Effects of visual field defects on driving performance

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VIII.4 Effects of visual field defects on driving performance

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Abstract

To elucidate the possible traffic safety risks induced by visual field defects, volunteers have been studied in a driving simulator. In the traffic scene, stimuli randomly appeared in any of 24 different positions. The measured parameter was the latency between stimulus appearance and braking. Twenty younger and older normals served as controls. Only four out of 27 subjects with field defects showed compensation as did one of two one-eyed drivers. Contact lenses or glasses made no difference in two myopic persons. The results support the opinion that homonymous field defects should constitute an obstacle to licensing.

Introduction

Normal visual fields have long been considered essential for safe driving. In theory, a normal field makes possible the early detection of obstacles, other vehicles etc in the peripheral field. It has, however, been difficult to prove in practice that visual field defects constitute a risk and there are not sufficient data to support a standard for visual fields in drivers. It is very difficult to prove a correlation between a certain visual defect and an increased frequency of traffic accidents or violations. The two main reasons are the low frequency and the multifactorial causes of these occurrences. When it comes to visual field defects, no correlation between the extent of the visual fields and the driving performance was found in several large-scale studies [1–4]. In these, non-standard perimetric techniques were used and only the horizontal meridian was tested.

In a more recent study, it was found that among over 17,000 volunteers those with bilateral visual field defects had a rate of accidents and convictions more than twice as high as the other subjects [5]. Here, a fast but nevertheless accurate perimetric procedure was followed. In another report, it was stated that the accident frequency of one-eyed drivers was increased and that these persons

tended to be involved in collisions to the anophthalmic side [6]. No study so far has been devoted to the possible compensatory mechanisms. It has been claimed, especially by the patients themselves, that they learn to see in the blind area by frequent head and eye movements. Drivers, almost without exception, deny any problems with detection in the direction of the blind zone (as related to the dominating fixation point straight ahead).

We considered that it was of great interest to study the detection capacity in a simulated driving situation. A computer-assisted program was designed for the driving simulator at VTI (Swedish Road and Traffic Research Institute) in Linköping, Sweden. The reaction time for randomly appearing stimuli was measured in normals and subjects with visual field defects as well as one-eyed drivers.

Methods

The subject was seated in a real car body. In front of this, the computer-controlled traffic scene was projected on a wide-angle screen with the aid of three TV-projectors; the luminance of the screen was 15–25 cd/m². The scene was a two-lane grey road on each side surrounded by a flat green-coloured landscape; above the horizon was the sky. The road wound through the landscape with a speed that was controlled by throttle commands, braking etc.; inside the car body, the speed was also evident from the ‘motor’ sound and the tachometer reading. The subject had to drive with a speed of 100 km/h, which was a difficult task that demanded constant attention. If he could not hold the car on the road, it seemed to skid out in the green ending up in a crash. Such an accident, as well as crossing to the left lane was recorded by the computer.

On the screen, quadratic yellow and black 6 Hz flickering stimuli of three different sizes were presented; they subtended an angle of 0.96° (large), 0.46° (medium) and 0.23° (small). The luminance contrast to the background made them clearly suprathreshold as was evident from the readings of peripheral small stimuli in normals. Stimuli appeared randomly, one at a time, in any of 24 positions within an area of 20° vertically and 120° horizontally. The stimuli were located in areas of traffic safety and ocular pathology interest (Fig. 1). The stimulus disappeared after braking or after 10 seconds. One test session lasted half an hour during which stimuli appeared in each position 10 times, ie, a total of 240 presentations. In the first and last sessions, the medium-sized stimuli were used, in the second the small and in the third the large objects.

The subjects had to respond to a stimulus by immediate braking; the measured parameter was the latency between the appearance of the stimulus and brake pedal movement, ie, *the detection capacity*. *The driving capacity* was recorded as the ability to drive with the specified speed on the right side of the road.

Figure 1. Location of the stimuli in the field of view. The frame shows the boundaries of the windscreen and part of the left side window.

Subjects

Twenty subjects with normal visual acuity and fields volunteered for the study; they were divided into two groups: 20–30 years and 50–60 years. Twenty-seven subjects with visual field defects have been studied so far. In all cases, the duration of the defect was at least one year. Most subjects had had brain lesions giving rise to homonymous field losses, a few had central/paracentral scotomas due to optic nerve disorders and a few had bilateral glaucoma.

Two one-eyed subjects who had lost the other eye several years ago were also tested. The single eye was normal. Two persons were tested with both contact lenses and spectacles. Their refraction was sphere $-8.5/-8.0$ D and $-8.5/-8.5$ D.

In the subjects with visual field defects, monocular kinetic perimetry was done with the Goldmann perimeter to define the extent of the absolute and relative visual field deficiencies.

Results

The subjects kept the speed required and the departures from the right lane were quite few.

Normals

There were 10 reaction times for each stimulus location in every test session. The reaction times of the 10 younger and the 10 older subjects were grouped together. Fig. 2 shows an example of the results obtained. The figure shows the medians of the reaction times and the 90th percentile. Median values were typically of the order of 0.8 seconds. There were small differences between the reaction times for central and peripheral stimuli; these differences were somewhat more outspoken

Figure 2. One example of reaction times obtained in the group of older normals: medium-sized stimuli, first presentation. Depicted are medians and 90th percentiles.

for older subjects and small stimuli. The reaction times of the older subjects were a little longer than those of the younger.

Subjects with visual field defects

For each stimulus location and session, the median reaction time (the 6th longest time) was compared to the results of the normals of corresponding age. If the value of the subject exceeded the 90th percentile of the normals, this was considered to mean an *overall increment of the reaction times* and marked on the perimetric chart (circles).

From the traffic safety point of view, it could also be of importance if *the reaction times of single presentations were prolonged*. A fourfold increment, ie, times exceeding 3.00 seconds was arbitrarily considered significant. Single delays were accepted (chance lack of attention?); thus two or more reaction times over 3.00 seconds were considered of importance and this was marked with filled dots on the charts.

Even more significant were reaction times over 10 seconds, ie, that *the subject did not observe the stimulus at all*. Two or more such misses were recorded and marked with filled triangles on the charts. Since we considered it more significant if larger stimuli were affected, circles, dots and triangles of three sizes were used to mark the abnormal reaction times.

A visual evaluation of the perimetric charts served to decide whether there was an overrepresentation of prolonged reaction times in the affected visual field areas. Single abnormal points often appeared in normal field areas, but could usually be explained by interference from the rear-view mirror or a wind-screen post. Several deviant points within the pathological field was taken to infer that the subject did not compensate for the defect; this point was strengthened by increments over 3 or 10 seconds.

Figure 3. The result of one subject judged to compensate for the visual field defect. Rings: abnormally long reaction times; Dots: two or more reaction times longer than 3 seconds; Triangles: two or more presentations not seen. Small, medium-sized and large symbols correspond to stimulus size.

Out of the 27 subjects with visual field defects, we found that only four compensated for their field loss (Table 1). Representative examples of compensation and non-compensation are given in Figs 3 and 4. Of the two subjects with only one eye, one performed as well as the normals whereas the other showed markedly prolonged reaction times in the periphery of the blind side.

Figure 4. The result of one subject with prolonged reaction times especially in the abnormal visual field area. Symbols as in Fig 3.

Spectacles and contact lenses

The results of these two subjects were, except for a point corresponding to a window post, quite normal both with contact lenses and spectacles.

Discussion

Visual field defects are considered to impair the drivers' ability to detect objects in the traffic scene. Safety is at risk if other vehicles, children, etc are observed too late or not at all. However, several other factors probably have to play a part as well for an accident to occur; therefore drivers with field defects can drive for years without crashes and correlations between the visual impairment and the driving performance are hard to establish.

Measuring the detection capacity in the traffic would meet great methodological difficulties. The driving task in the simulator used in this study imitates real driving to a very high degree and sharp attention has to be paid to steering and speed control. In the simulator, controlled stimuli can easily be presented and a parameter related to detection capacity selected and measured. The chosen flickering stimuli were suprathreshold; no attempts to measure their size or luminance thresholds were made, however.

The data obtained in the normal groups showed little variation between stimulus locations and subjects. Somewhat longer reaction times were recorded in the periphery and with the older drivers. Median latency values were used to compensate for the possibility of pressing the brake pedal by chance. So far, we have operated with three arbitrary levels to denote important increases of the reaction times: median values exceeding the 90th percentile of the normals, two or more times longer than 3 seconds and two or more times longer than 10 seconds. Symbols for these occurrences were drawn on the perimetric charts. Single abnormal points could be explained by interference from structures in the car body if they coincided with the direction of the rear-view mirror or a window

Table 1. Types of visual field defects and degree of compensation.

Number of subjects	Type of field defect	Result
2	Local scotoma	+ -
3	Irregular defects	+ + +
4	Partial quadrant	+ + - -
6	Quadrant	+ + + + + +
8	Partial hemidefect	+ + + + + + + +
4	Hemidefect	+ + + -

+ = impaired detection capacity.

- = compensation.

post. Four subjects were able to compensate for their defect: their performance was good in the whole area tested. In the other 23 pathological cases, it was easy to conclude that the deficient field areas comprised an excess of abnormal stimulus points. In all these cases, the total number of abnormal points was large (>8) and there were also at least two points with reaction times longer than three seconds.

The subjects that did compensate belonged to different types of field abnormality (Table 1). The way these subjects control their deficiency is as yet not known to us. Further studies are under way where the fixation pattern of compensating and non-compensating subjects will be recorded.

License standards for visual fields vary between countries. In many, a normal field in one eye or the two eyes together is required. Scientific support for this opinion has been hard to furnish but was brought forward by the recent Californian study [5]. Our study demonstrates that most subjects with homonymous visual field defects show impaired detection capacity in deficient field areas. From perimetry it is not possible to tell if a driver can compensate for the defect. If the abnormal area is located in a part of the visual field of relevance to driving, it seems justified to deny the subject a license.

One-eyed persons are allowed to drive passenger cars in most countries; in Sweden after an adaptation period of half a year. Some patients claim that they get used to the condition in a short time, others that it takes months. Our study only includes two subjects so far; one compensating and the other not. More testees are required in order that one should get support for the opinion that these drivers could run into collisions more often than normals [6]. The experiments with myopic subjects do not prove that persons with a moderate degree of this refractive error are handicapped by wearing spectacles instead of contact lenses.

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