Are globality and locality related to driver’s hazard perception abilities?

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Abstract

Driving requires various skills, amongst them hazard perception that has been directly linked to involvement in traffic accidents. Navon-type tasks may provide a framework for understanding perceptual processing and logical reasoning. Yet, limited attempts were made to formulate associations between globality and locality in visual processing and perception of real world stimuli like hazards while driving. A study aimed to link Navon-type tasks with hazard perception abilities of drivers was conducted. A sample of 39 young novice drivers, 60 adult students, and 21 adult drivers completed a battery of cognitive test including Navon tasks. Then they performed a hazard perception test (HPT), in which they observed video-based traffic-scenes and were asked to press a response button each time they detected a hazard, followed by classification and rating of hazardous scenes. While there is a known statistically significant effect for experience, results reveal significant ties between global and local processing, and hazard perception. The significant effect of the global/local scores in the Navon tasks on performance on a real-world traffic situation test suggests that the Navon tasks, as well as other cognitive tests may be useful in predicting performance in real world complex situations such as driving.

Introduction

Among the different types of skills required for good driving, the only one that has been identified to have direct connection to involvement in car accidents is Hazard Perception (HP), the ability of the driver to predict hazardous situations (Horswill & McKenna, 2004). Studies have shown a connection between cognitive abilities and car accidents occurrences, mostly among adults (Horswill et al., 2008). In McKnight and McKnight (1999), cognitive abilities such as: attention allocation, perception speed and short-term memory were tested, along with their effect on driving skills and dangerous behaviour on the road. A positive correlation was found between driving skills and cognitive abilities. In addition, a negative correlation was found between the number of traffic tickets and car accidents in which the participant was involved in, and cognitive abilities. Other studies found that other cognitive skills such as: spatial perception (Maratolli, 1998), and handling functions (Daigneault, 2002) affected driving.

Several studies have shown that the ability to perceive hazards is related to Higher-Order abilities. Among them: cognitive flexibility, problem solving, urge control (Delis et al., 2001), task analysis, strategy monitoring, (Borkowsky & Burke, 1996),
attentional control and goal setting (Anderson et al., 2001). Horswill and McKenna (1999) have found that during a hazard perception test, young drivers who were given an additional verbal task, that was nor motor or visual, were taking substantially more time to respond to danger. They therefore claim that the hazard perception process requires allocating higher-order abilities.

In the literature the terms “Hazard Perception” and “Situational Awareness” are described as bearing one meaning when it comes to driving. They both describe the way in which a driver is aware of details in the surroundings (vehicles, pedestrians, traffic-signs), and how the awareness to those details aids him in predicting hazardous situations. Situational awareness (SA) is considered to be related to higher-order cognitive abilities. In FMRI and EEG imaging tests, a connection was found between SA and cerebral structures in charge of higher-order cognitive abilities (Borghini et al, 2012; Brookings, Wilson & Swain, 1996). Previous studies, specifically conducted on experienced drivers, detailed the cognitive and psycho-motor features that effect driving and safety (Horswill et al., 2008; Anstey, 2005), but the cognitive abilities that relate to hazard perception among all driver population is a field that has yet to be studied.

A traffic Hazard Perception Test (HPT) was developed at Ben-Gurion University of the Negev (Borowsky, Oron-Gilad, Shinar & Meir, 2010). The HPT is a computer-simulated test composed of three components: at first drivers are shown a set of movies and asked to identify hazardous situations, all while eye-motion is being documented; in the second component they are asked to classify scenes by certain similar properties, and in the final stage – a set of six pairs of still-scenes are shown and at this point they are asked to mark the still that they perceive as being the more dangerous one (see Borowsky & Oron-Gilad, 2013 for detail).

In the current study, the aim was to find ties between the HPT components and higher order cognitive abilities. Specifically two cognitive abilities were examined: logical reasoning by using Navon tasks (Navon, 1977; Stanovich & West, 1997) and attentional control, by the Attentional Control Scale (Derryberry & Reed, 2002). According to Navon (1977; Schooler, 2002, in Foster, 2010), people can use different processing styles. By using a global processing style, people attend to the Gestalt of a stimulus set, whereas when using a local processing style they attend to its details. The attentional control scale measures abilities such as attention focusing, directing attention from target to another and thoughts control. It was hypothesised that participants’ performance in logical reasoning and attentional control will affect their scores in each one of the three components of the HPT.

**Experimental materials and method**

**Participants**

A hundred and twenty participants: 39 young-novice drivers (17–18 years old) with less than three months of driving experience; 60 experienced drivers (24–28), with an average of 8.2 years of driving experience; 21 very experienced drivers (40–60), with an average of 28.2 years of driving experience. Young-inexperienced participants received monetary compensation for their participation. Experienced
participants completed the experiment for course credit in an introductory
ergonomics course and the very experienced drivers had all volunteered. The very
experienced participants were recruited from the city of Ashkelon. The experienced
drivers were students in the University, and the young-inexperienced drivers were
recruited through driving schools in the city of Beer-Sheva.

Apparatus

Participants were measured for their abilities in driving related hazard perception,
and other more general cognitive abilities, using a computer-based test. The hazard
perception test (HPT) was the one developed by Borowsky, Meir, Oron-Gilad and
Shinar (2010). Through the years several sessions of experiments were executed,
and several iterations of the HPT were created in order to refine the test until it
reached its final version. A 19” wide screen with 1024×768 pixels was used to
display the hazard perception test and the cognitive abilities tests. Participants sat at
an average distance of 70 cm from the screen.

Hazard Perception Test (HPT)

The HPT includes three components: Identification, Categorization and
Rating tasks. In the identification component participants were asked to
observe 21 traffic movies from the perspective of a driver and press the
“Space” button on the keyboard each time they detected a hazardous
situation. At the end of each movie participants were asked to verbally note
the hazard instigator for each hazardous situation that they have detected
(Figure 1).

![Image](image.png)

*Figure 16. Left: An example of the movie presentation (a snapshot sample) and
Right: the following screen, at the end of the movie where participants had to
register each button press they made.*

Following the active identification component, in the categorization task,
participants observed eight traffic scene movies for the second time and were asked
to categorize them into an arbitrary number of groups according to the similarity in
their hazardous situations (Figure 2). This procedure resembled the one used in Borowsky et al. (2009).

Figure 17. Representative photos of eight movies that were used in the classification component of the computer based HPT.

In this third component, participants were asked to compare 6 pairs of pictures that were taken from the HPT movie database that the participants just observed in previous components of the test. In each comparison two pictures appeared with a hazardousness scale. The scale ranged from “a more severe danger/a greater danger” located at the end of the scale under each picture, and “equal danger” which was located in the middle between the two pictures (Figure 3).
The cognitive test battery consisted of Navon tasks (Navon, 1977) and the Attention control scale (Derryberry & Reed, 2002) using standard administration protocols and trained examiners.

**Navon Tasks.** In this type of tasks, the global large letter is combined of small letters (e.g., the letter ‘H’ in Figure 4). Attending to the large letter represents the global level, while attending to the small letters represent the local level. Participants were asked to press the letters ‘S’ or ‘H’ on a keyboard as soon as they identified one of those letters, when the letter could be portrayed either as a big letter (global level), or a small letter constituting a big letter (local level). In each of the conditions, the big letter is presented as slanted to one side and for a very brief time. In this task, the accuracy is measured, meaning whether the participant was correct/incorrect in identifying the letter, and the response time (RT).

**Figure 4.** On the right image, the small letters ‘H’ represent the local level. On the left image, the letter ‘H’ represents the global level (Navon, 1977).

**Attention Control Scale.** Attention control is evaluated according to a value scale containing a person’s personal ability to divert attention to the appropriate direction in accordance to the environment in which he is located. Factor analysis indicates that the scale measures the general ability to control attention, combined with the following personal skills: a) focusing the
attention, b) displacing/ refocusing attention between various tasks, c) flexibility of control in thinking.

Procedure

To generate randomization and to avoid priming effect, half of the participants started with the hazard perception test, and half of them started the experiment with the cognitive ability battery. Before starting the HPT, participants were given instructions and two training hazard perception movies in order to verify that they understood the experimental task. At the end of the training, the instruction screen appeared again, and then the test with the 21 hazard perception movies began. The order of the movies was randomised and movies were separated by a fixation screen. Upon finishing the hazard detection task, participants were instructed on the classification task. They were told that they are about to observe eight movies for the second time, and then were asked to name each group of movies, in a way thought would best describe them. In the third part of the test participants were asked to compare 6 pairs of still-scenes and to locate the pointer on the hazardousness scale.

Before starting the cognitive tests, participants were told that they would be completing a series of cognitive ability tests. The presentation order of the two was counterbalanced across testing sessions. Written test instructions were read aloud to the participants by the test examiner before each test was administered. Participants completed the cognitive ability battery and the three components of the HPT, in a total duration of approximately 1 hour.

Results

The main purpose of the experiment was to discover whether having specific abilities and traits related to visual attention, can predict perception of real world stimuli like hazards while driving. The analysis was made on the three components of the HPT. Results are presented in the same order as the experimental procedure. The generalised linear mixed-effects model (GLMMs) was used for the statistical analysis. Performance outcomes of the three hazard perception’s components were set to be the explanatory variable; Navon tasks, and the attention control scale were set to be the potential exploratory variables of the model. The ‘participants’ variable was set to be the random effect, and included in the model in order to care for individual differences among participants. Using a backward elimination process by p-values, the most fitting model was set for each of the explanatory variables. Consequently, the appropriate GLMM was applied on the data set.

Component Identification of events in a dynamic scene

Accuracy. Hazardous events were not defined a priori, but were data driven, subjectively defined according to the pool of all participants’ responses. The beginning of an event was defined as the minimum time to respond, of all responses related to it. Similarly, the end of each event was defined as the maximum time to respond, of all responses related to it. Thus, the duration of each event was defined as the time interval between its beginning and its end. Participants’ responses which referred to the same hazard instigator and had a temporal proximity to each other
were gathered and defined as the same event. I.e., an event was an instance that was
detected by any number of participants, who used approximately the same
explanation to describe it, and occurred in nearby frames. Each of these events was
then titled based on the idiosyncratic definitions given to it by each of the
participants who registered it. This event-definition procedure ended up with a total
of 67 events spread across the 21 HP test movies. Events were defined and labeled
as “Experienced-Based Events” (EBEs) if at least 31 of the experienced drivers group
(i.e., 50% of the experienced drivers) reported them as hazardous (as reflected by
their button presses and written descriptions). This criterion allowed the creation of
an array of representative, noteworthy genuine EBEs, thus enabling the experienced-
drivers’ group to be set as a goal standard.

A multinomial regression with a logit link function was applied in the framework of
GLMM. The dependent variable was response to EBE (0 or 1) and the independent
variables were (1) Logical reasoning measured by Navon task measures and 2) Attention control by attentional control (AC) scale. Applying a backward elimination procedure found the best fitting model has two significant exploratory effects: Accuracy and Global RT in the Navon tasks both were statistically significant (F(1,111)=10.39, p=.002; F(1,111)=7.17, p=.008), respectively. No significant effect has been revealed for AC. Meaning, there was a correlation between recognition of hazardous events, and logical reasoning, and the processing of global features as they show in the Navon tasks.

Response time. Response time analysis was also conducted on the EBEs, where
there is meaning to the immediacy of response. For each of the participants’ mouse
clicks, an elapsed time in milliseconds was assigned for the time in which it was
performed since the initiation of the video. Each press made by a participant was
recorded according to its frame number. To standardize response time, the interval
between a participant’s response (frame number) to a specific event and the
beginning of that event (frame number) was divided by the length of the event
(frames), see Equation 1.

Applying the GLMM revealed that AC, and Navon in the Global RT were
statistically significant predictors for quicker reaction time to hazardous events
(F(1,113)=29.38, p<.0001; F(1,113)=19.57, p<.0001; F(1,113)=10.97, p<.0001,
respectively). Meaning that there was a correlation between fast responses to
hazardous events, and logical reasoning and global analysis and AC.

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\text{Standardized response time} = \frac{\text{Participant’s response frame} - \text{event start frame}}{\text{Event end frame} - \text{Events start frame} \times 100}
\]

Equation 1. Calculation of the standardised response time for EBE events in the
computer based HPT component 1

Component 2 – Classification

In the categorization task the dependent variable, i.e., the number of categories and
the number of movies in each category varied from one participant to another.
Although the number of possibilities to categorize the movies is theoretically
unlimited, the observed number of arrangements was much smaller (e.g., Borowsky et al., 2009). It was decided to identify dominant clusters of movies, i.e., clusters or combinations of clusters that were categorised by a certain percentage of all participants and to scale them according to the abstraction of the classification, where higher abstraction implies on higher understanding of the road environment. Five possible structures for classification were rated with 1 being a criterion of classification indicating a low level of classification abstraction and 5 being the highest level according to Benda and Hoyos (1983): (1) No hazards; (2) Similarity in the Hazard Instigator - intersection, pedestrian, field of view, other vehicle behavior, driver’s behavior, crosswalk and traffic circle; (3) Hybrid-Hazard Instigator and Traffic Environment; (4) Traffic Environment - urban, residential, and inter-city; (5) Level of hazard-low, medium and high. A priori, the set was categorised on the basis of these five structures. This a priori categorization reflects exclusive reliance on either one of the five structures—that is a driver who related solely to a single categorization criterion (1-5). Notably, it was not expected that drivers will categorize movies exclusively according to the pre-defined categorization structures (Ahn & Medin, 1992).

Multinomial regression with a Logit link function was applied in the framework of the GLMMs on the data. Applying a backward elimination procedure found the best fitting model had only one statistically significant exploratory effect: Navon task in the local Accuracy condition \(F(1,111) = 3.039, p = .08\). Meaning, there was a correlation between participants who succeeded in the classification task who their abstraction rank was high and logical reasoning and local analysis.

Component 3 – Ratings

In this task each participant was asked to compare between two pictures by locating the pointer on the picture according to its danger. Analysis of the results began by defining a priori a gold standard solution based on a pilot experiment with very experienced drivers. Based on its results every one of the six comparisons got one of three grades: The highest grade was 2, meaning that the selected picture was rated as more dangerous than the other picture according to the gold standard solution; The lowest grade was 0, meaning that the selected picture wasn’t the most dangerous picture out of the two pictures according to the gold standard solution; The intermediate grade 1 was given when these two pictures were equally dangerous. After grading each of the six comparisons for every participant, an average grade was calculated for each participant’s rating abilities. The minimum average grade was 0.33 and the maximum average grade was 2, which means that some participants were always correct in the way they rated the most dangerous picture in a similar way to the gold standard solution. Applying the GLMM revealed that only the Navon task in the Local RT condition affects the correct rating in comparing two hazardous events \(F(1,113) = 10.45, p = .002\). Meaning, there was a correlation between successful rating of hazardous events, and logical reasoning and local analysis.
Discussion

In the literature there is little evidence of studies that tested which of the higher-order cognitive abilities may improve drivers’ ability to perceive hazards. The current study is a primary research to evaluate the connection between logical reasoning, and attentional control, and the ability to commit hazard perception in driving.

Logical reasoning was measured using the Navon Tasks. In the Navon tasks several sub-measures were produced: an accuracy scale – whether the right letter was recognised, a response-time scale – how fast was the letter recognised, a scale for the letter’s level – whether the recognised letter was in a global or a local processing level. It was found that logical reasoning was manifested in all three components of the HPT; participants who succeed in the identification task, and detected many events quickly, succeed as well in logical reasoning with global analysis. Furthermore, participants who succeed in the classification task, and their abstraction rank was high, succeed as well in logical reasoning with local analysis. In addition, Participants who succeed in the rating task, and their rating’s score was high, succeed as well in logical reasoning with local analysis.

Navon (1977) has claimed that people process information using two procedures: a global processing procedure and a local processing procedure. At the global level, processing is conducted by a general stimulations layout (looking at the “forest”), while at the local level, it is conducted by a more specific layout paying attention to details (looking at the “trees”). Navon has demonstrated that the time it takes to respond to a big letter (global level) is shorter than the time it takes to respond to the smaller letters (local level) that make the bigger one. With this in mind – he claimed that the entire population’s default is the global processing procedure. Based on Forster’s (2010) research and Navon’s (1977) claim that the population’s default is indeed a global processing procedure – it could have expected that the processing procedure in the Navon Task would be global. The results of the study have shown a different outcome: while at the first component of the hazard perception test – the corresponding processing procedure in the Navon Task was global, as expected, for the second and third components - classifying and rating pictures - the processing procedure in the Navon Task was local. This can be explained by the characteristics of the HPT. For the first component of the hazard perception test – each movie scene evolved and changed in a short period of time – at which the participant was required to identify the danger and respond by pressing a button. In the second and third components – the time to respond was unlimited. When participants are required to perform the test component in an unlimited amount of time – there is no feeling of pressure – as opposed to the first stage. Therefore, the test participants performed the classifying and rating tasks while delving into details and concentrating on all of the pictures’ elements.

As for the attentional control, it was found that this ability was reflected only in the first component of the test and not in the second and third components. There is disagreement in the literature as to how this ability is expressed in dynamic versus static displays. Some researchers claim that attentional control reflects differently in
dynamic displays as opposed to static ones (Kramer, Larish & Strayer, 1995). It is possible that the characteristics of the first component of the test, movies that dynamically changing, compared to the second and third components which are presented in a static display, contributed to the way this cognitive abilities were expressed in the test.

Research limitations and practical implications

According to Horswill (2008), a decline in cognitive abilities can affect the manner in which adult drivers perceive hazards. Studies show a decrease in responsiveness (Salthouse, 1996) and task-shifting (Mayr & Liebscher, 2001) that can affect a driver’s performance on the road. This calls for a future research that will focus on adults above the age of 65, and test how hazard perception takes place among that particular group, considering sustained changes in cognitive procedures.

In the current research - a computed hazard perception test was used. It consisted of 21 videos depicting various hazardous situations. This study cannot reflect upon the total spectrum of driving situations, nor can it simulate all realistic driving situations. Additionally – higher-order cognitive skills include: problem solving, rule activation, attention, locating and fixing errors and memory. Perhaps other cognitive abilities would render different results than the current ones. Since this study constitutes a primal research, future studies can measure the effects of the aforementioned higher-order cognitive skills on drivers’ ability to perceive hazards.

Neuroergonomics is a field that has evolved during the past several years and it holds two principles: Neuroscience and Ergonomics. One of the purposes of Neuroergonomics is to establish and expand an understanding of the connection between brain functions and real-life performances (Parasuraman & Rizzo 2007; Parasuraman, 2003; 2008). Due to the emergence of un-intrusive brain-monitoring techniques, future studies can test the functionality of specific areas that act during hazard perception in driving, and by doing so – determine the location of that specific area of the brain and the set of cognitive skills involved.

Mapping and identifying the cognitive abilities required to perceive hazards may be beneficial at two levels. First of all – from the evaluation side – a hazard perception test can be used to assess the performance of a driver on the road, specifically among the senior adult community – where there is a need for more assessment tools to determine competency. A computerised HPT that also measures cognitive abilities such as spatial ability, logical reasoning and attentional control can objectively assess a person’s competence to drive a vehicle, as opposed to today’s subjective evaluation. Secondly – since it was found that cognitive abilities have an effect on hazard perception in driving, a training program devised to improve these abilities can be issued, so that weaker populations such as senior citizens and people with attentional disabilities can train to improve their ability to perceive hazards.

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