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Becoming an expert: Eye movements in static traffic scenes

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Abstract

Eye movements are a key behavior for visual orientation in traffic situations and for vehicle control. Although some studies address the cognition of dangerous situations while driving, little is known about the development of visual orientation in novice drivers. Recent studies show that effective ways of eye guidance are directly related to the recognition of dangerous situations [7]. In the present eye movement study, we especially looked at the first months of driving experience compared to expert driving while looking at static traffic scenes with varying degrees of danger. These scenes were already evaluated by previous RT studies with N=2025 drivers [3]. Relevant parameters will be discussed: the development of the functional field of view, efficiency of individual scan path routines, time of first fixation on danger, and danger processing time with respect to relevant theoretical conceptions and previous studies in the field.

Keywords: Eye Movements, Young Drivers, Hazard Perception, Visual Orientation

1. Introduction

Eye movements are probably the most important part of visual orientation and particularly suited as valid indicators for the selection of to-be-processed objects. In a driving situation, it is especially important to detect and process objects that may be dangerous and possibly lead to accidents. Previous studies have shown that experienced drivers are significantly faster in detecting dangerous traffic situations, compared to novices [6]. However, these studies usually do not report distinct subprocesses of hazard perception, such as danger detection time and danger processing time.

Regarding differences in visual orientation in traffic situations, differences between experts and novice drivers can be considered as secured [5]. Recent studies found that experienced drivers showed shorter gaze durations on dangerous objects and increased horizontal variance in fixation locations compared to novice drivers [1]. Crundall and Underwood [2] reported similar results, showing that experienced drivers adjust their scanning patterns to different road types, whereas the strategies of inexperienced drivers were rather inflexible. Falkmer and Gregersen [4] found that inexperienced drivers tended to locate their focus of attention more on in-vehicle objects, whereas experienced drivers had more fixations on objects closer to the vehicle.

These studies were conducted using either dynamic traffic scenes (videos) without a vehicle control demand or during driving in real traffic situations. However, it might additionally be interesting to compare different degrees of expertise while looking at static traffic scenes with a sudden onset because of two reasons. First, in normal traffic situations it is a common task to rapidly process a completely new visual scene without any preparation, e.g. looking to the left and right prior to crossing a street. Second, it is reasonable to assume that this highly time-limited situation is especially useful to detect differences in expertise. In the current experiment we additionally avoided any further tasks related to the handling of vehicle controls, since we selectively wanted to look at individual differences concerning visual orientation.

In previous hazard perception studies, the main parameter of interest was the time between the onset of a scene and a reaction, for example whether the situation is dangerous or not [6]. In this experiment, we look at two separate processes that constitute reaction time (RT), that is the time until a dangerous element of a scene is looked at for the first time (danger detection time) and the time from the first fixation until manual response (danger processing time). This analysis is only possible combining standard RT and eye movement analyses.

2. Method

2.1. Participants

14 experienced and 16 novice drivers, aged from 18 to 41 years, took part in this study. Experienced drivers were mainly students from RWTH Aachen University. Novice drivers were recruited from local schools. The experienced drivers had a mean driving experience of 77 months and the novice drivers of 9 months, ranging from 0,2 to 276 months. The mean age of the experienced drivers was 24 years (sd = 4 years) and 18 years (sd = 0,5 years) for the novices.

2.2 Materials and apparatus

The pictures used in the current experiment were taken from a previous reaction time study [3] and consisted of 150 scenes, which show traffic situations from the drivers perspective. The pictures stem from real traffic environments and selectively contain dangerous situations, such as road works, a sudden braking of a car ahead, pedestrians or suddenly appearing children. The pictures were divided into three hazard categories (highly dangerous, medium dangerous, and safe traffic scenes). These categories were validated by previous RT experiments with N = 2025 subjects that showed significant RT differences [3]. Prior to the main experiment, scenes with landscapes combined with safe traffic scenes were shown in the context of a task that was not related to traffic to ensure that no differences in general eye movement behavior existed between groups. Eye movements were recorded using a head mounted EyeLink I system with a temporal resolution of 250 Hz and a spatial resolution of few minutes or arc. Subjects were seated in front of a 21”-monitor with a chinrest and a keyboard.

2.3 Procedure

In the main experiment, 90 pictures from all 3 categories were presented in a fixed randomised sequence. Calibration was progressed every fifth picture. Each picture was shown for two seconds. Pictures were separated by a pause of one second, followed by a white fixation cross in the upper left corner of the black screen in order to ensure that the first fixation position was not already placed in the picture during onset. The subjects were instructed to respond as quickly as possible to those scenes which subjectively implicate braking or speed reduction by pushing the space button of a keyboard in front of them. This instruction was given in order to introduce a task that most closely resembles the natural driving situation.

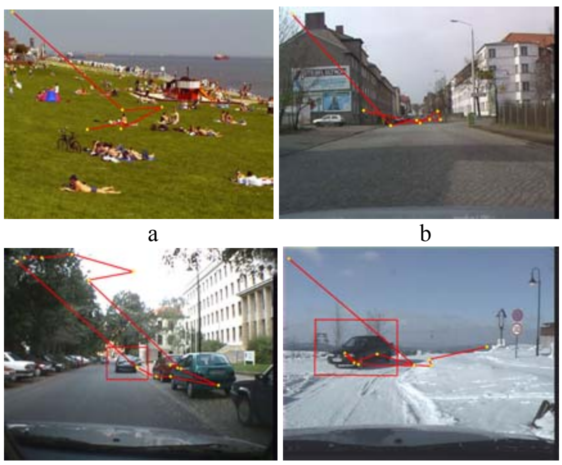

Fig. 1:
Examples for the two picture categories used in the pretest (a: landscape scenes, b: safe traffic scenes) and three in the main experiment (b, c: medium dangerous and d: highly dangerous) with examples of eye movement patterns from one subject. The rectangles in c and d define regions for potentially dangerous objects.

Table 1
Reaction time based parameters (reaction time, danger detection time, danger processing time) as a function of expertise and picture category (sd are given in brackets)

		Reaction time (ms)	Danger detection time (ms)	Danger processing time (ms)
Experienced drivers	highly dangerous	869 (135)	433 (99)	435 (167)
	medium dangerous	1060 (194)	572 (183)	458 (246)
Novice drivers	highly dangerous	901 (140)	402 (52)	498 (154)
	medium dangerous	1066 (158)	497 (124)	569 (156)

The pretest contained fixed randomised landscape and safe traffic pictures that were also shown for two seconds. The subjects' task was to explore the pictures and to answer an easy question after every fifth picture concerning the content of the previously viewed scenes. This task was supposed to induce a natural eye movement behavior and serves as a control condition to ensure that no differences in general scene scanning patterns occur between novices and experts.

3. Results

This study is currently in progress, and thus the results in this section are from those subjects tested so far, or who are currently in the process of being tested. This implicates that the reported differences do not all reach statistical significance, especially those regarding group differences.

3.1 Results from the Pretest

The pretest revealed no significant differences in general picture scanning routines that were not related to hazard perception in traffic. This is expressed in similar distributions of numbers of fixations, mean fixation durations, saccade amplitude, and relative frequency of saccade directions. Furthermore, there were significant differences regarding scene type, with fewer ($F(1, 28) = 44{,}760$; $p = .000$) but longer fixations ($F(1, 28) = 13{,}245$; $p = .001$) for landscape scenes compared to safe traffic scenes, but no reliable group differences.

3.2 Results from the main experiment

As a main effect, we could replicate earlier results with the same material showing that pictures classified as highly dangerous were responded to with a button press (braking) in 92% of the trials, with a mean RT of 886,43 ms (sd = 136,95). Scenes from the medium dangerous category were responded to in 46% of the trials with a mean RT of 1063,69 ms (sd = 173,31). Safe traffic scenes received no responses at all. Differences in RT and relative number of responses were statistically significant ($T(1,29) = 8{,}94$; $p = .000$).

Eye movement recordings allowed to divide RT into danger detection time and danger processing time (see section 1). *Danger detection time* was generally significantly lower for highly dangerous situations (mean RT = 416,99 ms; sd = 77,99) compared to medium dangerous situations (mean RT = 531,07 ms; sd = 155,31). *Danger processing time* was also significantly lower for highly dangerous situations (mean RT = 469,43 ms; sd = 161,48) compared to medium dangerous situations (mean RT = 519,53 ms; sd = 205,50) (see Fig. 2). Interestingly, novice drivers tend to be faster regarding danger detection for both, medium and highly dangerous situations, whereas they are slower in the processing of a dangerous object. Nevertheless, we found experienced drivers to respond faster in overall RT measures (see Table 1).

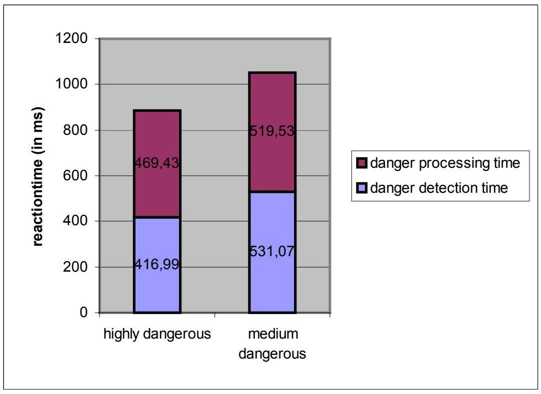

Fig. 2:
Mean reaction times, danger detection and danger processing times across level of expertise for highly and medium dangerous traffic scenes.

Table 2
Eye movement parameters (number of fixations, fixation duration, saccade amplitude) as a function of expertise and picture category (sd are given in brackets)

		Number of fixations (N)	Fixation duration (ms)	Saccade amplitude (pixel)
Experienced drivers	highly dangerous traffic scenes	7,33 (0,94)	312 (27)	144 (16)
	medium dangerous traffic scenes	7,59 (1,05)	312 (29)	67 (22)
	safe traffic scenes	7,55 (0,99)	316 (29)	134 (21)
Novice drivers	highly dangerous traffic scenes	8,19 (0,71)	304 (27)	155 (21)
	medium dangerous traffic scenes	8,18 (0,59)	305 (27)	70 (7)
	safe traffic scenes	8,35 (0,78)	301 (30)	148 (12)

Concerning eye movement behavior, novices tend to show more fixations, have shorter fixation durations and a greater saccade amplitude than experienced drivers. There is a significant difference between experienced and novice drivers in their number of fixations on highly dangerous pictures ($T(1,28) = 2{,}850$; $p = .008$) and on safe traffic scenes ($T(1,28) = 2{,}464$; $p = .020$). The experienced drivers showed fewer fixations in both categories than did the novice drivers (see Table 2).

For both groups, mean saccade amplitudes are significantly shorter in medium dangerous situations compared to both other categories ($F(1,28) = 426$; $p = .001$).

4. Discussion

The eye movement data from the pretest show that landscape scenes are processed in a different way than traffic scenes. This can be due to different physical properties of these types of pictures, with varying informativeness for different positions across the screen (see Fig. 1 for examples of the pictures). More importantly, scanning routines did not differ significantly between groups, showing that there are no differences in general scene processing. This allows to compare eye movement behavior of the groups in the main experiment.

In the main experiment we could replicate the fact, that subjects are generally responding faster towards highly, compared to medium dangerous situations [8]. The validity of the categorisation was proven by the substantial difference in the number of braking responses across categories.

Reaction times, measured from picture onset until manual reaction, tended to be faster for the experienced than for the novice drivers. The division of RT into two subprocesses turned out to be very promising: The results show that especially danger detection time determines the difference between RT in high versus medium dangerous situations. However, novices tend to be slightly faster in detecting possible dangers than experts. Although this difference is not statistically significant in the tested sample, it appears consistently in both scene categories. On the other hand, experts are faster in processing a potentially dangerous object.

Concerning scanning strategies, we could show that novices generally tend to exhibit more fixations with shorter fixation durations, especially in highly dangerous and in safe traffic scenes. This might be a possible reason for their benefit in danger detection time compared to experts.

Medium dangerous situations received shorter saccade amplitudes compared to highly dangerous or safe situations. This might be explained by the higher ambiguity of this category, where a very detailed close examination with short saccades might be necessary in order to conclude whether the situation should be regarded as dangerous.

In sum, the results hint at typical differences in visual orientation and hazard perception between experts and novices. Especially the separation of danger detection and danger processing time, which can only be provided by combining traditional RT experiments with eye movement registration techniques will be an important aspect in further research.

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