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Abstract

***Objectives*—This study examined the scanpaths of patients with homonymous hemianopia while viewing naturalistic pictures in their original and also spatially filtered forms. Features of their scanpaths with respect to various saccade and fixation parameters were examined to determine whether they develop compensatory eye movement strategies. The effects of various lesion parameters including location, size, and age on the evolution of such strategies were considered.**

***Methods*—Eye movements of eight patients with homonymous hemianopia (four left, four right), but lacking neglect, were recorded while they viewed 22 images of real scenes, and they were compared with the eye movements of eight age matched controls. Subjects viewed each image for 3 seconds, initially in a spatially filtered form in which much of the semantic content had been removed, and then in their unfiltered, original form.**

***Results*—Patients differed significantly from controls in various fixation and saccade parameters. For fixation parameters patients with hemianopia fixated different spatial positions from controls, made more fixations which were more widely distributed and of shorter duration than controls, and spent a greater proportion of their total fixation time in the area corresponding to their blind hemifield. They did not make significantly more refixations than controls. For saccade parameters patients made more saccades into their blind hemifield, these saccades having shorter latencies and shorter amplitudes than those made into their seeing field, and had longer scanpaths than control subjects. The amplitude of their first saccade was longer than that of controls although its direction did not correlate simply with the side of the field defect. Their mean saccade amplitude was similar to that of controls. Filtering out high spatial frequencies within images seemed to accentuate the described differences between eye movement characteristics of hemianopes and controls. Scanpath differences correlated with increasing age but not location or size of lesions causing the hemianopia.**

***Conclusion*—Various features of scanpaths produced by hemianopes were different from normal subjects. These differences correlated with lesion age and may reflect the evolution of a compensatory eye movement strategy.**
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Keywords: homonymous hemianopia; eye movements; visual search

Human beings are largely unaware of the eye movements that they execute to select items of interest from their complex visual environment, and to navigate their safe passage in the world. Visual search patterns (scanpaths) have been studied by several groups, who have employed paradigms using images of stationary scenes to examine the sequences of saccades and fixations that normal subjects make in unfamiliar environments.[1] Some have demonstrated that subjects viewing a given scene will produce remarkably similar eye movement patterns, particularly during the initial few seconds of exposure.[2–5] Others have attempted to elucidate the exact features of images that attract fixations and induce such stereotyped eye movement patterns. They have identified areas of high contrast—namely edges,[6] corners, symmetry,[7] and irregular contours as areas of importance.[4 8] By contrast, others have debated the relative importance of visual and semantic attributes of objects within scenes in the guidance of eye movements.[3 4 9 10] Yet others have shown that whereas image features are fundamental to the generation of eye movement patterns, they are influenced and can be altered by cognitive factors, such as the instructions given to observers[11–15] and specific practice.[16–18]

Patients with posterior visual pathway lesions may develop homonymous hemianopia and lose the vision in one hemifield. As a consequence they cannot process images in the same way. During searches for a target object hidden among non-targets they repeat saccades and fixations to the same object, resulting in longer search times, and longer unsystematic scanpaths.[19 20] In addition their fixations dwell in their intact hemifield, and their saccades are less regular and accurate, and too small to allow rapid, organised scanning. Consequently they omit objects or relevant parts of a scene located in their blind hemifield.

There is evidence, in common with normal subjects, that cognitive influences can alter the eye movement patterns of patients with hemianopia. Experiments in which subjects view simple patterns have shown that whereas normal controls look mainly at the centre, hemianopic patients paradoxically concentrate on their blind hemifield.[21] Some authors consider this to be a compensatory strategy,[19 22] as deviating their fixation point towards the

Table 1 Summary of patient information

Patient	*Age*	*Side of field defect*	*Pathology*	*BIT score*
H1	39	R	Migrainous infarct	145
H2	25	R	Migrainous infarction	146
H3	40	L	Meningioma	133
H4	24	R	AVM	146
H5	38	L	Infarction	146
H6	26	R	Cystic suprasellar teratoma	145
H7	51	L	Haemorrhagic infarction	142
H8	33	L	AVM	145

hemianopic side brings more of the visual scene into their seeing hemifield. Similarly they adopt compensatory strategies when faced with simple visual targets which are presented in an unpredictable fashion.[23] However, there is limited literature considering the specific issue of how patients with homonymous hemianopia look at images of real scenes.

In this paper we have posed the question "How do patients with homonymous hemianopia scan the world?" We have recorded the eye movement patterns such patients make while viewing naturalistic pictures and compared them with those of age matched controls. We have also taken a novel approach and presented the same images in a spatially filtered form where the fine detail has been removed, rendering them blurred and difficult to recognise. By presenting them with filtered images we aimed to explore the scanning behaviour of patients with hemianopia when local image features and semantic information are removed. We have examined the features of their scanpaths with respect to various saccade and fixation parameters, to determine whether they develop compensatory eye movement strategies. We have considered the effect of various lesion parameters including location, size, and age.

Methods

SUBJECT SELECTION

We recorded the eye movements of eight patients with isolated homonymous hemianopia and compared them with those of eight age matched controls. The age range in the patient group was 24–51 years with a mean of 34.5 years, and it was 24–48 years in the control group with a mean of 36.9 years. All patients were right handed. Four patients had left and four had right field defects, which were complete and respected the vertical meridian. Their diseases varied: three had cerebral infarctions, two had arteriovenous malformations that had bled, one had a haemorrhagic infarction, one had an occipital meningioma, and one had a suprasellar cystic teratoma (table 1). None of the patients had coexisting eye movement abnormalities, or visual neglect as measured with the Rivermead behavioural inattention tests.[24] The visual acuities of all subjects were corrected to 6/6 (Snellen notation) using trial lenses.

EXPERIMENTAL DETAIL

Pictures

Patients viewed 22 computer controlled monochrome images of real scenes which were displayed on a high resolution (1280×1024 pixel) 20 inch Hewlett Packard monitor (D1187 A), which provided 256 grey levels via a 24 bit TIGA graphics card.[5] The images varied in complexity and familiarity, ranging from scenes of Westminster to unusual views of the space shuttle and were selected such that they contained items of interest on both sides (fig 1 top and middle).

Each image was presented in two forms; a low pass filtered form and an original, unfiltered form, making 44 images in total. The process of filtering involved computation of the 2D Fourier transform of each 1024×1024 pixel image, which was then multiplied by a first order Butterworth filter, defined by:

$$H(u, v)=(1+(D(u, v))D_0^{-1})^{-2}$$

where u and v are the orthogonal spatial frequency coordinates, D_0 a constant equal to 5 pixels, and $D(u,v)$ the distance in the frequency plane from the origin to the location (u, v)—that is:

$$D(u, v)=(u^2+v^2)^{1/2}$$

This produced an image in which the high spatial frequencies (fine detail) had been removed.

Procedure

The 44 images were presented in two separate sessions, in which filtered and unfiltered pictures were shown respectively. The sessions were separated by an interval of 1 hour. The order in which images were presented was randomised within each session. Subjects were seated 78 cm from the screen and viewed the images binocularly so that they subtended 20°×20° at the eye. The apparatus provided a chin rest and clamps at the temples to prevent head movements.

Before the presentation of each image subjects initially fixated a central cross to ensure that their fixation commenced at the centre of the image, and then rapidly examined the image which was presented for 3 seconds after the fixation cross had disappeared. We selected a viewing time of 3 seconds for two reasons: firstly, because we were particularly interested in the eye movements generated during the initial brief presentation of the images, and secondly because it is a comfortable time for subjects to refrain from blinking, which interferes with the eye movement recording.

Subjects were instructed to examine the pictures carefully and without blinking to provide a brief description of each image at the end of its presentation.

Eye movement recordings

Eye movements were recorded using the P scan system, a binocular, video based infrared device with 50 Hz sampling rate and 0.2° spatial resolution.[25] They were analysed using existing software written for the dedicated processor (Hewlet-Packard Vectra RS/25C) which also controlled the P scan system.

ANALYSIS OF EYE MOVEMENTS

The eye movement data were analysed by the methods described by Jacobs.[26] A fixation was

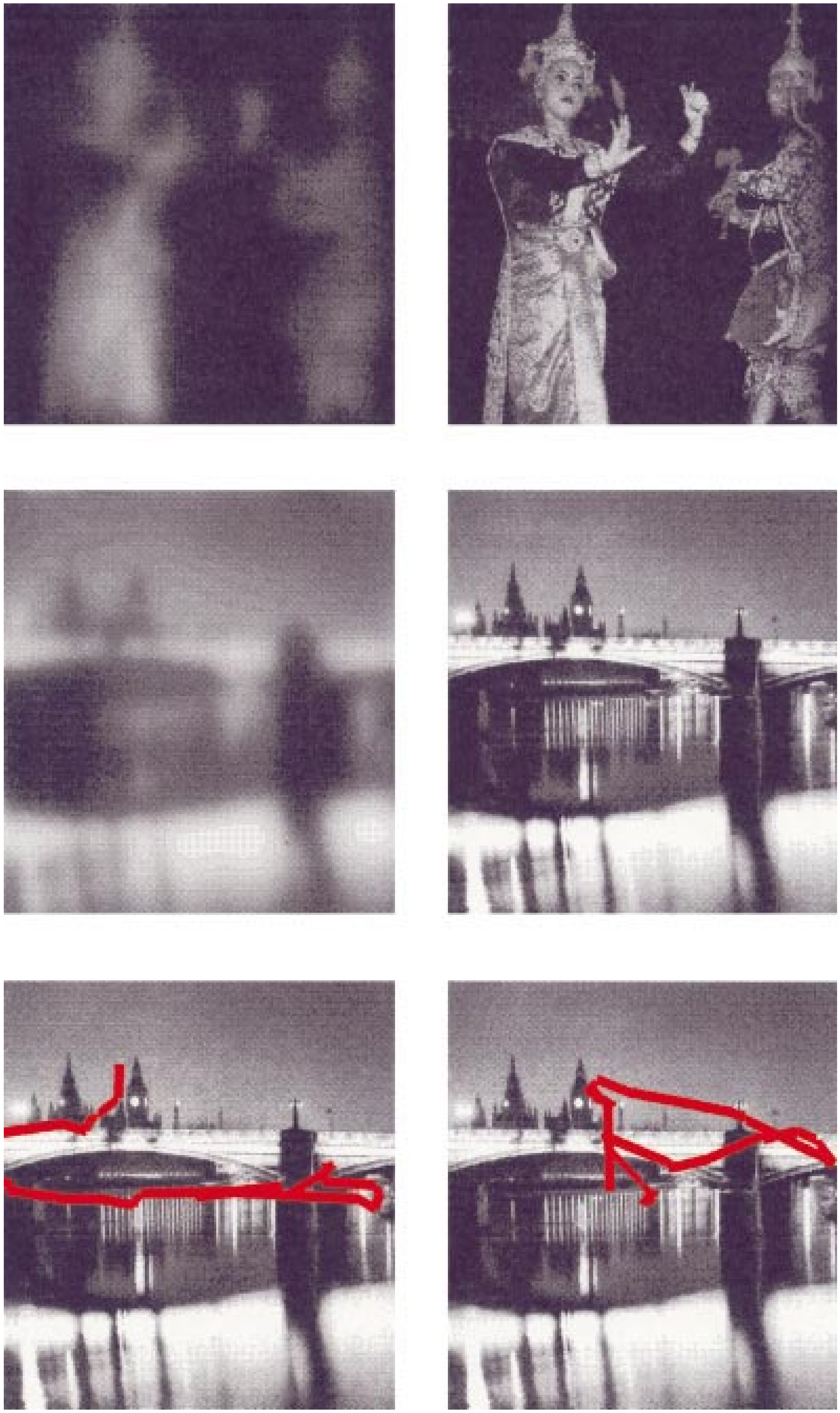

Figure 1 (Top and middle) Examples of images used in this investigation. The filtered versions of two images are presented on the left hand side together with the unfiltered versions in the corresponding locations in the right hand column. (Bottom) Eye movement patterns of a left hemianope (left) and a control subject (right) superimposed on the image that elicited them. From S K Mamman, et al, with permission.

taken as a point where the eye position varied less than 0.5° over a minimum of three successive 20 ms frames. Two successive fixations were taken as points whose mean positions were separated by at least 0.5°.

Index of similarity

To compare the positions of fixations we used an index of similarity (I_s) measure based on a least squares method first described by Mannan *et al*.[5] The I_s can be used to compare the spatial locations of fixations in any two sets of scanpaths, but does not consider the order of fixations. The similarity of two sets of fixations is compared with the similarity of two sets of randomly positioned fixations, such that two eye movement traces with fixations in identical positions will yield an I_s of 100%, whereas two random traces will have an I_s of 0.

The I_s was used for two comparisons; firstly to compare the degree of similarity of fixation patterns within the control group and secondly to compare hemianope and control groups. To compare control subjects, the fixation pattern made by a given control subject to a given filtered image was compared with the fixation patterns made by the other seven control subjects to the same image, yielding seven pair comparisons. The second control subject was compared with the six remaining control subjects, the third subject to the remaining five, and so on, giving 28 indices for a given image, which were averaged. A similar comparison was made for the other 21 filtered images, and the values averaged to give a mean interobserver similarity for filtered images based on 616 pair comparisons. A similar series of comparisons was performed for the hemianope group by comparing each patient in turn with each member of the control group, to give a mean I_s value for the hemianope group based on 1408 pair comparisons. Similar calculations were made for the unfiltered images. In this way, two sets of similarity indices were obtained, the first comparing the interobserver similarity of control subjects, and the second comparing the fixation patterns of hemianopes with those of normal controls for both filtered and unfiltered images. An unpaired *t* test was used to compare the means of these two sets of indices. In a separate calculation we obtained the mean similarity index for each individual control subject to filtered images by comparing their eye fixation patterns for a given image to that of the seven other controls, averaging the seven indices thus obtained. This calculation was repeated for each of the 22 images and the results averaged to give the mean similarity for each control subject to filtered images based on 154 pair comparisons. A mean index of similarity for each hemianope was similarly calculated by comparing the fixation patterns for the given hemianope to that of each of the eight controls, and thus obtaining a mean similarity index based on 176 pair comparisons. This calculation was repeated for unfiltered images. An unpaired *t* test was used to compare the mean similarity index for each hemianope with the mean interobserver similarity obtained for all control subjects.

Other saccade and fixation parameters

A one factor analysis of variance (ANOVA), using subject group (hemianopic *v* control group) as the factor, was employed to analyse the following eye movement parameters: mean duration of the first fixation, mean fixation duration, total number of fixations, percentage of refixations, mean amplitude of first saccade, mean saccade amplitude, total scanpath length, and ratio of local to global saccades. We examined the distribution of saccade amplitudes using the concept of "local" and "global" saccades developed by Groner *et al*.[16] Saccades smaller than 1.0° were taken as local and those larger than 1.6° were taken as global.[27] In this study we have adopted the same definitions.

A further one factor ANOVA was used to analyse the eye movement parameters that depend on the side of the patients' field defect: the percentage of fixations and the percentage of fixation time spent viewing the half of the image corresponding to the blind hemifield, the percentage of saccades made in the direction of the blind field (including all saccades with a non-zero horizontal component), and the mean latency and mean amplitude of saccades made in a rightward and leftward direction.

Scanpath lengths

Total scanpath lengths were calculated as the sum of the amplitudes of all saccades made to a given image by a specific observer.

Area of image explored by subjects

We calculated the areas enclosed by fixations in each scanpath trace to quantify the percentage of each image explored by subjects. By dividing each image in half vertically, we calculated the percentage area explored on the left and right half of each image.

LESION PARAMETERS

The positions and volumes of patients' cerebral lesions were calculated from CT and MRI using methods outlined by Damasio and Damasio.[28]

Results

ANALYSIS OF EYE MOVEMENTS

Index of similarity

There was no significant difference in the fixation patterns made by control subjects, which ranged from 45%-53% for the filtered images and 37%-45% for the unfiltered images, indicating good interobserver similarity. The difference in the means of the two sets—the control and hemianopic group—however, was significant using an unpaired *t* test ($p<0.05$) for both the filtered and unfiltered images (fig 2). This difference was greater for filtered images. The data for individual hemianopes showed two notable exceptions, H1 and H2, who consistently made fixation patterns that were similar to those of control subjects (fig 2).

To elucidate the nature of these differences we examined further fixation and saccade parameters.

Other fixation parameters

Patients made significantly more fixations than control subjects while viewing filtered but not unfiltered pictures (table 2). These fixations were of significantly shorter duration than those of control subjects (table 2). The duration of the first fixation was analysed separately and did not differ significantly between the two groups (appendix). The percentage of refixations (calculated as the number of fixations made within 1° of each other) was not significantly different between hemianopes and control subjects (appendix).

Saccade parameters

The temporal resolution of the P scan (50 Hz) limited the calculation of certain saccade parameters, such as saccade duration and peak

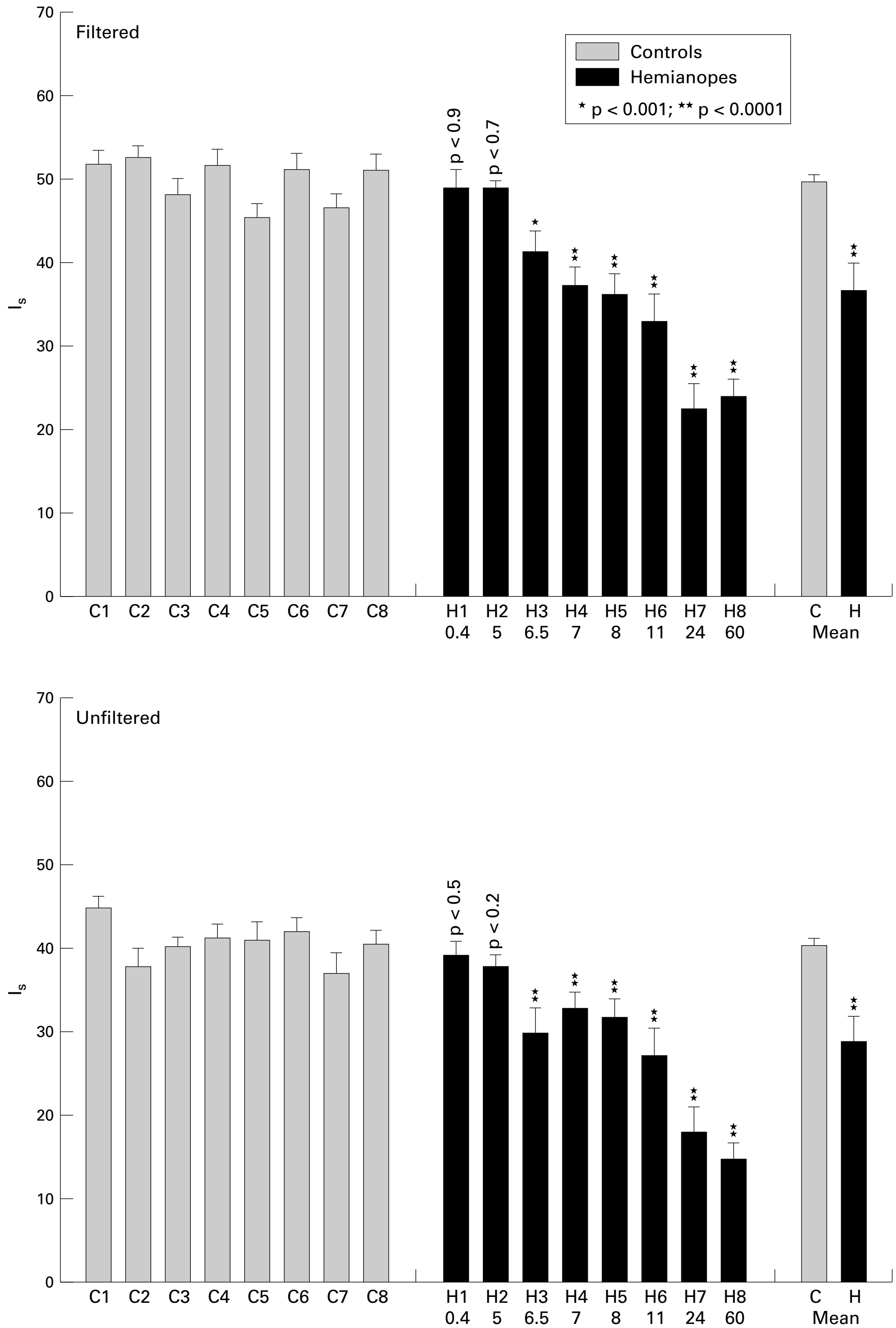

Figure 2 Index of similarity for each control subject, derived by comparing the eye movements of each control observer to the other seven controls is shown by the grey bars. The similarity of the eye movements of each hemianope to the control subjects is shown by the black bars. The mean index of similarity for each group is given by the rightmost bars in each graph. The upper panel gives values for the filtered images and the lower one for the unfiltered images. The age of the lesion in months is given below each patient. Error bars=SEM.

Table 2 Data for various saccade and fixation parameters (mean (SEM))

	Filtered images			Unfiltered images		
	Control	Patient	p Value	Control	Patient	p Value
Mean number of fixations	7.7 (0.1)	8.7 (0.2)	<0.0002	9.6 (0.1)	9.8 (0.1)	<0.2
Mean duration of fixations (ms)	372 (11)	312 (8)	<0.0001	302 (11)	286 (6)	<0.2
Mean amplitude of first saccade (deg)	2.3 (0.1)	3.2 (0.1)	<0.0001	2.6 (0.1)	3.3 (0.1)	<0.0001
Mean deviation of saccade from horizontal (deg)	42.0 (0.8)	33.3 (0.9)	<0.0001	43.4 (0.8)	37.4 (0.8)	<0.0001
Total scanpath length (deg)	26.8 (0.8)	32.2 (1.4)	<0.0001	37.2 (0.8)	39.8 (1.0	<0.0415

velocity. Nevertheless it was possible to identify several significant differences between patient and control subjects. The mean amplitude of the first saccade was significantly larger for patients than control subjects for both filtered and unfiltered images (table 2), whereas the mean amplitude of the remainder of the saccades did not reach significance (appendix). The direction of the first saccade made by the hemianope group did not correlate simply with the side of their field defect.

Visual inspection of the traces suggested that some hemianopes were making a series of largely horizontal saccades across images (fig 1 (bottom)). The angle between each saccade in a scanpath and the horizontal was calculated and averaged to give the mean angle for each eye movement trace. By definition the maximum possible deviation from the horizontal is 90° and the minimum is 0°. The mean angle of deviation for the hemianope group was significantly less than that for the control group when viewing filtered and unfiltered images (table 2).

Table 3 Mean (SEM) number of fixations made in blind hemifield (%) (control data in square brackets)

Filtered images		Unfiltered images	
Subject group	% Fixations landing in blind hemifield	Subject group	% Fixations landing in blind hemifield
Left hemianopes	51(1.4) [42 (1.2)] p<0.05 Left hemifield	Left hemianopes	48 (1.3) [46 (1.1)]
Right hemianopes	63 (1.6) [58 (1.2)] p<0.05 Right hemifield	Right hemianopes	Left hemifield 57 (1.2) [54 (1.1)] p<0.05 Right hemifield

Table 4 Mean (SEM) values for the % of time spent fixating the blind hemifield (ms) (control data in square brackete)

Filtered images		Unfiltered images	
Subject group	% Fixation time in blind hemifield	Subject group	% Fixation time in blind hemifield
Left hemianopes	71(2.3) [42 (1.9)] (p<0.05) Left hemifield	Left hemianopes	59 (2.9) [50 (2.1)] (p<0.05) Left hemifield
Right hemianopes	71 (2.5) [58(1.9)] (p<0.05) Right hemifield	Right hemianopes	58 (2.3) [50 (2.1)] (p<0.05) Right hemifield

Table 5 Percentage (SEM) of saccades made towards the blind hemifield (control data in square brackets)

Filtered images		Unfiltered images	
Subject group	% Saccades towards blind hemifield	Subject group	% Saccades towards blind hemifield
Left hemianopes	71 (2.1) [44 (2.5)] (p<0.05) Left hemifield	Left hemianopes	61 (2.6) [50 (2.1)] (p<0.05) Left hemifield
Right hemianopes	71 (2.4) [56 (2.5)] (p<0.05) Right hemifield	Right hemianopes	60 (2.1) [50 (2.1)] (p<0.05) Right hemifield

Scanpath lengths

Patients produced significantly longer scanpaths while viewing both filtered and unfiltered images (table 2).

Ratios of local to global saccades

We did not find that the proportion of local to global saccades differed significantly between patients and control subjects viewing either filtered or unfiltered images (appendix).

Hemifield differences

When patients with hemianopia fixate the centre of an image they are only able to see the half in their unaffected hemifield. By dividing each image into left and right halves it is possible to examine differences in the left-right spatial distributions of fixations in a crude fashion. The percentage of fixations made to the right or left half of each image was calculated and averaged over all 22 filtered and unfiltered images respectively. When viewing filtered images, left and right hemianopes made significantly more fixations in the area corresponding to their respective blind hemifields (table 3). When viewing unfiltered images, right hemianopes made significantly more fixations in the area corresponding to their blind hemifield, whereas left hemianopes were no different from control subjects (table 3).

The total duration of fixation time was also calculated differentially for each hemifield, by calculating the sum of the fixation durations to the right or left half of each image as a proportion of the total fixation time. Most of the images were symmetric and control subjects showed an even distribution of gaze when viewing them. Some images were asymmetric and contained a natural bias of interest to the left or the right. As a group, the left/right biases were balanced. The apparent tendency for control subjects to look into the right hemifield when viewing filtered images was not significant (table 4). Both left and right hemianopes spent significantly longer making fixations in their respective blind hemifield when examining both filtered and unfiltered images. The effect was more pronounced for filtered images (table 4).

As patients with hemianopia examine an image; the extent of the image falling within their blind hemifield will vary with each saccade, and will not usually coincide with the midline of the image. We therefore looked at properties of saccades made in the seeing or non-seeing direction. Patients made significantly more saccades towards their blind side (table 5). These saccades were significantly

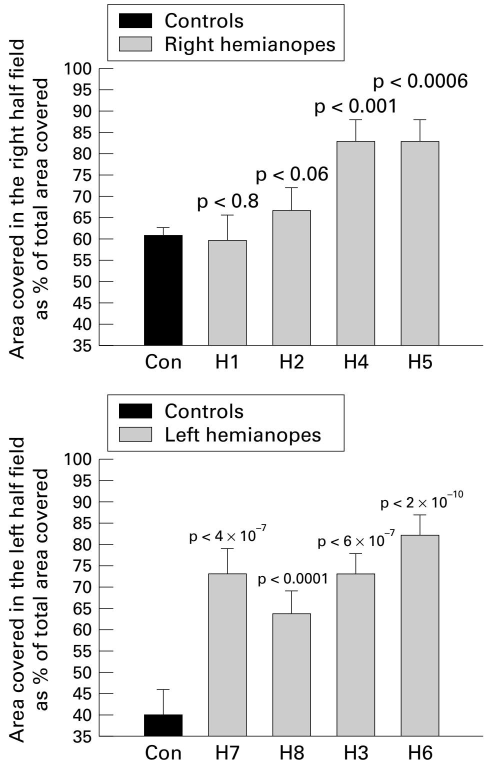

Figure 3 Mean area enclosed by fixations made by each hemianope into their blind half field is shown as a percentage of the total area enclosed by their fixations for each hemianope. The upper panel shows data for right hemianopes and the lower panel for left hemianopes. The data for control subjects (black bars) shows the mean percentage area enclosed by fixations, averaged over all subjects, on the left half of the image (upper panel) and for the right half of the image (lower panel).

shorter in amplitude and duration than those towards the seeing side ($p<0.05$).

Area of image explored by subjects

As a group, patients made more widespread fixations, covering a larger percentage area of both filtered and unfiltered images than controls, who tended to revisit the same areas (ANOVA, $p<0.0001$). Patients explored a significantly larger area on the side of the image corresponding to their blind hemifield than normal controls with the exception of two patients, H1 and H2, who did not follow this pattern and inspected a similar area to control subjects on either half of each image. The effect was more pronounced for filtered images (fig 3).

Effect of spatial filtering

Filtering out high spatial frequencies within images accentuated the described differences between the eye movement characteristics of patients with hemianopia and control subjects. For many parameters, differences only reached significance for filtered images.

IMAGE RECOGNITION

Recognition of images was assessed from the subjects' responses. Generically accurate descriptions were accepted as correct by the authors—for example, the two dancers shown in fig 1 could be described as "two dolls". For filtered images, hemianopes on average identified 7.8 images and were worse than control subjects, who identified a mean of 12.0. They were equally good at identifying images in their unfiltered, original form.

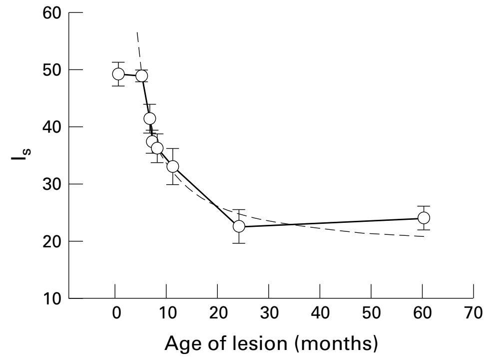

Figure 4 Relation between the mean index of similarity for each patient and the age of their lesion. The index of similarity was obtained by comparing the eye movements of each patient with controls for low pass filtered images (see fig 2). An inverse second order fit (dashed lines) gives a correlation coefficient of 0.96. A similar correlation coefficient r=0.96) was demonstrated for unfiltered images (results not shown).

LESION PARAMETERS

The interaction between lesion parameters and differences in eye movement patterns described above were studied. This was achieved by taking the index of similarity as a measure of differences between fixation patterns of hemianopes and controls, and comparing each patient's I_s with the location, volume, and age of their lesion. There was no clear relation between lesion position or size and index of similarity.

Lesion age was calculated as the time interval between onset of the hemianopia and recruitment into this study. There was a reciprocal relation between increasing lesion age and index of similarity, in that patients with longer standing lesions had lower I_s values, indicating increasingly different fixation patterns from normal subjects (figs 2 and 4). The two patients with the most recent lesions, H1 and H2, had the highest I_s values that approximated those of normal controls. At the time of testing, their lesions were less than 6 months old.

We examined the relation between each of the eye movement parameters described above and the age of the lesion to determine which aspects of the eye fixation pattern evolve with age of the lesion. The mean angle of saccades for filtered and unfiltered images decreased linearly with increasing age of the lesion ($r^2=0.68$, $p<0.02$, filtered images; $r^2=0.76$, $p<0.01$ unfiltered images). The scanpath length for filtered images only increased linearly as a function of lesion age ($r^2=0.51$, $p<0.05$).

Discussion

We have studied the explorative behaviour of patients with homonymous hemianopia and conclude that their eye movement patterns when viewing stationary scenes are abnormal. Patients differ significantly from control subjects in various fixation and saccade parameters, which seem to correlate with increasing lesion age, but not its location or size, and may reflect the evolution of a compensatory eye movement strategy.

There is a general consensus that while looking at the same image, different observers make fixations in discrete and highly conserved locations.[2 5] These are determined primarily by local perceptual features of the image[5 10] but are also influenced by its semantic content[9] and cognitive factors.[11–15] Our results show that with the exception of H1 and H2, patients with hemianopia make fixations in significantly different spatial locations than normal controls when viewing both filtered and unfiltered images. It is possible that this difference simply reflects the fact the fixation patterns of hemianopes are random. However, a more interesting interpretation is that hemianopes have a strategic fixation pattern which is distinct from that of normal controls.

The notion of a strategy is supported by the finding that hemianopes, with the exception of H1 and H2, are consistent in making more fixations which are more widespread and spend a greater proportion of their total fixation time in the area corresponding to their blind hemifield. Other features which distinguish the scanpaths of hemianopes from normal controls include the following: they make more fixations which are of shorter duration, the amplitude of their first saccade is significantly longer although its direction does not correlate with the side of the field defect and is not followed by a fixation of substantially longer or shorter duration. They make more saccades which are quicker and of shorter amplitude into their blind compared with their seeing hemifield, and have longer scanpaths.

It is notable that many of the scanpath differences between hemianopes and control subjects are seen only when patients view images in their filtered form. We suggest that this finding is strategically based:

Postulating a novel eye movement strategy, raises the question of whether it is visually, semantically or cognitively driven. By virtue of their field defect, patients with hemianopia have lost much of the visual and semantic information that is crucial for directing fixation patterns. Despite this handicap they are equally efficient at identifying and describing images in their unfiltered, original form as normal controls, suggesting that they successfully utilise low level visual and semantic information for "bottom up" processing. When viewing filtered images, however, their ability to identify relevant objects from among the grey blur is significantly impaired, and they can no longer rely on local image features to direct their eye movements. We suggest that in consequence, hemianopes trade off "bottom up" processing for a more "top down" cognitive approach in which cognitive mechanisms that do not require identification of images exert significant control over visual scanning. As they are unable to make sense of the parafoveal or peripheral field, particularly on their blind side, their parafoveal preprocessing abilities are limited and they cannot use the concluding milliseconds of a fixation to programme subsequent eye movements. In support of this theory, our data show that hemianopes make more horizontal saccades across images, to locations less driven by image features and have shorter fixations because they lack the peripheral information required to preplan future saccades. Interestingly, hemianopes seem to apply the strategy differentially within their two hemifields, as saccades made to the blind side are more numerous, quicker, and of shorter amplitude than those into the seeing hemifield, enabling more efficient scanning of the blind side.

These findings vary from those of Zangemeister *et al*[27] who demonstrated that the eye movement patterns of patients scanning complex images were similar to normal controls, whereas the data presented here show a clear difference. In addition, their patients made more fixations in their seeing hemifield and had a lower ratio of global to local saccades towards their blind side. With repetition however, this ratio reversed and patients developed a more even distribution of gaze. These findings were presented by the authors as evidence for the emergence of a more efficient eye movement strategy, but may equally represent overfamiliarity with the images. By contrast, our results show that untrained patients with hemianopia spontaneously make more fixations in their blind hemifield and have a lower ratio of global to local saccades towards their blind side. We suggest that in itself, this is a spontaneously acquired compensatory eye movement strategies that develops with time, although may undoubtedly be enhanced by specific practice. The compensatory bias for making fixations in the blind hemifield is well documented.[20 21 29] Although in recent years the ratio of global to local saccades has been adopted as a measure of cognitive control in normal visual search,[16 27 30–32] our results question whether this same measure can be applied meaningfully to patients with hemianopia.

Several groups have trained patients with hemianopia in visual search tasks and have concluded that they adopt compensatory eye movement strategies with training.[20 33 34] Others have shown that patients can acquire similar strategies spontaneously.[19 21–23] Using the index of similarity as a marker, our data demonstrate that patients with more longstanding lesions had increasingly different fixation patterns. We propose that this correlation reflects the highly significant evolution of a spontaneous compensatory eye movement strategy. This requires at least 6 months to develop, as patients with more recent lesions (H1 and H2) made fixation patterns that approximated to those of normal controls (fig 4). In an attempt to outline the strategy more fully, we performed regressions of our individual fixation and saccade parameters with lesion age. Unfortunately few meaningful correlations were seen. It is possible that clearer trends would have become apparent if the sample sizes had been larger.

Theoretically the strategy confers several advantages on the observer. By making more saccades towards their blind side, they bring ever increasing areas into their seeing hemifield, which they examine with numerous rapid fixations. Unfortunately it was not possible to demonstrate a functional benefit in this experiment. Further work is in process to explore this specific question when hemianopes view images in particular and the world in general; and to elucidate whether or not the strategy can be manipulated advantageously with specific training in visual search.

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Appendix

	Filtered images			*Unfiltered images*		
	Control	*Patient*	*p Value*	*Control*	*Patient*	*p Value*
Mean duration of initial fixation (ms)	481 (19)	517 (21)	>0.2	369 (15)	384 (14)	>0.5
Percentage refixations (%)	20 (2)	19 (1)	>0.7	22 (2)	21 (1)	>0.7
Mean saccade amplitude (deg)	4.4 (0.1)	4.2 (0.1)	>0.1	4.4 (0.1)	4.2 (0.1)	>0.1
Mean ratio of local to global saccades	0.25 (0.02)	0.21 (0.02	>0.1	0.20 (0.02)	0.22 (0.03)	>0.4

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