signalized intersection. The Smart Road is a two-lane highway constructed to interstate specifications, equipped with guardrails where necessary.

Equipment—The test vehicle was a 1997 Ford Taurus with safety equipment including anti-lock brakes, driver and passenger airbags, and an emergency passenger-side brake. The vehicle

was instrumented with a customized, real-time data acquisition system (DAS) with a separate computer to run the experimental scenarios. The DAS recorded speed, acceleration, radar data (i.e., distance to vehicle in front when applicable), lane position, pedal positions, four video data streams, and an audio stream. A hand-held Nokia 6019i cell phone was used for the in-vehicle cell-phone (i.e., text-messaging) tasks.

Design

Age (novice teen and experienced adult) was the between-participants variable, and scenario (Hidden Stop Sign, Hidden Pedestrian, and Lane Closure [with pedestrian & text-messaging]), was the within-participants variable. Dependent measures included discrete (yes or no) data such as stopping the vehicle, looking at the hazard, suspending the secondary task, and showing other indications of indecision, late recognition, or caution with regard to the scenario.

Procedure

Two experimenters (one sitting in the front passenger seat and one sitting in the rear, behind the driver/passenger) were present during the entire testing procedure. The front-seat experimenter conducted all orientation tasks as well as provided initial and on-going instructions to the participant. The back-seat experimenter operated the data collection software and did not interact with the participant.

All participants underwent a static orientation of the vehicle controls and in-vehicle tasks prior to entering the test track. Once on the test track, the front-seat experimenter instructed the participant to stop the vehicle and final instructions were given. At this time, the participant was instructed to maintain a “comfortable speed,” exercise normal lane management, obey all traffic regulations, and maintain road safety. Participants were also instructed: “There will be no other traffic or pedestrians on the road unless they are part of the experiment; however, a maintenance crew may be present on the road.” Specific instructions were then provided previous to each scenario while the vehicle was in motion. The entire testing session consisted of 15 driving scenarios; however only three hazard detection scenarios will be discussed in this paper. These hazard detection scenarios were developed adapted from scenarios used by Fisher and colleagues (7–10,22–24), and included the following:

Hidden Hazard: Stop-Sign Scenario—In this scenario, the driver had just entered the Smart Road and had been instructed to drive at a comfortable speed while monitoring the trip odometer. As the participant approached the Smart Road intersection for the first time, the signal was turned off (no red, amber, or green light was illuminated). A large 15-passenger van was parked on the right side of the road at the intersection (see Figure 1). A portable stop sign was placed just in front of the van, thus obscuring the sign so that the driver could not see the sign until the vehicle was fairly close to the intersection (approximately 50 ft). Three questions were answered by the data analysts when reviewing the video, audio, and sensor data:

1. Did the participant glance at the stop sign?
2. Did the participant stop at the stop sign?
3. For cases in which the participant did not stop, did the participant show signs of indecision or late recognition such as foot movement, comments, or facial expressions?

Hidden Hazard: Pedestrian Scenario—During this scenario the driver was instructed to drive at a comfortable speed while monitoring the trip odometer. The driver encountered the 15-passenger van located on the right-hand shoulder (see Figure 2). A confederate (VTTI employee) was stationed at the back of the van with the doors open posing as a maintenance

worker. Once the participant was within sight of the van, the confederate closed both of the van doors and slowly walked towards the front of the van on the passenger side. As the participant approached and passed the front of the van, the confederate walked across the front of the van but did not enter the roadway. Since the pedestrian (confederate) had initially been visible to the participant, but then disappeared from view between the moving vehicle and the parked van, there was a possibility that the pedestrian could re-appear somewhere around the van as it was being passed. This scenario was designed to determine whether the participant recognized and reacted to this potential hazard. Two questions were answered by the data analysts when reviewing these data, including:

1. Did the participant look for the pedestrian?
2. Were there any behaviors indicating caution? (e.g., indecision/awareness)

Hidden Hazard: Lane Closure with Pedestrian and Text-Messaging Scenario—

The final hidden-hazard scenario was a lane closure and hidden pedestrian situation presented while the participants were also involved in a text messaging task. The driver encountered a series of six orange cones closing the right lane and the 15-passenger van parked in the right lane in front of the cones (see Figure 3). A confederate (VTI employee) was stationed at the back of the van with the doors open posing as a maintenance worker. Once the participant was within sight of the van, the confederate performed the same actions as were completed in the previously described scenario. The current scenario was designed to assess not only how the participant dealt with the lane closure, but also to determine whether the participant recognized this potential hazard, and to see how the participant handled the text messaging task. Three questions were answered by the data analysts when reviewing these data including:

1. Did the participant look for the pedestrian?
2. Were there any behaviors indicating caution (e. g., indecision/awareness) with regard to the pedestrian?
3. Did the participant suspend the text-messaging task while following the lane closure?

Measurement/Data Reduction/Analysis

Data reduction (coding) was completed by trained data reductionists using a formal protocol. A rigorous protocol for scoring the key subjective measures was developed for each task. The data reductionists undergo training for each protocol, and their work is extensively spot checked (>10%). The in-vehicle experimenters also took notes during each run, and the experimenter notes could be checked for ambiguous cases. Continuous audio was also available, which made the data reduction much less subjective (as participants often made verbal comments regarding the hidden hazards). Data reductionists listened to this audio as part of the reduction process. More than 10% of the data points were spot checked and inter-rater agreement was greater than 95%. This level of agreement was considered to be quite acceptable given the subjective nature of these measures.

For the results discussed in this paper, differences between teens and adults were examined using Fisher's Exact Test. Although data were collected on 84 participants, in a few cases, there were some missing data, mostly due to data collection failures. Thus 74 data points were available for analysis in the case with the greatest data loss (10 data points missing). Statistical analyses were conducted individually for each of the three scenarios and then on the three scenarios combined.

RESULTS AND DISCUSSION

Hidden Stop-Sign Scenario

Recall that the following three primary questions were addressed by data analysts for this scenario: whether participants looked or glanced at the stop sign, whether participants stopped; and if participants did not stop, whether there were signs of indecision.

Results—The results indicated that 46% of adults and 28% of teens stopped at the sign ($p = 0.103$). Of those participants who did not stop, significantly more adults (76%) than teens (32%) showed signs of indecision/late recognition ($p = 0.0012$). Examples of indecision or late recognition included foot movements back and forth between the brake and accelerator, observations of facial grimaces as the participant passed the sign, and comments such as “I was supposed to stop, wasn’t I?” Finally, significantly more adults (87%) than teens (51%) exhibited eyeglances in the direction of the stop sign ($p = 0.0037$). Figure 4 illustrates these findings with statistical differences indicated by the arrows and p-values. The dashed arrows indicate comparisons with a p-value >0.05 .

Discussion—These results support previously reported trends in the research conducted by Fisher and colleagues on a driving simulator where more adults stopped at the stop sign, were more deliberately scanning the environment, and/or recognized that they should have stopped but realized too late (8). For this scenario, it is important to remember that there was no cross-traffic present and the experiment instructions had indicated no other traffic (except maintenance) would be present on the road. Therefore, the adults and teens may have concluded that continuing through the intersection without stopping was relatively safe. Most of the teen drivers, however, were not scanning and did not even see the stop sign, much less demonstrate signs of indecision. Another caveat that should be discussed is that this task was the first scenario that the participants encountered. The fact that the teens were still relatively unfamiliar with driving as well as with the Smart Road test track provides further explanation for not exhibiting appropriate caution when entering an unfamiliar intersection.

Hidden Pedestrian Scenario

Two following questions were evaluated in the hidden pedestrian scenario: (1) did the participant perform eyeglances in the direction of the pedestrian; and (2) did participant exhibit signs of caution.

Results—For the first question, a trend was found with 34% of adults glancing in the direction of the pedestrian as compared to 13% of teens ($p = 0.0571$). For the second question, significantly more adults (53%) than teens (18%) demonstrated cautious behaviors ($p = 0.0019$) including comments indicating they noticed the pedestrian, glances to the rear-view mirror, or facial expressions. Figure 5 illustrates these findings. The dashed arrows indicate a trend (i.e., $0.1 < p\text{-value} > 0.05$).

Discussion—These results indicate that more adults than youth exhibited cautious behavior when encountering the hidden pedestrian than did teen drivers. A trend found for teens being less likely than adults to look toward the pedestrian, partially supports the finding by Fisher (10) that a majority of teens do not look at a hidden pedestrian (i.e., hazard). Notably, while adults performed somewhat better than teens on these tasks, they did not perform well, similar to the finding of Fisher et al. (10). Additional analyses involving other tasks, other driving performance metrics (e.g., speed deviation, percent time eyes on forward roadway, etc.) are needed to better assess these driving skills.

Lane Closure with Pedestrian and Text-Messaging Scenario

For the combined hidden-hazard and text-messaging scenario, the following questions were addressed: (1) did the participant exhibit eyeglances in the direction of the pedestrian; (2) did the participant's behavior indicate indecision; and (3) did the participant suspend text-messaging.

Results—The results indicated a trend for more adults than teens glancing in the direction of the pedestrian (19% vs. 5%; $p = 0.0818$). The results for suspension of the text-messaging task were not statistically significant (67% vs. 55%).

Discussion—A majority of adults and slightly over half of the teen drivers suspended the text-messaging task when negotiating the lane closure. Also, very few adults and teens looked ahead to determine pedestrian presence. These results might indicate that the task was difficult for both adults and teens, most of whom were unable to effectively scan the environment while performing a text-messaging task or negotiate a lane change due to the right-lane closure. This demonstrates the possible propensity even for experienced drivers to not look ahead while text messaging. However, it is notable that 45% of teen drivers did not suspend the text-messaging task while navigating through the lane closure scenario, and only 5% of the teen drivers scanned to look for the pedestrian. This provides evidence that a high proportion of teens fail to disengage in peripheral tasks when encountering unfamiliar and potentially dangerous situations (see 25 for other research on this topic).

Combined Results

Results—The results of this analysis indicated that 48% of adults and 23% of teens glanced in the direction of the potential hazard ($p < 0.0002$). Also, 69% of adults and 41% of teens demonstrated signs of awareness of potential hazards ($p < 0.0001$). Figure 6 illustrates these findings.

Discussion—The results from the combined analysis demonstrate significant differences between adults and teens in recognizing hazards and responding to potential hazards in a safe manner. These driving behaviors required similar responses from the participants across several driving scenarios. For example, an alert or experienced driver would be expected to look toward the stop sign during the hidden stop-sign scenario and search for the disappeared pedestrian in the scenarios involving the van. The results provide evidence of differences between teens and adults in the perception of hazards in the driving environment, similar to the driving simulation results reported by Fisher and colleagues (7–10,22–24).

CONCLUSIONS

Hidden Stop-Sign Scenario

Over three-quarters of adult participants who did not stop for the hidden stop-sign scenario displayed behaviors suggesting awareness that they should have stopped. Adults generally realized, just a bit too late, that they should have stopped at the intersection, and were forthcoming in their expressions of frustration at having not stopped. However, less than one-third of the novice drivers displayed behaviors indicating such awareness. Some teens may not have been comfortable offering unsolicited comments with experimenters present. Most teens demonstrated no realization or reaction to the potential hazard of a van parked on the side of road (with its 4-way hazard flashers on) suggesting that a stop might be necessary. However, most adults looked at the stop sign and displayed signs of indecision/late recognition. Previous research over the last 35 years and across several testing environments has consistently reported that adults scan more thoroughly and widely than novice teenagers (8–17). Notably, in the present research, only half of the teens looked at the stop sign in this scenario.

Hidden Pedestrian Scenario

For the hidden pedestrian scenario, almost three times as many adults as teens demonstrated behaviors indicating caution for the hidden pedestrian scenario. Observed behaviors included overt comments about the presence of a pedestrian. Again, adults may have been more likely than teens to speak up during the session. Other observed behaviors indicating awareness included facial expressions (such as eyebrow raises or smiles) and glances toward the rear-view mirror. It is likely that adults noticed the pedestrian initially and looked into the rear-view mirror to confirm her presence, or that the adult driver only perceived the pedestrian via peripheral vision. In such a case, the driver may have (habitually) looked into the rear-view mirror to confirm the presence of a pedestrian.

The majority of both adults and teens did not exhibit eyeglances in the direction of the pedestrian as they passed the van. Other driving performance metrics may be more sensitive to the eyeglance scanning patterns of adults and adults such as the percent-time eyes off the forward roadway. Analyses of this sort will be conducted in the future. This scenario was also encountered at the beginning of the testing session. Therefore, all drivers were potentially still familiarizing themselves with the vehicle and Smart Road environment.

Lane Closure Scenario

Although significant results were not revealed for this scenario, in both of the hidden pedestrian scenarios the trend was for two to three times more adults than teens to look at the pedestrian. It seems likely that all drivers experience a high cognitive load during this scenario with the lane closure, pedestrian, and text-messaging tasks happening simultaneously. However, 45% of teens did not suspend their engagement in the text messaging task and a total of 95% of the teens did not scan for the pedestrian. Many teens did not suspend peripheral task engagement and most did not scan for the hazard. This finding is similar to a previous study (18,19) where 28% of teens drove through an amber light while performing a cell-phone task, whereas none of the adults did so. Some driving performance metrics, such as speed deviation, may also demonstrate or be more sensitive to driver reaction to potential hazards; these analyses will be reported in a future paper.

Summary

Review of the overall findings aids in understanding why adults out-performed the teens based on the results observed. Over all three scenarios, significantly more adults looked at hidden hazards including the obscured stop sign and pedestrian. Additionally, the majority of adults displayed signs of recognition that a potential hazard was present. Apparently, experienced drivers learn what is relevant and important to attend to in a given situation. In contrast, novice drivers are still developing these skills, abilities, and habits. The findings are in agreement with previous simulator findings, and will be compared to the data collected in the 18 months of continuous data collection.

The novice young driver problem (26) is one of poor driving performance and high crash rates for a period of time after licensure, particularly under high-risk driving conditions. In previous test track research, our group found that novice teen drivers performed as well as experienced adults on usual driving skills such as speed and lane management, but not as well on more complex skills, such as stopping performance at signalized intersections, particularly when engaged in secondary tasks (18,19). The current research extended test track research by comparing novices and experienced adults on complex hazard detection scenarios. In general, the findings are consistent with an effect of experience, with adults performing consistently better than novices on all tasks. However, as has been found in other research (8), experienced adults also made many errors.

Limitations

There are two main limitations that should be addressed in discussing this study. 1) Test track method. Every method of data collection has its advantages and disadvantages. Naturalistic studies offer high ecological validity, but no experimental control (not every participant will encounter every possible traffic scenario under the same conditions). Test track studies offer wonderful experimental control, but less ecological validity. The full protocol of the 40-Car study attempts to combine the best of both worlds by exposing each participant to nearly identical conditions on the test track, and then to compare that data to real world data using naturalistic data collection. The researchers must keep participant safety topmost in mind when designing experiments. The test track protocol, developed with the collaboration of an expert and pilot tested with several participants, was conceived with high visual complexity and demands for vehicle controls. 2) Presence of experimenters and equipment. Every teen and adult participant was exposed to the same conditions, and it is impossible to determine to what degree the presence of these experimenters impacted the behavior of either teens or adults. The equipment is fairly unobtrusive, and similar to the instrumentation contained in the participants own vehicles for the naturalistic portion of the study, so it would likely have little impact. At present there is no way to conduct this type of test track study without an experimenter in the vehicle, so can be posited that it had little impact. For safety reasons, experiments on the test track are conducted with an experimenter in the vehicle, so the basis of comparison would have to be to the naturalistic portion of the study, which will take place in the future.

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FIGURE 1.

Hidden Stop Sign Scenario. The participant should stop at the intersection since the light is turned off and since a stop sign is present.

FIGURE 2.

Hidden Hazard: Pedestrian Scenario. A pedestrian may emerge from behind the van parked on the right shoulder. The participant driver should look to the right and/or slow down as he or she passes the van.

FIGURE 3.

Lane Closure with Pedestrian and Text-Messaging Scenario. A pedestrian may emerge from behind the van parked in the right lane. The participant driver should change lanes to the left and then look to the right as he or she passes the van.

FIGURE 4.
Graph Showing Results from Hidden Stop-Sign Scenario.

FIGURE 5.
Graph Showing Results from Hidden Pedestrian Scenario.

FIGURE 6.
Combined Results from all Three Scenarios.