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The Role of Driving Experience in Hazard Perception and Categorization: A Traffic-Scene Paradigm

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***Abstract*—**This study examined the role of driving experience in hazard perception and categorization using traffic scene pictures. Specifically, young-inexperienced, moderately experienced and very experienced (taxi) drivers observed traffic scene pictures while connected to an eye tracking system and were asked to rate the level of hazardousness of each picture and to mention the three most prominent hazards in it. Target pictures included nine, nearly identical, pairs of pictures where one picture in each pair included an actual hazard as an additional element. Altogether, 22 areas of interest (AOIs) were predefined and included 13 potential hazards and 9 actual hazards. Data analysis included both verbal reports and eye scanning patterns of these AOIs. Generally, both experienced and taxi drivers noted a relatively larger number of potential hazards than young inexperienced drivers Thus, by relating to less salient potential hazards, experienced drivers have demonstrated a better situation model of the traffic environment.

***Keywords*—**Concept Construction, Hazard Perception, Eye Movements, Driving Experience.

I. Introduction

HAZARD Perception (HP), i.e., drivers' ability to discern hazardous situation while driving along the road, is a skill and therefore improves with practice. It is widely accepted that experienced drivers possess better HP skills than young-inexperienced drivers, e.g., [3], [15], and [13]. Reference [16] suggested that there are at least two separable components of hazard perception; one is the degree of perceived hazard associated with a situation, and the other is the perception-reaction time to the perceived hazard. Recently, [3] has argued that although much research in the field of hazard perception and expertise favors the latter, the former component may actually play the key role in expanding our understanding regarding how drivers with a varied level of driving experience enrich their conceptual knowledge on HP. It would be not too presumptuous saying that the number of hazardous situations that one may encounter over a life time of driving experience is unlimited. Coping with these situations requires some sort of categorization of similar situations to construct an organized conceptual knowledge of hazards in the traffic environment. Furthermore, different traffic environment may produce different hazards [3]. For example, a pedestrian crossing the road is probably more common in residential areas rather than in inter-city areas. A deeper examination of expertise effect on conceptual knowledge and knowledge organization of hazards may assist in designing specific computer based traffic scenarios to enhance hazard perception skills among novice drivers.

In an attempt to further explore the effect of driving experience on HP conceptual knowledge it is highly important to review research dealing with attitude differences between novice and experienced drivers toward categorization of hazardous situations, e.g., [1], [2], [9], [11], [3], and [6]. Reference [6] presented pairs of nearly identical traffic scene pictures (one picture in each pair contained an additional object which made the scene more complex). Drivers had to note the speed they would adopt if they were driving in similar situations. The research findings indicated that novice drivers adopted higher speeds in the more complex situations whereas experienced drivers adopted lower speeds. These findings might indicate that experienced drivers are sensitive to aspects of the situation that are not discernable by novices. In a different study [2], participants had to classify 39 traffic situations that showed various road and weather conditions into an arbitrary number of groups of similarly hazardous situations. Results showed that experienced drivers built a ranking order of groups, thus dealing with hazardousness as a quantity (e.g., ''This is most . . . least hazardous group", etc., p. 5). On the other hand, drivers with half the driving experience, used a nominal scale for classifying the pictures into groups of equal quality of hazardousness (''The situations in this group are similarly hazardous because of the intersections in each", ''all wet road situations", etc., p. 6). The conclusion suggested that ''the greater the driving experience the more able the driver to regard hazardousness as being a holistic attribute of the traffic situation and to integrate many different aspects of the situation" (p. 6). Although the researchers argued that experienced drivers integrate many aspects of the traffic situation to create a holistic picture

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(mental model) of the hazardous situations they did not indicate what exactly those elements are, how they are integrated, and which elements are better perceived with increasing driving experience.

Recently [3] found conceptually-related differences between experienced and young-inexperienced drivers that may provide initial evidence to the types of elements (i.e., dimensions, aspects) in a hazardous situation that are associated with driving experience. In their research, young-inexperienced, experienced, and older drivers had to observe six traffic-scene movies and classify them into an arbitrary number of groups according to the similarity in their hazardous situations. It was found that young-inexperienced drivers tended to classify the movies according to the similarity in the hazard instigator (e.g., "in both movies there is a sudden brake of a lead vehicle") and did not relate to aspects of the traffic environment. Experienced drivers, on the other hand, tended to classify the movies according to the similarity in their environmental aspects (e.g., "in both movies the road is narrow inside a residential area"). It was concluded that experienced drivers tend to consider potential hazard components (e.g., parked cars, intersections, and lack in the field of view) in their classification whereas young-inexperienced drivers consider primarily actual hazards (e.g., a roller skater entering the road, or a lead vehicle brakes). Discrimination between a potential hazardous situation (i.e., a situation in which one or more factors may be obscured or absent from the scene but yet may turn into an actual threat in the near future) and an actual hazardous situation (i.e., a situation which requires an imminent response to prevent a crash) is highly important. Yet it is not clear which factor(s) are considered potential hazards and when these factors become salient enough to evoke an evasive action. Some studies however, showed that young-inexperienced drivers do not visually scan areas embedding potential risks such as intersections, e.g., [15] and [4].

A large body of research investigated how expertise, affects the way knowledge is organized and what exactly is the type of knowledge about objects and events which is more accessible to experts than novices. Reference [14], for example, explored the effects of expertise on basic level of categorizations. In that study, individuals with varying levels of knowledge about songbirds generated lists of attributes, named objects, and verified category membership at 4 hierarchical levels (super-ordinate, basic-level, subordinate, and sub-subordinate). The authors found that expertise increased access to categorical information at subordinate level for both intermediate and experts, causing these sublevels to function as basic. Specifically, the authors showed that bird expert named much more new features of an object at sub-ordinate and sub-subordinate levels than novices, and that bird experts related more to behavioral features (i.e., attributes that were relevant to the behaviors of functions of category exemplars) than physical features (i.e. attributes that related to form and perceptually-based features) at the sub-subordinate level whereas intermediate experts related equally to both physical and behavioral attributes at the sub-subordinate level. The novice related much more to physical attributes at this level. The authors concluded that experts attend to different and more subtle perceptual features than novices. These findings were consistent with previous descriptions of expert categorical knowledge [5] in which experts tended to categorize on the basis of abstract (deep) features, whereas novices were bound to perceptible (superficial) features.

Taking it all together back to the driving domain, such evidence might suggest that experienced drivers are able to perceive deeper structures of the traffic environment. Those may contain specific aspects of the environment that are either obscured or currently absent from the driver's direct perception of objects along the road. Such aspects are potential hazards that can be rarely perceived without domain-specific knowledge [3]. It might be argued that being aware of those deeper structures of the traffic environment assists the experienced driver in predicting near future events.

To conclude, the present study aimed at examining whether experienced drivers are more sensitive to potential hazards than young-inexperienced drivers when both potential and actual hazards are under control. Young-inexperienced, moderately experienced, and very experienced (taxi) drivers observed still photographs from a variety of traffic situations and had to name three prominent hazards in each picture. While observing the traffic scenarios participants were connected to a head-free Eye Tracking System (ETS) and their scanning patterns were recorded on a designated computer. The pictures array included 8 pairs of nearly identical target pictures and 105 distracter pictures. The only different between a pair of pictures was an additional actual hazard element that was added to one of the pictures in each pair.

II. Hypothesis

1) Moderately experienced and very experienced (taxi) drivers will indicate more potential hazards than young-inexperienced drivers
2) Both moderately and very experienced drivers will fixate more on potential hazards than young-inexperienced drivers.
3) On the continuum of driving experience (based on the number of accumulated driving years and kilometers), differences will be more pronounced between very experienced and young-inexperienced drivers, i.e., conceptual knowledge continues to develop even among moderately experienced drivers.

III. Method

A. Participants

Twenty-nine participants: 10 young-inexperienced drivers (17–18 years old, mean of 1.8 (SD=0.9) *months* of driving experience), 10 moderately experienced drivers (23–28 years old, mean of 8.9 (1.6) *years* of driving experience, driving on

average 3700 (2100) km/year), and 9 very experienced (taxi) drivers (30–58 years old, mean of 29.7 (8.1) *years* of driving experience and a mean of 13.8 (7.6) years as taxi drivers, driving on average 87,000 (48,000) km/year). The moderately experienced drivers were students in Ben-Gurion University. Young-inexperienced drivers were recruited through local driving schools. The taxi drivers were largely recruited from taxi stations in Beer-Sheva. Participants received monetary compensation for participation. All participants had normal vision, with uncorrected Snellen static acuity of 6/9 (20/30) or better, normal color vision, and normal contrast sensitivity.

B. Apparatus

The experiment was conducted in the Eye Tracking Laboratory at Ben Gurion University. A 19" wide LCD screen connected to a Pentium 4 PC displayed the different pictures. The participants sat at an average distance of 63 cm from the LCD creating a visual field of 23 degrees vertically and 35 horizontally. During the experiment, the LCD resolution was set to 1360 by 768 pixels.

1) Eye tracking System ASL-D6 and ILAB analysis software

Participants were connected to a head-free Eye Tracking System (ETS), a product of Applied Science Laboratories (ASL) model D6. The D6 does not require any equipment attached to the participant allowing free movement of the head. The ETS records the location of gaze (both horizontal and vertical location) 60 times a second (60Hz) on the participant's screen. The accuracy of the system is 1degree of visual angle. D6 allows a relatively fast calibration as it uses facial recognition program to find the participant's eye. A designated MATLAB-based freeware [10], ILAB, was used to produce fixations from raw data.

2) Stimuli: traffic scene pictures, targets and distracters

Participants observed 137 traffic scene pictures taken from a driver's perspective in different traffic environments. The pictures included 8 pairs of Target Pictures (TPs), 105 Distracter Pictures (DPs) and 5 pictures that were used for training and accommodation to the experimental procedure. Each TP pair was manipulated to produce two nearly identical pictures with a single difference. Specifically, TPs included various potential hazards (e.g., intersections, brow of a hill, curved roads, vegetation obscuring the field of view, etc.) but only one picture in each pair included an additional actual hazards (e.g., a pedestrian crossing the road, a car emerging from the right side , etc.), as shown in Fig. 1. On the left column of Fig. 1 the pictures include a materialized hazard (a vehicle (top) and a pedestrian (bottom)) and on the right column the actual hazards are absent.

To keep pictures' naturalism, the actual hazard was either removed from the scene using Photoshop or the same photograph was taken twice at the same location from the same point of view.

Fig. 1 An example of two pairs of target pictures (TP)

3) Picture presentation software

Self-developed software was utilized to present the pictures. Pictures were presented randomly and for a pre-determined duration of 3 seconds. In order to reduce memory effects (i.e., the ability to recall that a pair of pictures was nearly identical) the number of distracters between two consecutive TPs was set to six (based on a pilot study with a varied number of distracters). After presenting a TP participants were asked (instructions were presented on the computer screen) to verbally indicate three prominent hazards that they have identified in the picture and to verbally rate the level of hazardousness on a 0-100 scale. To further reduce memory effects, identical instructions were presented for two out of every six DPs separating two consecutive TPs. These two DPs were randomly selected. The software recorded an MP3 audio file for each verbal description. Finally, while a participant observed a picture the software sent the picture number to the eye tracking system to allow synchronization between the eye movements and the appropriate picture.

C. Task instructions

Participants were given the following definition for hazard: *''In terms of hazards to road users, any object, situation, occurrence or combination of these that introduce the possibility of the individual road user experiencing harm should be included. Hazards may be obstructions in the roadway, a slippery road surface, merging traffic, weather conditions, distractions, a defective vehicle, or any number of other circumstances"* [17], p. 3. A participant was asked to mention only three hazards (or less if he or she could not find more than one or two). Then, the participant was asked to indicate "what was the total level of hazardousness in the picture you have just seen"? A 0-100 scale with 5 tick intervals appeared on the screen and the participant noted the rate verbally. Verbal responses were used in order to maximize participants' memory recall.

D. Procedure

Each participant arrived separately to the Eye Movements Laboratory and signed a consent form. Then, he or she was

asked to complete a demographical questionnaire that included data such as driving experience, gender, accident records, etc. Once completed, he or she was presented with the experimental instructions. Then, a short eye tracking calibration procedure was applied and the participant began the training session. Five traffic scene pictures were presented during training and for two of them (randomly selected) the participant was asked to verbally indicate three hazards and verbally specify the level of hazardousness in the picture. During this phase, experimenters made sure that data was appropriately recorded. Following training, the participant was instructed to ask questions if something regarding the task was misunderstood. Then, the experiment began.

IV. Results

Two contrasting approaches can be used to analyze the data. The *a-priori* hypotheses top-down approach relates to data analysis according to predetermined hypotheses which are prominently based on expected differences among drivers with a varied level of driving experience. The *data driven* approach relates to a complementary analysis based on clustering derived from the observed data. The a-priori analysis can capture aspects of experience-related differences but may also overlook other aspects which were not hypothesized a priori. This paper includes only the a-priori, hypotheses-driven analysis. For each participant, data collection included two types of data:

1) Verbal descriptions of hazard elements in the TPs for each picture,
2) The scan path for each picture composing points-of-gaze sampled at 60Hz (using and Eye Tracking System).

To analyze scanning patterns, both actual and potential hazards in each TP were pre-defined as Areas of Interest (AOI). Fig. 2 shows an example of such predefined AOIs in a pair of TPs. The white rectangle in Fig. 2 shows an example of actual AOI (the woman walking along the road) and the black dashed rectangles show examples of potential AOIs (the emerging road on the left, and the intersection in front). Overlap of white and black rectangles was required here to include the intersection and stop sign.

Altogether there were 13 predefined AOIs of potential hazards and 8 of actual hazards (one for each TP pair).

Fig. 2 An example of pre-defined AOIs in a pair of TPs.

AOIs were analyzed by separately examining: (1) whether the verbal analysis of hazardous elements in each TP corresponded to the AOIs defined for each particular TP, and (2) whether fixations analysis as derived from the eye tracking data corresponded to the AOIs defined for each particular TP. Analyzing of the verbal descriptions required going over the verbal descriptions for each TP for each participant and deciding whether the participant mentioned the specific predefined AOIs in the picture. If a participant explicitly mentioned the area (e.g., “there is a dangerous curve in front of me”) then the specific AOI was marked as “1”, otherwise, it was marked as “0”. Secondly, a similar screening was conducted on the fixation patterns in order to examine whether drivers had actually fixated on these AOIs and for how long. The fixation analysis is complimentary to the verbal response as it allows investigating whether drivers who did not mention a specific AOI did, however, fixate on it (i.e., did they see it but failed to perceive its hazardousness or did they miss seeing it altogether). Furthermore, this analysis enabled discovering whether drivers with varied level of driving experience detected potential and actual hazards in a similar fashion.

The presents paper present only the verbal response analysis while the fixations analysis will be reported elsewhere.

A. AOI: Verbal analysis

The distribution of the dependent variable related to whether a driver mentioned a pre-determined AOI as hazardous in the verbal description is binomial (“1” if mentioned and "0" if not). Therefore, data were analyzed using logistic regression with a random intercept to represent random effects of participants and pictures. The logistic regression model was applied for all TPs twice: (1) AOIs with Potential hazards, and (2) AOIs containing actual hazards. The variables 'Driver Type' and TP Type' were entered as fixed effects in addition to the two random effects previously mentioned.

Running the logistic regression using backwards elimination yielded a statistically significant main effect for 'Driver Type' (χ^2_2=14.2739, p<0.01). Both TP Type' main effect and the interaction between TP Type' and 'Driver Type' were not statistically significant (χ^2_2=0.06, p>0.1; χ^2_2=1.95, p>0.1 respectively). To further investigate the 'Driver Type' main effect a pairwise comparison revealed that the young-inexperienced drivers were statistically different from both moderately experienced and very experienced (taxi) drivers (t255=-3.9, p<0.01; t255=-3.53, p<0.01 respectively) and the difference between the moderately experienced and taxi drivers was not statistically significant (t255=-0.33; p>0.1). The likelihood that a moderately experienced and or taxi driver will indicate an area of interest as hazardous was 0.372 whereas the likelihood of a young-inexperienced driver to indicate an area of interest as hazardous was 0.164. The odds ratio between experienced and young-inexperienced drivers was 3.02.

A similar analysis was conducted on AOIs of actual hazards, in order to examine whether drivers detected the actual hazards in the TPs. As expected, no statistically significant differences were found among drivers (χ^2_2=2.26,

p=0.32) suggesting that all drivers detected the actual hazards at a similar likelihood of 0.80.

B. AOI: results summary

The verbal response and analysis revealed there were significant self-report differences between the more experienced drivers and the young-inexperienced drivers. These findings suggest that young-drivers failed to perceive and understand the hazardousness in the examined AOI's. Therefore young-inexperienced drivers did not mention these AOIs in their verbal descriptions.

V. Discussion

The present study aimed to examine whether experienced drivers are more sensitive to potential hazards than young-inexperienced drivers regardless of whether the actual hazards are present or not.

It was investigated whether moderately experienced and very experienced (i.e., taxi drivers) did indeed verbally report and on more potential hazards than young-inexperienced drivers. Preliminary analysis revealed that both moderately experienced and taxi drivers were significantly more likely to report on potential hazards than young-inexperienced drivers regardless of target type (i.e., whether an actual hazard was absent or present).These findings suggest that young-inexperienced drivers were less aware of the potential hazards embedded in the examined AOIs.

Consistent with others, e.g., [5], [14], and [3] the present findings also suggest that only moderately experienced and very experienced drivers extracted more subtle aspects of the traffic environment (i.e. potential hazards), sometimes also called "deep structure" elements [5].

Furthermore, the preliminary analysis shown here did not find any verbal report differences between moderately experienced and very experienced drivers with regard to potential hazards. One possible explanation would be that the potential hazards investigated here were all conceptually inherent to both driver groups. There are other aspects of the traffic environment which were not investigate here that may have showed more pronounced differences between moderately and very experienced drivers. Reference [14], for example, showed that although intermediate level bird experts related to behavioral features of song birds similarly to experts they still related to more physical features in a close way to novices. Current findings might suggest that the potential hazards investigated here were sufficiently practiced among moderately experienced drivers and therefore did not produce any significant experience-based differences. In addition to other road-related potential hazards that were not presented here, data driven analysis might reveal additional differences which were not found in the a-priori analysis and this will be further investigated.

To conclude, the present study, although presenting only initial and partial results, suggests that both moderately and very experienced drivers are more aware of potential hazards than young-inexperienced drivers. Thus, by relating to the deep structure of the traffic environment (i.e., potential hazards) regardless of the presence of an actual hazard, experienced drivers possess a better situation model of the traffic environment according which they evaluate current state, anticipate various future states and select the most appropriate maneuver under these circumstances.

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