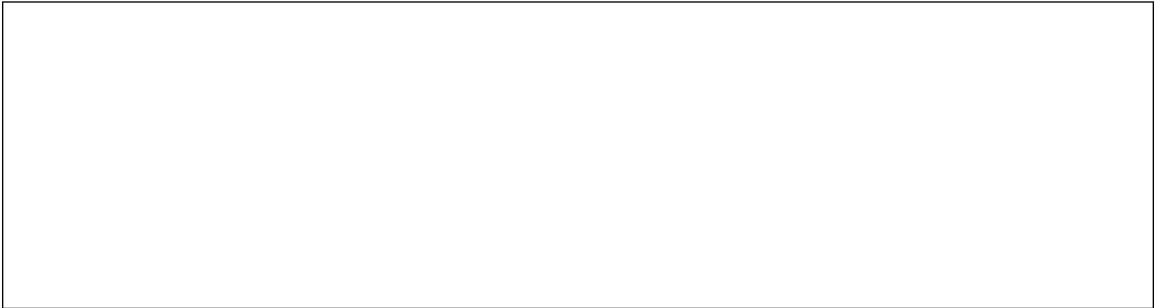


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1981; Treisman, 1986), rather than attention facilitating grouping operations to form perceptual units. Nevertheless, there has been evidence that perceptual grouping can be affected by top-down attention. For example, the ability to identify perceptual groups defined by proximity or similarity can be impaired when attention is engaged in a secondary concurrent task (Ben-Av, Sagi, & Braun, 1992; Mack, Tang, Tuma, & Kahn, 1992). Facilitation of the detection of a central Gabor patch (a Gabor patch consists of a sinusoidal contrast modulation convolved with a Gaussian function) by collinear flankers also requires the flankers to be attended (Freeman, Sagi, & Driver, 2001, 2004). Recent neuroimaging studies provide further evidence that interactions between attention and perceptual grouping can take place as early as in human primary visual cortex. For instance, we have recently found that an attentional effect on the integration of collinear Gabor patches can occur as early as 50 ms after stimulus delivery over the occipital area (Wu, Chen, & Han, 2005). Stimulus arrays of Gabor patches elicited a negativity over the posterior occipital cortex at 48–72 ms which was enhanced when attention was allocated along the collinear patches in the stimulus arrays than when attention was directed to the orientation orthogonal to the collinear patches. Having participants attend to the color of a central fixation cross, rather than to more global stimulus patterns, also weakened the early ERP component normally responsive to grouping by collinearity (Han et al., 2007). We have also demonstrated similar modulation of grouping related activities in human primary visual cortex using fMRI, when grouped stimuli are of low relative to high task relevance (Han et al., 2005a, 2005b). These data indicate that grouping operations in the visual cortex are influenced, at least to some degree, by top-down modulation from higher brain structures that control visual attention.

There is now considerable evidence that visual attention is controlled by a fronto-parietal network that provides top-down modulation of activities in early visual areas (Corbetta, 1989). fMRI studies have frequently observed activation of this network in tasks involving orienting of spatial attention (Gitelman et al., 1999; Kim et al., 1999; Nobre et al., 1997; Yantis et al., 2002). Attentional orienting can in turn result in enhanced activity in the visual cortex associated with stimuli presented at attended relative to unattended locations (Gomez Gonzalez, Clark, Fan, Luck, & Hillyard, 1994; Hopfinger, Buonocore, & Mangun, 2000; Mangun & Hillyard, 1991; Martinez et al., 2001; Luck, Chelazzi, Hillyard, & Desimone, 1997). In addition, damage to the fronto-parietal network can lead to impaired spatial orienting to the contralesional field (Posner, Walker, Friedrich, & Rafal, 1984; see Mesulam, 1999 for review) and result in absence of attentional modulation of the visual activities (Han et al., 2004, Han & Jiang, 2004). These findings strongly suggest that the fronto-parietal network plays a major role in modulating perceptual processing in the visual cortex.

In the present paper we tested the role of the fronto-parietal network in the top-down attentional modulation of grouping in the visual cortex, for a range of different Gestalt laws. ERPs were recorded using high-density electrodes from two

patients with fronto-parietal lesions. Similar to our previous ERP studies (Han et al., 2005a, 2005b), participants were presented with stimulus arrays in which local elements were either evenly distributed or grouped into rows or columns, (i) by the proximity or the similarity of the shapes (Experiment 1) or (ii) by the collinearity or similarity of orientation (Experiment 2). The grouping e

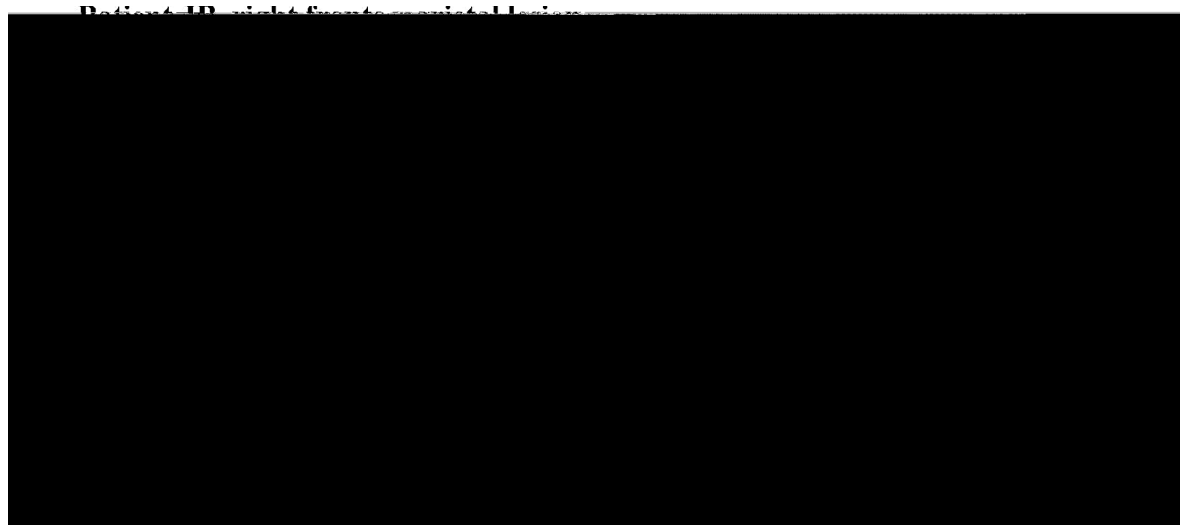


Fig. 1. Illustration of the brain damages of the two patients. MRI scans show JB's lesions in the right fronto-parietal areas and MH's lesions in the left parietal cortex.

Stimuli and procedures

Experiment 1

White stimulus elements were presented on a black background on a 17-inch color monitor at a viewing distance of 100 cm. A white fixation cross of $0.28 \times 0.28^\circ$ (width and

height) was continuously visible in the center of the monitor. Nontarget stimuli consisted of a square lattice of grey elements (either filled circles or squares) in an 8×8 array, as shown in Figure 2. The luminance of the grey elements was 43.2 cd/m^2 . The uniform stimulus consisted of alternate circles and squares distributed evenly across the lattice. This

Experiment 1



Fig. 2. Illustration of the stimulus arrays in Experiments 1 and 2. In Experiment 1 local circles and squares were white on a black background and grouped into columns or rows based on proximity or shape similarity in the grouped stimuli, whereas the elements were evenly spaced in the uniform stimulus. In Experiment 2 local Gabor patches were presented on a grey background and grouped into columns or rows based on collinearity or similarity of orientation in the grouped stimuli, whereas the elements were evenly spaced in the uniform stimulus. Subjects identified the orientations (vertical vs. horizontal) of the grating in both experiments.

arrangement prevented the local elements from grouping into rows or columns. The proximity-grouped stimuli consisted of alternate circles and squares arranged in arrays to form separate perceptual groups (i.e., rows or columns) by adjusting the distances between two adjacent rows or columns of local elements so that the spaces between two near or remote rows (or columns) were 0.12° and 0.85° , respectively. The similarity-grouped stimuli were made by placing the circles and squares in the uniform stimulus to form rows or columns of elements with the same sh

=9.41, $p < .05$) and between 220 and 280 (Nd240, $F(1, 7)$ =9.99, $p < .01$), respectively. The Nd130 showed maximum amplitudes over the medial occipito-parietal area, whereas the Nd240 showed maximum amplitudes over bilateral occipital areas. The difference waves related to similarity grouping in Experiment 2 also showed a negative deflection; however,

electrodes ($F(1, 8)=5.14, p < .05$). The N130 and the following P2 showed larger amplitudes relative to those recorded from the controls. However, these effects did not reach signifi-

(Pd100).¹ Such early grouping effect has been reported in previous studies of young adults and has been localized to the calcarine cortex (Han et al., 2001, 2002, 2005a). In replicating this, the present results su

Pd100 is modulated by top-down attention (Han et al., 2005a). The Pd100 is significantly reduced when the features making up the perceptual groups were of low rather than of high task relevance. In addition, the Pd100 was also influenced by the size of spatial attentional window, being present when grouped stimulus arrays fell inside the attended area but eradicated when grouped stimulus arrays fell outside the attended area. Here the comparison of ERPs between the patients with fronto-parietal lesions and the healthy controls suggests that the fronto-parietal cortex is necessary for the early grouping operations to occur in the visual cortex.

In contrast, the parietal lesions produced less effect on the long-latency grouping effects. The difference waves related to the proximity grouping from both the patients and the controls showed negativities over the occipito-parietal area.

elements into larger ‘chunks’ whereas the late grouping operations function to process the features of the perceptual groups (e.g., orientation in this study) in other brain areas. The functional roles of the early and late grouping processes require different feedback from the parietal cortex, which facilitates mainly the initial segmentation operation.

Similar effects of fronto-parietal lesions on grouping by collinearity were observed in Experiment 2. The collinear grouping effects in the controls were indexed by an early Nd130 over the medial occipital area and a late Nd250 over the occipital cortex bilaterally. However, non-collinear Gabor patches that were similar in orientation did not generate significant ERP grouping effect, suggesting that similarity of one simple feature (i.e., orientation in Experiment 2) was not as strong a grouping cue as similarity of shape in Experiment 1. We recently found that, for young adults who were presented with similar stimulus arrays as those in the current study, the collinear grouping effect could occur at 40–80 ms after stimulus delivery indexed by a positivity over the medial occipital area. There was also a long-latency negativity over bilateral occipital areas in association with collinear grouping (Han et al., 2007). Thus our data with older controls here suggest that age alone may lead to a weakening/slowing of the early grouping effect (though, unlike with patients with fronto-parietal lesions, the effect remains). This is consistent with the ERP studies with younger adults where an enlarged early component has been observed (80 ms post-stimulus) when fewer Gabor patches were presented in each stimulus array (Khoe et al., 2004), so that weaker grouping takes place.

In Experiment 2, both short- and long-latency grouping

condition of no TMS, disruption of the left/right parietal cortex reduced the amplitude of the early extrastriate activity. Disruption of the precentral gyrus, however, did not influence the early visual activity such as the P1 component compared with when no TMS was applied. These results suggest that it is unlikely that disruption or damage of any brain areas would produce similar effect on the early visual sensory/perceptual processing. Further research is required to examine whether early perceptual grouping receives top-down modulation from brain areas outside the frontal and parietal lobes.

Previous research has shown abundant evidence for top-down effects in visual perception. For example, the early sensory/perceptual pro

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