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Research report

Specific impairments in visual processing following lesion side in hemianopic patients

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ABSTRACT

Introduction: Following unilateral damage of the primary visual cortex one of the most common visual field defects observed is Homonymous Hemianopia (HH), a loss of vision of the contralesional hemifield in each eye. The ipsilesional (“intact”) part of the central visual field is often used to compensate for difficulties encountered in the peripheral hemianopic visual field. However, the quality of vision within the central visual field is not well-known.

Methods: To better describe and understand visual processing in hemianopia, two tasks were conducted with 25 healthy controls, six left hemianopes, and five right hemianopes. Filtered (in high, above 6 cycles/degree, or low, below 4 cycles/degree, spatial frequencies – HSF and LSF, respectively) and unfiltered natural scene images (5° of visual angle) were briefly presented (100 msec) centrally on a computer screen. Participants were required either to respond when a natural scene was presented (yes/no detection task) or to indicate if the stimulus was a city or a highway (categorization task).

Results: The three groups showed similar accuracy levels but significant differences were observed in response times. More precisely, left hemianopes were impaired both in the detection and in the categorization tasks whereas right hemianopes were only impaired in the categorization task. However, the three groups had similar responses to spatial frequencies: HSF were processed more slowly than LSF.

Conclusions: Overall these results suggest that central vision is not intact in hemianopia. Lesion side selectively affects reaction times (RTs) in the detection and the categorization tasks, but does not seem to determine a specific deficit in spatial frequency processing.

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1. Introduction

Visual analysis starts with an extraction of elementary information at different spatial scales/frequencies (for review, Basole et al., 2006), usually segregated as Low and High Spatial Frequencies (LSF and HSF, respectively). Experimental data from psychophysics (Ginsburg, 1986), functional neuroanatomy of magnocellular and parvocellular pathways (Van Essen and DeYoe, 1995) and ultra rapid categorization in humans and monkeys (Fabre-Thorpe et al., 1998) confirm the idea that visual analysis starts with a parallel extraction of different elementary visual attributes at different spatial scales or frequencies, with a coarse-to-fine processing design (Schyns and Oliva, 1994). According to this design, a rapid extraction of LSF should provide a global outlook of a stimulus structure, thus allowing an initial perceptual categorization. This perceptual categorization should be refined, confirmed or infirmed by the information conveyed by HSF whose extraction takes place later (Ginsburg, 1986; Hughes et al., 1996; Schyns and Oliva, 1994). Coherent with this hypothesis some authors have proposed that LSF conveyed by the magnocellular pathway reach higher order cortical areas (parietal and temporal cortices) more rapidly than HSF conveyed by the parvocellular pathway (for further details, see Bullier, 2001). Moreover, numerous behavioural and functional imagery studies using lateralized presentation of altered visual stimuli among healthy individuals as well as brain-damaged patients indicated that there could be a hemispheric asymmetry for LSF and HSF processing (Fink et al., 1996, 1997, 2000; Heinze et al., 1998; Robertson et al., 1988; Sergent, 1982; Wilkinson et al., 2001; Yamaguchi et al., 2000). These data revealed a left visual field/right hemisphere advantage for LSF yet a right visual field/left hemisphere advantage for HSF. This asymmetry takes the form of shorter response times (RTs, of about 30 msec) when detecting LSF in the left than in the right visual field as well as HSF in the right than in the left visual field (see for example, Peyrin et al., 2003). This asymmetry has been reported both for gratings of different spatial frequencies (Jonsson and Helige, 1986) and for filtered images of natural scenes (Peyrin et al., 2003, 2004). However, it seems sensitive to a wide range of factors, including task instructions (Oliva and Schyns, 1997) or time presentation (Peyrin et al., 2006a). In addition, some studies also report a general left visual field (right hemispheric dominance) advantage for visual processing whatever the spatial frequencies of the stimulus (e.g., Kitterle et al., 1990; Peyrin et al., 2006b) suggesting that although both hemispheres do not use exactly the same type of visual information, the right hemisphere may be more sensitive to all spatial frequencies (Rebaï et al., 1998).

Visual processing has been extensively studied regarding hemispheric asymmetries for spatial frequencies in associative cortices and less research has focused on asymmetries regarding the occipital cortex, notably in cerebral stroke patients. Yet, as underlined by Peyrin et al. (2006b), a population of choice to evaluate the implication of the each occipital lobe in visual processing is the one of patients suffering from a Homonymous Hemianopia (HH) following unilateral occipital damage (or a post-chiasmatic lesion). This disorder, in which patients are blind to the contralesional visual field, is particularly disabling regarding visual memory (e.g., Kerkhoff, 2000) but also results in significant deficits in activities of daily living. For example, impairments in visual exploration often result in the discontinuation of driving (Tant et al., 2002). Reading has also been found to be affected in these patients. These hemianopic patients show slowed reading, make several errors, or can even suffer from alexia (e.g., Leff et al., 2006). Given that reading relies largely on the central, detailed vision, it is likely that hemianopic patients experience impairments not only in their contralesional visual field but in their central visual field as well. Yet it is the central and the ipsilesional visual fields of these patients that are usually used in clinical practice and rehabilitation to compensate for their contralesional deficit (see for discussion Chokron et al., 2008). In spite of the classic assumption that these visual fields are perceptually unaffected in hemianopic patients, vision may not be fully intact. For example, it has recently been shown that hemianopic patients are impaired in detecting figures presented in their ''intact'' visual field (Paramei and Sabel, 2008). Regarding the asymmetry for spatial frequency processing, and thus for the nature of the underlying information, the Paramei et al. study also raises the question of the quality of global and local information processing in the central visual field.

The goals of the present study were three-fold. First we wanted to evaluate the quality of central vision in hemianopia. The scarce reports in the existing literature lead to suggest that there are some anomalies in the central visual field. Moreover, due to the right hemisphere superiority in visual processing (including the occipital lobe), impairments are expected to be greater in left hemianopic/right cerebral stroke patients. Second, we aimed to assess the effect of a lateralized occipital injury on cerebral asymmetry for spatial frequency processing. We expected to observe an LSF processing deficit in left hemianopic patients (with a right occipital lesion), but an HSF processing deficit in right hemianopic patients (with a left occipital lesion) in regard to the occipital asymmetry reported in imaging studies (e.g., Peyrin et al., 2004). Given the fact that at a behavioural level, such asymmetry can be observed when stimuli are presented in lateral visual fields (e.g., Peyrin et al., 2003) and because our study used central presentation, this asymmetry for spatial frequency processing could be attenuated. Finally, the task constraint effects were also evaluated using two tests: detection and categorization tasks of natural scenes images. Detection is the process of finding out the existence of a body or a hidden phenomenon; experimentally, it requires deciding on the presence of an object. Categorization is the ability to discretize physical reality by creating classes containing objects of similar nature; experimentally, it asks to assign exemplars to its corresponding category. According to Kitterle et al. (1990), hemispheric differences are more often found in the identification, but not the detection, of LSF versus HSF. Due to the right hemisphere superiority for visuospatial processing (e.g., Benton and Tranel, 1993), we expected left hemianopic/right cerebral stroke patients to be impaired in both tasks and to a larger extent in the detection task (Peyrin et al., 2006b). However, due to the supposed specialization of the left hemisphere for categorization (Kitterle et al., 1990) we

expected right hemianopic/left cerebral stroke patients to be specifically impaired in the categorization task.

2. Material and methods

2.1. Participants

Eleven brain-damaged men with isolated HH from unilateral post-chiasmatic lesion were recruited for this study. Diagnoses were confirmed with a visual field examination (Humphrey automatic perimetry 24-2, SITA-FAST program) with individual results presented in the Fig. 1. Six of them presented a right visual field defect following left brain damage (right homonymous hemianopia-left brain damage – RHH-LBD group; mean age: 61.04 ± 9.94 years; mean educational level: 13.67 ± 5.09 years), and the remaining five were left hemianopic patients following right brain damage (left homonymous hemianopia-right brain damage – LHH-RBD group; mean age: 67.33 ± 10.68 years; mean educational level: 7.80 ± 4.76 years). None of them suffered from confusion, general mental deterioration, or psychiatric disorders. Twenty-five healthy men (mean age: 60.50 ± 12.14 years; mean educational level: 13.76 ± 3.90 years) constituted the control group.

All participants were right-handed, had normal or corrected-to-normal visual acuity, and completed a consent form before entering the study. Moreover, contrast sensitivity of all but 2 patients (right hemianopes) was assessed using the Pelli–Robson chart. Individual scores were similar to those previously reported in a group of aged healthy participants [Hirvela et al., 1995; RHH-LBD group: mean (*M*) ± standard deviation (SD): 1.80 ± .07; range: 1.65–1.95; LHH-RBD group: *M* ± SD: 1.86 ± .14; range: 1.65–1.95]. The three groups were matched regarding their age (one-way analysis of variance – ANOVA, $p > .05$) and sex (see Table 1 for details). Nevertheless, a significant group effect was observed regarding the mean educational level [$F(2,33) = 4.29$; $p < .05$]. Indeed, the LHH-RBD group had a lower educational level than both other groups (post-hoc, LSD test; both $p < .05$). Finally, lesion extent, evaluated through lesion volume [calculated from T1 weighted Magnetic Resonance Imaging (MRI) scans] was similar in both groups (RHH-LBD: 22.61 ± 23.97 cm^3; LHH-RBD: 12.04 ± 8.32 cm^3). Regarding lesion sites, patients were very similar except for one left hemianope (patient 5). In both groups, cerebral stroke was localized in the occipital lobe (BA17 in all but one patient; BA18 in 5 right hemianopes and 4 left hemianopes; BA19 in 3 right hemianopes and 2 left hemianopes) and extended in the temporal horn (BA20 or BA21) and the fusiform gyrus (BA37), or even the angular gyrus (BA39) in two *right* hemianopic patients (patients 7 and 10). The one particular patient (patient 5) was a left hemianope showing a lesion largely extending in the temporal lobe (BA20–22, 26, 41, 42, and 48) and resulting from a meningioma resection.

2.2. Material

Stimuli were 8 black-and-white photographs (256 × 256 pixels) of natural scenes (6 cities and 2 highways, mean luminance of 122 and 123 respectively, on a grey-level scale; see Fig. 2a) selected from the database of natural scene images of the Computational Visual Cognition Laboratory (available online at http://cvcl.mit.edu/database.htm). In addition to these eight greyscale pictures (256 grey-level), two identical, grey images were built as null stimuli (see Fig. 2e) which made a total of 10 images. Angular size of all stimuli was fixed at 4° of visual angle. From each natural scene image, two additional stimuli were created, an LSF and an HSF-filtered scene images (see Fig. 2d). Spatial frequency content of scenes was filtered by multiplying the Fourier transform of original images by Gaussian filters. The SD of the Gaussian filter is a function of the spatial frequency cut-off, for a standard attenuation of

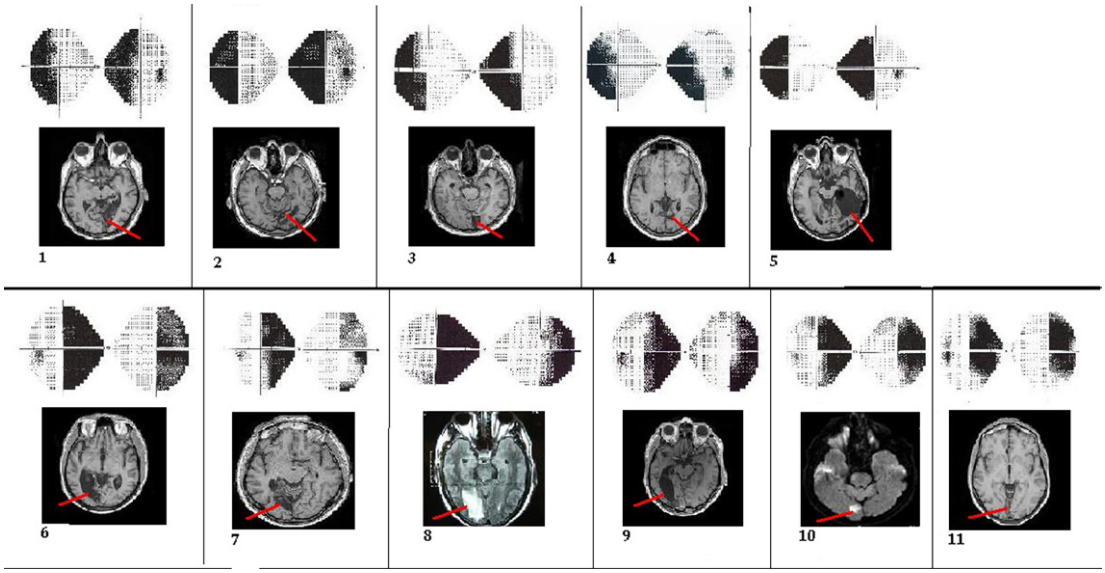

Fig. 1 – Visual field examination (Humphrey automated perimetry, 24-2, SITA-FAST program) and scan images (axial slide) of the 5 left hemianopic (top lines) and the 6 right hemianopic (bottom lines). On the scan images, the arrow indicates lesion site.

Table 1 – Demographic and clinical details of each hemianopic patient and of the control group.

	Age (years)	Educational level (years)	Lesion aetiology	Lesion location	Lesion volume (cm^3)	Time interval from lesion (months)	Macular sparing
LHH-RBD group							
Patient 1	70.01	5	Ischemia	BA17–19	11.47	34	Partial
Patient 2	78.90	5	Infarct	BA17–19	21.27	24.79	None
Patient 3	71.05	5	Ischemia	BA17, 18	14.22	21.20	Partial
Patient 4	49.90	8	Ischemia	BA17	1.21	25.30	Full
Patient 5	71.05	5	Surgery (meningioma)	BA20–22, 36, 41, 42, 48 and thalamus (posterior)	57.70	21.20	None
Mean (±SD)	67.33 (±10.68)[a]	7.80 (±4.76)[b]	–	–	21.17 (±21.65)[c]	55.52 (±65.46)[c]	–
RHH-LBD group							
Patient 6	48.11	14	Ischemia	BA17	.93	9.73	None
Patient 7	59.85	17	Ischemia	BA17–20, 37	51.00	28.23	Partial
Patient 8	56.75	12	Ischemia	BA17–19	17.80	36.00	None
Patient 9	56.25	20	Haemorrhage	BA17, 18	8.76	2.40	None
Patient 10	69.90	7	Haemorrhage	BA17–19, 21, 37, 39	54.20	30.43	None
Patient 11	75.39	5	Ischemia	BA17, 18	3.00	17.50	None
Mean (±SD)	61.04 (±9.94)[a]	13.67 (±5.09)[b]	–	–	22.61 (±23.97)[c]	20.71 (±13.05)[c]	–
Control group (n = 25)	60.50 (±12.14)[a]	13.76 (±3.90)[b]	–	–	–	–	–

SD: Standard deviation.

a Non significant difference (ANOVA).

b Significant group effect [ANOVA, $F(2,33) = 4.29$; $p < .05$]: the LHH-RBD group had a lower educational level than both other groups.

c Non significant difference between both patients groups (*t*-test).

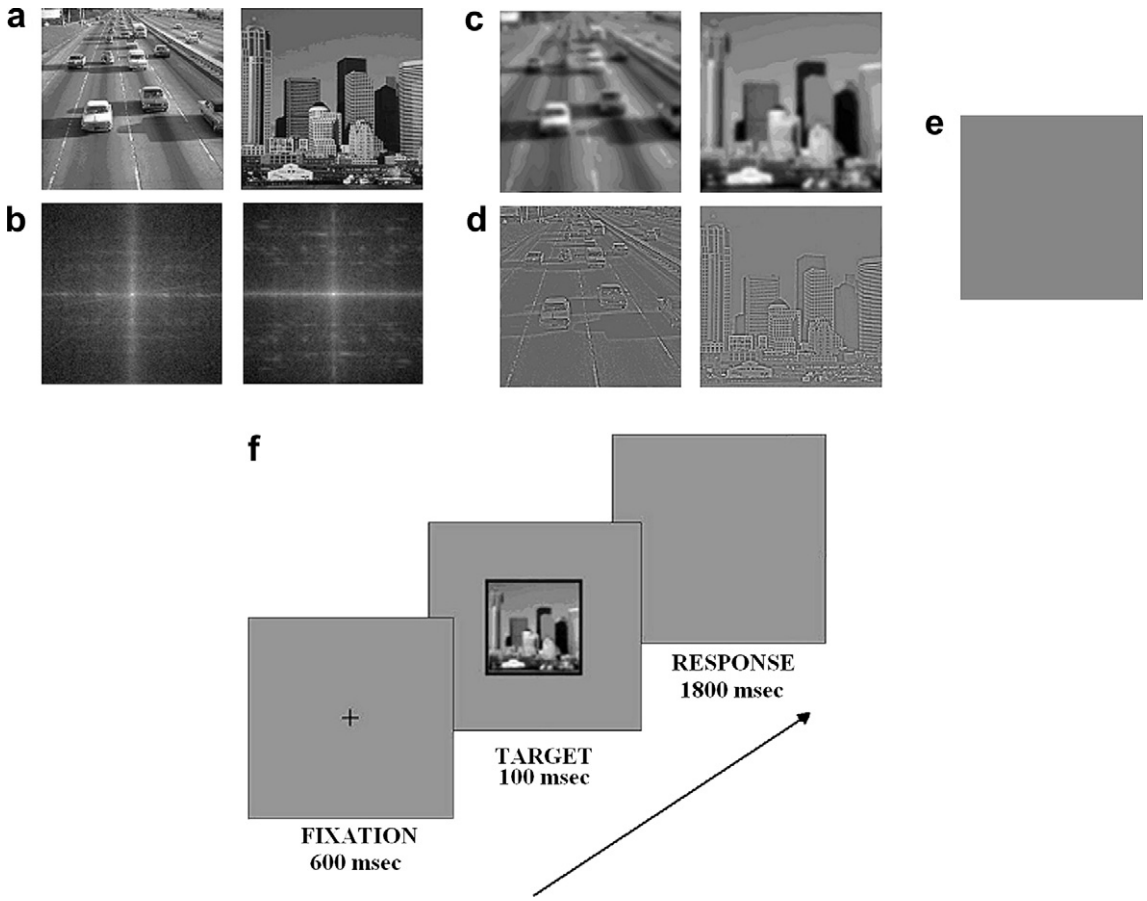

Fig. 2 – (a) Examples of scene images of each category (highway and city) used both in the discrimination and categorization tasks and (b) the mean amplitude spectra of each category. Each image was filtered in (c) low spatial frequencies (LSF, <4 cycles/degree) and (d) high spatial frequencies (HSF, >6 cycles/degree). (e) Null stimulus. (f) Time course of each trial: within a trial, a fixation cross was first presented centrally for 600 msec; then the stimulus appeared for 100 msec, and was finally followed by a grey screen lasting for 1800 msec while the participant pressed a button to give his/her response.

3 dB. We removed the spatial frequency content above 4 cycles per degree of visual angle (i.e., low-pass cut-off of 16 cycles per image) for LSF scene images and below 6 cycles per degree of visual angle (i.e., high-pass cut-off of 24 cycles per image) for HSF scenes images. In order to create stimuli that did not bias visual processing the total energy for LSF and HSF images was equalized for each scene[1] (for further details, see Peyrin et al., 2006a, 2006b; see Fig. 2b for illustration). All images (including null stimuli) were presented surrounded with a black frame so their final size was 264×264 pixels. From here, 3 blocks, each including the 6 cities, the 2 highways, and the 2 null stimuli, were elaborated: one block with non-filtered (NF) images, one block with LSF-filtered images, and one block with HSF-filtered images. Each block was repeated 4 times which made a total of 12 blocks per task.

2.3. Procedure

Participants sat facing the centre of a 19-inch computer monitor (1024×768 resolution) at a distance of 100 cm, in a dark room. This way images covered 5° of visual angle. They were presented centrally on a grey background screen via the E-Prime software (E-prime Psychology Software Tools Inc., Pittsburgh, USA). A trial (illustrated in Fig. 2f) was composed of a central fixation cross (presented for 600 msec), an image (presented for 100 msec) and a grey response screen (presented for 1800 msec).

Participants were required to perform two tasks. In the detection task they were instructed to press a button when the black frame was filled in with an image (either a city or a highway) and another one when it was the null stimulus. In the categorization task, they had to press a button when a city was presented and another one button when a highway or a null stimulus was presented in the black frame. The terminology of detection and categorization was chosen because:

[1] The energy level for LSF and HSF stimuli was equalized for each scene as follow: If $\mathrm{LSF}(i,j)$ and $\mathrm{HSF}(i,j)$ represent the value of the pixel at position (i,j) of respectively the low and the high-pass filtered images of a scene, their energies are given by $E_{\mathrm{LSF}} = \sum_{i,j} \mathrm{LSF}(i,j)^2$ and $E_{\mathrm{HSF}} = \sum_{i,j} \mathrm{HSF}(i,j)^2$. The average energy between LSF and HSF stimuli is then given by $E_{\mathrm{AVR}} = (E_{\mathrm{LSF}} + E_{\mathrm{HSF}})/2$. The stimuli are then normalized by the average energy, $\mathrm{LSF}_{\mathrm{norm}}(i,j) = \mathrm{LSF}(i,j)E_{\mathrm{AVR}}/E_{\mathrm{LSF}}$ and $\mathrm{HSF}_{\mathrm{norm}}(i,j) = \mathrm{HSF}(i,j)E_{\mathrm{AVR}}/E_{\mathrm{HSF}}$.

i) it suggests a greater language implication in the second than in the first task, consistent with tasks instructions; ii) in literature about blindsight (i.e., the ability to act, without awareness, on contralesional stimuli), authors tend to distinguish detection tasks, in which participant has to decide if a stimulus is present or not, from other types of ''forced-choice'' tasks (e.g., Stoerig et al., 2002); iii) studies of blindsight phenomenon (e.g., Stoerig, 2006) highlighted that primary visual areas are necessary to complete a simple detection task (because hemianopic patients are unable to detect simple stimuli presented in their contralesional visual field), but they are implicated to a lesser degree in a ''forced-choice'' task, such as our categorization task (because hemianopic patients can be able to make a decision about stimuli presented in heir contralesional blind visual field). Participants gave their responses by pressing a button of an SR-BOX aligned on the mid-sagittal plane of each participant. The forefinger and the middle finger of their right hand were used to respond. The order of tasks and the fingers used to respond were counterbalanced across participants within each group. The quality of the central fixation was controlled by the experimenter only during the tasks. Nevertheless, stimuli were presented aligned on the central fixation cross, on the centre of the screen. Moreover, stimuli presentation duration was 100 msec. Such duration extremely reduced visual exploration as reflexive saccades can appear about 100 msec after stimulus onset and voluntary saccades only appear about 200 msec after stimulus onset (for review, Findlay and Gilchrist, 2003). Furthermore, results of each patient for the visual field examination, during which they are required to fixate on a central cross, did not highlight any significant loss of fixation (all examinations were interpretable).

2.4. Data analysis

Responses and RTs (in msec) were recorded. Accuracy was evaluated through the error rate (ER, percentage of correct responses). ER and RT were individually analyzed using a two-way ANOVA with the three groups (controls, LHH-RBD, and RHH-LBD) as a between-subjects factor, and tasks (detection and categorization) and spatial frequencies (NF, LSF, and HSF) as within-subjects factors. When necessary, the specific effect of each factor was analyzed with post-hoc analysis (LSD test). All statistics were performed by the Statistica software package (release 5.1, 1997), and the alpha-set level was fixed at 5%. In the results section, Ms and SDs are presented.

3. Results

3.1. ER

ER analysis did not reveal significant main effects or interactions. All conditions confounded, the three groups showed a low ER (controls: $M = 2$, $SD = 6\%$; LHH-RBD: $M = 2$, $SD = 3\%$; RHH-LBD: $M = 1$, $SD = 2\%$) which did not vary between detection and categorization tasks, or following the spatial frequencies presented.

3.2. Response time (RT)

Data are presented in Table 2. RT analysis showed three main effects and one significant interaction. The main group effect [$F(2,33) = 5.75$; $p < .01$] results from significant longer RTs in LHH-RBD patients ($M = 603.46$, $SD = 111.66$ msec) compared to controls ($M = 482.71$, $SD = 95.27$ msec; post-hoc analysis, LSD test, $p < .01$). The main task effect [$F(1,33) = 104.43$; $p < .001$], highlights that the detection task ($M = 446.87$, $SD = 88.26$ msec) induced significantly faster responses than the categorization task ($M = 565.69$, $SD = 98.26$ msec).

However these main effects were modulated by a significant group × task interaction, [$F(2,33) = 4.90$; $p < .05$]. As illustrated in Fig. 3, although the three groups had shorter RTs in the detection task than in the categorization task (all detection/categorization comparisons were significant; post-hoc analysis, LSD test, $p < .001$), the group effect was not similar in both tasks. In the detection task RTs of LHH-RBD patients ($M = 545.75$, $SD = 102.52$ msec) were significantly longer than controls' RTs ($M = 431.65$, $SD = 75.52$ msec; post-hoc analysis, LSD test, $p < .001$) or RHH-LBD patients' RTs ($M = 427.87$, $SD = 74.28$ msec; post-hoc analysis, LSD test, $p < .001$). RHH-LBD patients and controls did not differ in the detection task. In the categorization task, controls' RTs ($M = 533.76$, $SD = 85.38$ msec) were again significantly shorter than LHH-RBD patients' RTs ($M = 661.17$, $SD = 90.45$ msec; post-hoc analysis, LSD test, $p < .001$); however this time controls' RT was also significantly shorter than RHH-LBD patients' RTs ($M = 619.16$, $SD = 82.07$ msec; post-hoc analysis, LSD test, $p < .001$). LHH-RBD and RHH-LBD RTs were not significantly different.

Finally, there was a main effect of spatial frequency [$F(2, 66) = 9.86$; $p < .001$] with HSF-filtered images leading to

Table 2 – Mean response times (msec) ± SD of the three groups in the detection and categorization tasks with LSF, HSF, and NF-images.

		Control group ($n = 25$)	RHH-LBD group ($n = 6$)	LHH-RBD group ($n = 5$)	All group confounded
Detection task	LSF	421.23 ± 66.08	431.60 ± 70.88	536.65 ± 110.62	438.99 ± 81.90
	HSF	450.98 ± 79.26	441.99 ± 92.10	574.94 ± 82.18	466.70 ± 90.81
	NF	422.75 ± 79.71	410.00 ± 67.94	525.68 ± 126.97	434.92 ± 90.81
Categorization task	LSF	539.18 ± 84.67	618.54 ± 73.11	653.90 ± 114.27	568.30 ± 96.19
	HSF	532.31 ± 94.64	647.54 ± 109.32	665.35 ± 93.23	569.99 ± 110.40
	NF	539.79 ± 79.37	591.65 ± 61.04	664.26 ± 82.37	558.78 ± 89.46
All conditions confounded		482.71 ± 95.27	523.51 ± 123.94	603.46 ± 111.66	

significantly longer RTs than LSF or unfiltered images (post-hoc analysis, LSD test, both $p < .001$).

3.3. *Complementary analyses*

To ensure the observed difference between both patients groups did not result from a difference in lesion site between patient 5 and other patients, we ran complementary analyses excluding patient 5. The new analyses indeed led to very similar results. Regarding ER, as above described, no significant main effect or interaction was observed. Regarding RT, although the main group effect did not reach significance anymore [$F(2,32) = 3.17$; $p = .055$], we still observed a main task effect [$F(1,32) = 88.08$; $p < .001$], a main spatial frequency effect [$F(2,64) = 12.52$; $p < .001$], and a group × task interaction [$F(2,32) = 4.81$; $p < .05$]. Post-hoc analyses (LSD test) showed that, as in the previous analysis: i) RT to HSF was longer than either to LSF or NF; ii) the RHH-LBD group had similar RT as the control group in the detection task but had longer RT than controls in the categorization; iii) the LHH-RBD group had longer RT than the control group both in the detection and the categorization task. Notwithstanding, in the detection task the difference between right and left hemianopes no longer reached significance (LSD test, $p = .08$). Altogether, to exclude patient 5 did not fundamentally modify our results.

4. Discussion

To assess the quality of central vision in hemianopia, detection and categorization tasks of natural scene images (filtered or not) were performed by RHH-LBD and LHH-RBD patients.

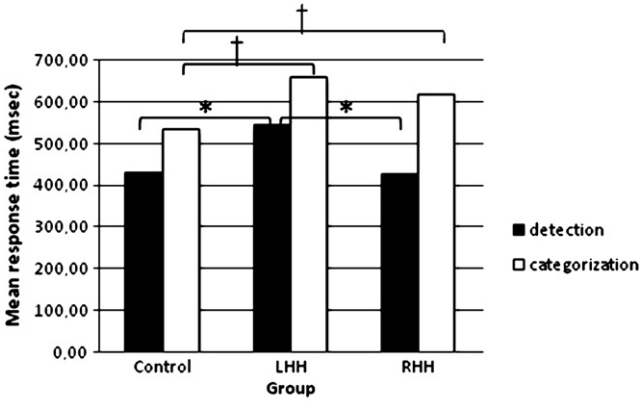

Fig. 3 – Mean response times (RTs, msec) observed in each group (healthy controls, left and right hemianopic patients [LHH-RBD and RHH-LBD]) and in each task (detection and categorization). In the detection task, left hemianopic patients had longer response times compared to both healthy controls and right hemianopic patients. On the other hand, in the categorization task, healthy controls had shorter response times than both left and right hemianopic patients.

Differential deficits were expected in these two populations since an early hemispheric asymmetry has been proposed for visual processing. Although our initial predictions were not fully confirmed, we indeed observed different patterns of impairment in these populations regarding their RT.

Compared to healthy controls, LHH-RBD patients showed longer response times in both task, whereas RHH-LBD patients showed longer response times only in the categorization task. This result supports previous studies showing a greater involvement (especially in terms of response times) of the right occipital cortex in passive vision (e.g., Grabowska et al., 1992), and, in general, greater sensitivity of the right hemisphere for visual characteristics (e.g., Rebaï et al., 1998; Peyrin et al., 2006b).

Comparison between detection and categorization tasks showed longer response times in the categorization task than in the detection task. Logically, the higher cognitive demand in the categorization task involves more sophisticated information processing, which in turn leads to more delayed responding.

The significant group × task interaction led us to modify the previous interpretations. In the detection task, LHH-RBD patients had longer response times than healthy controls whereas RHH-LBD patients had similar response times as controls. However, in the categorization task, both patient groups had similar response times which were longer than those of healthy controls. On the one hand, a left-sided lesion mainly alters categorization abilities; on the other hand, a right-sided lesion significantly alters both detection and categorization abilities. This dissociation is consistent with recent studies showing that detection and categorization are not intrinsically related and do not rely on the exact same mechanisms (Bowers and Jones, 2008; Mack et al., 2008). Nevertheless, results in the LHH-RBD group could contradict such an assumption and are indeed closer to other studies showing a temporal coupling or a common mechanism between detection and categorization (Grill-Spector and Kanwisher, 2005).

In the end, our data could reconcile these contradictory hypotheses by considering the hemispheric asymmetry in these processes. One can consider that detection and categorization rely *only in part* on similar mechanisms and do not implicate both hemispheres in the same way. A left hemisphere lesion induces mainly a deficit in the categorization task, whereas a right hemisphere lesion induces a deficit in both the detection and the categorization tasks. Compared to the left hemisphere lesion effect, the data suggest that the right hemisphere is preferentially implicated in detection abilities. Regarding categorization, our data suggest a preferential implication of the left hemisphere but also a contribution of the right hemisphere. The right hemisphere lesion defect could be interpreted as resulting from an alteration before, during, or after the processing within the left hemisphere. In the first case, the right hemisphere lesion alters detection processes within the right hemisphere which in turn alters the processing within the left hemisphere (i.e., the left hemisphere uses a degraded or delayed information to complete the categorization). In the second case, the right hemisphere lesion alters the left hemisphere functioning in itself. In the last case, the right hemisphere lesion induces an alteration of the final steps of the processing necessary in

a categorization task (e.g., through the elaboration of the response). Although this last assumption is particularly consistent in regard of the predominant role of the right hemisphere in visuo-attentional tasks further studies are obviously needed to conclude about the exact role of this hemisphere in categorization.

Regarding spatial frequency processing, only a main effect was observed. Overall, participants were slower to respond to HSF than to LSF or to NF images. In other words, LSF are sufficient to allow scene detection and categorization, as previously reported for categorization task (e.g., Guyader et al., 2004). Moreover, LSF are processed faster than HSF. There is a coarse-to-fine time course for spatial frequencies. Although it confirms a previous report for scene recognition in healthy individuals (e.g., Schyns and Oliva, 1994), our study suggests that hemianopic patients present the same time course than controls in spite of their unilateral occipital lesion. This assumption is supported by the lack of any significant interaction with the spatial frequencies factor. However, this lack of interaction challenges the classical view of an early hemispheric asymmetry for spatial frequency processing. Specifically, our results for LHH-RBD patients are in direct contradiction to the study by Peyrin et al. (2006b) that showed a larger impairment in LSF scene recognition in one left hemianopic patient. Nevertheless, some methodological considerations could explain the difference between our study and Peyrin et al. report. First, we assessed central vision whereas they assessed the intact visual field of their patient. Second, all but one patient received clinical rehabilitation for several months before entering this study whereas the hemianopic patient of Peyrin et al. was evaluated only 6 months after surgery (see Chokron et al., 2008 for precision on the rehabilitation programme). Moreover, this last point may explain our overall lack of specific deficit for spatial frequencies in hemianopic patients. Actually, the patients of the present study received regular practice for their hemianopia and were thus trained to detect, report, or localize stimuli presented in their blind field while fixating on a central point. Thus, this visual training could have improved spatial processing in hemianopic patients and masked the specific defect induced by the lateralized lesion. Nonetheless, further studies are necessary to determine if the cerebral reorganisation underlying some visual recovery could explain this negative result.

Altogether, our results highlight that a HH consecutive to a post-chiasmatic lesion is associated to a specific deficit in detection or categorization abilities depending on the lesion side. Specifically, a lesion of the right visual areas will mainly induce a specific deficit in detection abilities whereas a lesion of the left visual areas will mainly induce a specific deficit in categorization abilities. In the end, the central visual field of hemianopic patients may not be as intact as one can assume and should benefit from a specific rehabilitation to ensure better use in everyday tasks.

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