GESTALT PERCEPTION IN HEMIANOPIC PATIENTS: PERFORMANCE MEASURES AND VEPS

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Abstract

Perceptual grouping, an essential mechanism of object recognition, is accomplished at early visual processing stages. Its electrophysiological correlate is the N1 component of the visual evoked potential (VEP). In the present VEP study, we investigated neural correlates of perceptual grouping in the perimetrically intact visual field of hemianopic patients. We studied six patients with homonymous hemianopia resulting from posterior brain lesions and compared them to nine healthy subjects. All observers were presented either random arrays of Gabor patches or arrays with an embedded circle. For the hemianopic patients, the circle was presented in their intact hemifield only. The subjects were instructed to detect the circle by pressing a corresponding button ("yes-no" paradigm). In addition to VEPs, error rates and response times were registered. Performance data did not show any differences between the patients and controls. In the VEPs for healthy subjects, N1 amplitudes were significantly larger for circular patterns than for random arrays. This N1 effect, however, was not found for the hemianopic group. Furthermore, P1 amplitudes were generally augmented in the patients' VEPs. The present findings provide electrophysiological evidence of impaired perceptual grouping in the intact hemifield of hemianopic patients. This confirms previous behavioral observations of impaired perceptual grouping in the intact field.

Visual field defects such as hemianopia are common consequences of posterior brain injury. Homonymous hemianopia (HH) refers to a loss of vision in one half of the visual field of both eyes contralateral to the site of the lesion. Hemianopic patients mainly complain of difficulties with reading and detecting objects in the affected half of the visual field. There is additional evidence that visual perception is affected in the intact hemifield. Some studies described a slower recognition of complex patterns (Bender & Teuber 1946) and difficulties in visual exploration (Zihl, 1995; Tant et al., 2002). In a recent psychophysical study, we observed that Gestalt perception in the intact hemifield of HH patients is impaired. They have difficulties in detecting a figure composed from Gabor patches and embedded in a "noisy" background (Paramei & Sabel, 2006). The mentioned studies focused on the behavioral shortcomings in the intact hemifield of HH patients. Presumably, neural processes underlying hemianopes` visual perception also differ from those in healthy observers. To date, this issue was examined in a very few studies (e.g. Vallar et al., 1991). In the present study, we investigated performance measures and neural correlates of Gestalt perception in the intact visual field of patients with HH compared to healthy controls by using electroencephalography (EEG). In particular, we studied perceptual grouping as the ability of the visual system to organize separate parts of a stimulus into an organized structure and segregate this structure from a noisy background. VEP correlates of Gestalt perception were recently studied in healthy subjects (Herrmann & Bosch, 2001; Ohla et al., 2005). The main finding is a more pronounced N1 amplitude for Gestalt patterns compared to non-Gestalt stimuli whereas the

former requires perceptual grouping mechanisms (for a review see Seghier & Vuilleumier, 2006). In the current study, we hypothesized behavioral impairments and differences in the neural processing of Gestalt patterns in hemianopic patients.

Methods

Subjects

Six patients (three female), aged 50-68 years (mean = 59.7 ± 7.6) with HH participated in the study. Their visual field defects resulted from lesions of various etiologies and sites (Table 1). Additionally, nine healthy controls (five female), aged 57-70 years (mean = 63.6 ± 4.3) were examined. All control subjects had normal or corrected-to-normal vision and reported no psychiatric or neurological disorders. All participants gave their informed consent and were paid for the examination.

Stimuli and Task

Stimulus patterns were made of Gabor patches (GPs). Parameters of GPs were defined as follows (cf. Braun, 1999): spatial period $\lambda = 0.647°$; phase $\phi = 0$; visual size = 1.2°. Maximal and minimal luminance values of GPs were set at 123 cd/m^2 and 0.4 cd/m^2 with a contrast of 100%. The patches were presented against a uniform gray background (32 cd/m^2). Two different stimulus categories were presented: random arrays of GPs (RANDOM) and random arrays of GPs that contained a circular arrangement of GPs, either in the left or right visual hemifield (CIRCLES) (Fig.1). The contour of the circle was built up of collinear GPs. This circle served as the target figure, subtended 6º of visual angle, and with a circumference presented at a distance of 1º from the midline. The background density (Δ) of the Gabor elements was set at $\Delta = 0.95$. Note that at $\Delta \leq 1$, a contour can be perceived solely on the basis of collinearity of the GPs (Kovács et al., 2000). Each stimulus was presented for 500 ms with a randomized interstimulus interval of 2300-2700 ms. A total of 400 trials (100 CIRCLES to the left of fixation; 100 CIRCLES to the right; 200 RANDOM) were presented to each control subject. Each patient was exposed to altogether 300 trials (150 CIRCLES presented contralateral to hemianopia; 150 RANDOM).

Table 1. Subjects`characteristics

Age, Gender	**Localization and type of the lesion**	**Time elapsed from lesion (months)**	**Site of the visual field defect**
55 F	Lesion of the optic tract following closed head injury	178	Right HH, with a wedge-shaped sparing in the lower quadrant
66 F	Posteriorinfarct right	160	Left HH
68 F	Posteriorinfarct right	13	Left HH
50 M	Occipito-parietal angiom right, surgical excision	287	Left HH
54 M	Posteriorinfarct left	29	Right HH
65 M	Posteriorinfarct right	63	Left HH

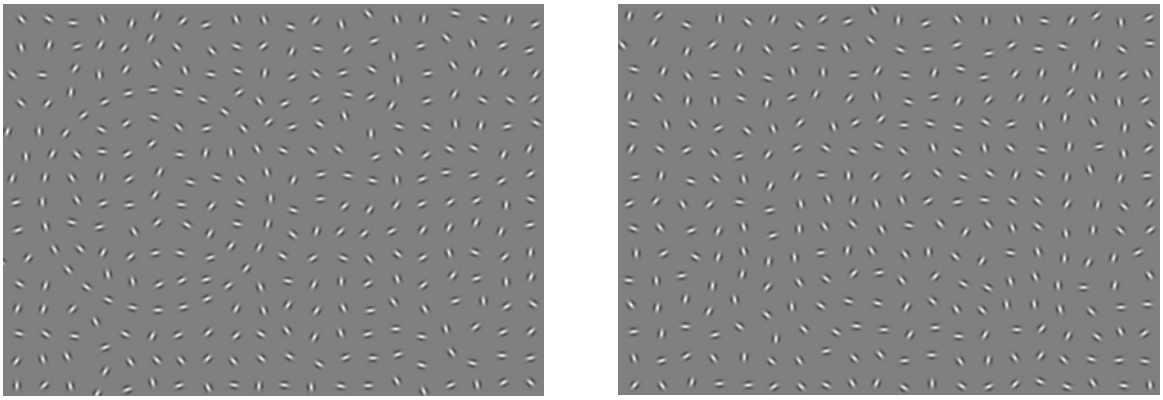

Figure 1. Stimuli. Left: A random array of GPs containing a circular arrangement (CIRCLES). Right: A random array of GPs (RANDOM).

The task for the healthy controls was to discriminate whether the circle was on the left or right side of the screen by pressing corresponding buttons on a response box. The patients were instructed to detect the target figure (circle) by pressing a button, whereas the circle was only presented in the intact hemifield. During the experiment, all subjects were required to fixate a red point in the center of the screen to avoid eye-movement artefacts.

Data acquisition and analysis

EEG was recorded with a BrainAmp amplifier using 32 sintered Ag/AgCl electrodes mounted in an elastic cap and placed according to the 10-10 system, with a nose-tip reference and ground electrode between Fz and Cz. Eye movement activity was monitored with an electrode placed sub-orbitally to the right eye. Electrode impedances were always below 5 kΩ. Data were acquired with a sampling rate of 500 Hz and hardware-filtered between 0.02-200 Hz. Averaging epochs lasted from 200 ms before to 600 ms after stimulus onset for VEPs. Baselines were calculated in the interval from -200 ms to the stimulus onset and subtracted before averaging. An automatic artefact rejection was computed, which excluded trials from averaging if the standard deviation within a moving 200 ms time interval exceeded 40 μV. All epochs were also visually inspected for artefacts and rejected in case of eye-movements, electrode drifts, or electromyographic activity.

In order to analyze condition-effects, all contralateral circle presentations (left/right) were averaged to "one circle"-condition for the healthy controls. Paired t-tests were calculated to compare both experimental conditions (CIRCLES vs. RANDOM). Group differences were analyzed by repeated measures ANOVA with one between-subject factor (GROUP, two levels: controls and HH patients).

Results and Discussion

Performance Measures

Although the task was very simple, both groups performed with a high error rate (23.4 % errors for healthy controls; 27.5 % errors for patients). Patients` responses were somewhat faster (mean RT = 429.2 ms) compared to the responses of healthy controls (mean RT = 438.2 ms). Supposedly this is due to the fact that the patients performed a detection task, whereas the controls accomplished a discrimination task. However, t-tests revealed no significant

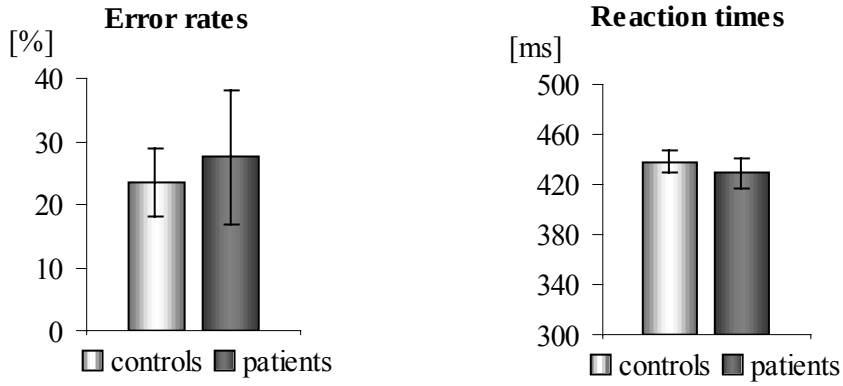

Figure 2. Error rates, RTs, and standard errors for control subjects and hemianopic patients.

differences between both groups for error rates [t(13) = 0.37, p = n.s.] as well as reaction times [t(13) = 0.63, p = n.s.] (see Fig.2).

Electrophysiological Results

For the control subjects, the VEPs of both conditions were characterized by a first positive peak at 110 ms (P1) followed by a negative peak around 241 ms (N1) and a further positive component at 466 ms latency (P3). For the patients, these components were also found for the hemisphere contralateral to stimulus presentation (intact hemisphere) with the following peak latencies: P1 at 113 ms, N1 at 183 ms, and P3 at 438 ms after stimulus onset. Figure 3 depicts the averaged responses recorded from electrodes P3/P4 in healthy controls (A) and hemianopic patients (B).

For the healthy controls, the analysis of the N1 amplitudes revealed the expected effect indicating larger amplitudes for the CIRCLES condition compared to the RANDOM condition [t(8) = -9.22, p < 0.001]. However, this N1 effect was not shown in hemianopic patients [t(5) = -2.5, p = n.s.]. Furthermore, for the late P3 component we observed the well-established target effect with larger amplitudes for CIRCLES than for RANDOM arrays. This effect was present in healthy controls [t(8) = 13.45, p < 0.001] as well as in patients [t(5) = 4.99, p = 0.004] and most pronounced at posterior electrodes.

The group analysis revealed significant differences for the P1 [F(1,13) = 5.84, p < 0.05] with larger amplitudes in patients as well as for the P3 [F(1,13) = 4.91, p < 0.05] with larger amplitudes in controls (Fig.3).

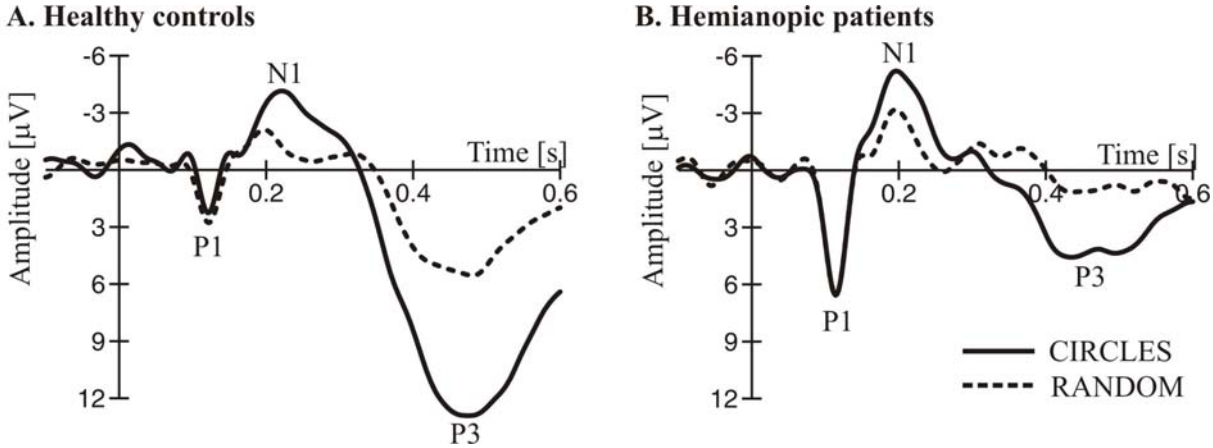

Figure 3. VEPs waveforms at electrode P3/P4 for CIRCLES (solid lines) and RANDOM (dashed lines) averaged across all healthy controls (A) and hemianopic patients (B).

Discussion

In contrast to our previous study (Paramei & Sabel, 2006), the performance data (error rates and RTs) in the present study indicate that Gestalt perception in the intact hemifield of hemianopic patients is comparable to that of age-matched healthy controls. The discrepancy might be caused by the difference in the background density (Δ) of the stimuli employed in the two studies. Nevertheless, the electrophysiological findings point to apparent differences in neural processing of the used Gabor patterns: (i) The patients do not show significantly larger N1 amplitudes for stimuli that require perceptual grouping as healthy subjects do; (ii) P1 amplitudes are more pronounced in patients; (iii) Amplitudes of the "target" P3 are smaller in patients compared to the controls.

N1 component. For the healthy controls, the N1 effect for circularly arranged Gabor patches points to perceptual grouping processes and is in accordance with results in previous studies. These studies demonstrated that the visual N1 (or N170) reflects bottom-up processes related to stimulus properties (Herrmann et al., 1999), but is otherwise associated with top-down processes such as the identification of a Gestalt (Herrmann & Bosch, 2001; Ohla et al., 2005). The perception of a Gestalt or the perceptual ability to group elements leads to a larger N1 compared to a non-Gestalt stimulus. The absence of the N1 increase in response to Gestalt stimuli (CIRCLES) in hemianopic patients provides electrophysiological evidence of impaired perceptual grouping even in their intact hemifield.

P1 component. A further difference between both groups is shown by the generally augmented P1 amplitudes in patients compared to the controls. The P1 component of the VEP is linked to early sensory processing in extrastriate visual areas and attentional processes (Luck et al., 1990). Martínez et al. (1999) emphasized that the P1 seems to be an index of "attentional amplification", which facilitates the perceptability of stimuli at attended locations. Both studies reported a larger P1 amplitude for attended stimuli compared to unattended ones. In connection with their findings, the enlarged P1 amplitudes in patients may be related to the different type of the perceptual task, i.e. detection (patients) vs. discrimination (controls). Presumably, the patients allocated their complete attentional resources to the intact hemifield, whereas the control subjects had to divide their attention between both hemifields since target stimuli were presented on the left as well as on the right side of the screen. The greater amount of attention to one hemifield have therefore resulted in larger P1 amplitudes in patients.

P3 component. In healthy subjects, correctly detected target stimuli evoked a slow positivity with a maximum in parietal electrodes that is in good agreement with previous studies (Donchin et al., 1986; Polich, 2004). In contrast, the hemianopic patients showed a greatly diminished P3 amplitude. The P3 amplitude is known to be modulated by the amount of attentional resources allocated to a given task and is linked to memory performance (Polich, 2004). Hence, Polich and colleagues assume that variations in the P3 amplitude reflect the degree of elaboration with which incoming information is processed (Polich & Herbst, 2001). To date, the P3 wave was investigated in several psychiatric and neurologic disorders (Hruby & Marsalek, 2003). Similarly to the hemianopic patients in the present study, P3 amplitude flattening was found in patients with Alzheimer's disease, Parkinson's disease, and in depressed patients. For all diseases, this electrophysiological finding is supposed as one of the signs of cognitive impairment.

In conclusion, the results of the present study indicate an impairment of neural processing in Gestalt perception in the intact hemifield of patients with hemianopia.

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