Spontaneous EEG Activity and Biases in Perception of Supra-Threshold Stimuli

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Abstract Human perception of oriented visual stimuli is biased: some orientations are seen more often than others. We studied how the orientation bias is represented in the electrical brain activity that preceded presentation of ambiguous supra-threshold visual stimuli. We examined scalp EEG over the parieto-occipital regions during 1 sec before stimulus presentation. The alpha activity of pre-stimulus EEG was associated with the orientation bias: the preference for vertical orientation in most observers corresponded to low pre-stimulus alpha power. The results indicate that the orientation bias is encoded in intrinsic properties of ongoing cortical dynamics, forming spontaneous orientation-specific patterns of activity.

Keywords EEG • Spontaneous alpha activity • Perceptual organization • Perceptual bias

1 Introduction

The perception of a stable and continuous world is mediated by neural mechanisms that are adept at resolving ambiguities of stimulation. One factor that helps to resolve the ambiguities is expectation of stimuli from prior experience in similar perceptual situations. Perception can therefore be viewed as a *competition* of two

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forces: current stimulus and stimulus expectation. Unnoticeable in regular viewing conditions, the competition comes to the fore in the perception of multistable stimuli [1, 2].

Gepshtein and Kubovy experimentally measured and modeled the competition in ambiguous visual stimuli [3]. They explicitly separated the factors extrinsic to the brain (called "stimulus support") from intrinsic factors ("perceptual bias") in grouping by proximity. The authors showed how perception depends on both factors, and how stimulation controls perception when it overcomes the intrinsic perceptual bias.

Gepshtein and Kubovy proposed that the intrinsic factor depends on ongoing brain activity [3]. Supporting this notion, previous studies found that the power [4] and phase [5] of ongoing electrical brain activity (EEG) affected perception of the upcoming stimuli. These studies mainly used stimuli near the threshold of detection. Here we asked whether ongoing activity may also affect perception of supra-threshold stimuli.

We studied perceptual grouping in ambiguous dot lattices, each of which can be seen as strips of dots in different orientations. Perception of these stimuli is an outcome of competition between stimulus factors that support several orientations, and intrinsic orientation bias that presumably originates in ongoing brain activity. We looked for associations between electrical brain activity that precedes stimulus presentation and the perception of subsequent dot lattices.

2 Methods

Thirteen healthy participants took part in the experiment. The stimuli were dot lattices which are spontaneously perceived as strips of dots [6]. The shorter the distance between the dots in a certain orientation, the more likely the dots group along that orientation. According to the pure distance law [7], grouping in dot lattices depends on their aspect ratio (AR), which is the ratio of two shortest inter-dot distances. We used dot lattices with four values of AR: 1.0, 1.1, 1.2, and 1.3. The lattices were presented at four orientations, such that the orientation of the shortest distance was rotated counterclockwise from the horizontal for 22.5°, 67.5°, 112.5°, or 157.5° (Fig. 1).

Each trial consisted of four phases: fixation, stimulus, blank screen, and response screen. During fixation, observers were instructed to look at a small circle at the screen center for a duration that varied randomly according to a uniform distribution on the interval of 1,200–1,500 ms. The durations of stimulus and blank-screen were both fixed at 300 ms. A response screen was presented until a response was received. The task was to report the orientation of the perceived dot grouping by choosing one of the four response icons (shown as white insets in Fig. 1) on the response screen.

EEG was recorded using a 256-channel Geodesic Sensor Net (Electrical Geodesics Inc., USA). Data were digitized at 250 Hz. All channels were referenced to the vertex electrode (Cz). Further details of stimulus, procedure, and EEG recordings are available in [8].

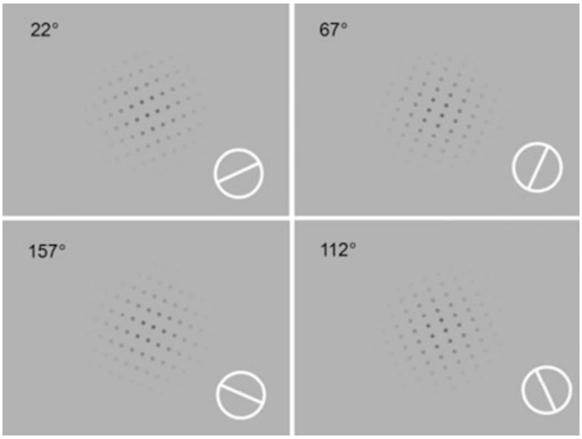

Fig. 1 A dot lattice presented at four orientations. The orientations of 22° and 157° are close to the horizontal, and the orientations of 67° and 112° are close to the vertical. The aspect ratio of this lattice is 1.3

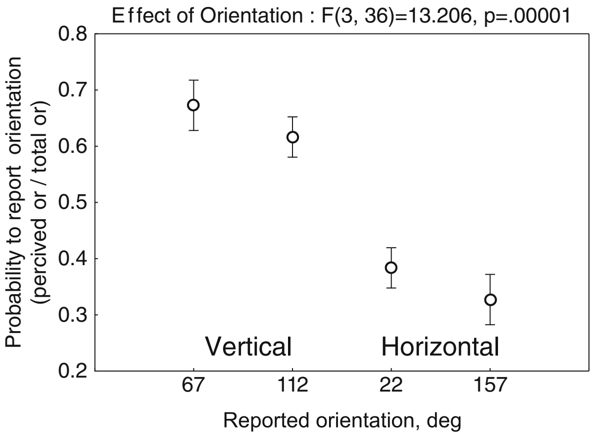

Fig. 2 Behavioral results: orientation bias. Reports of the close-to-vertical percepts were more common that reports of the close-to-horizontal percepts

We estimated the power of alpha-band activity (8–13 Hz) during a 1-s interval prior to stimulus presentation (i.e., during fixation). The alpha power was computed using FFT in 59 electrodes selected over the parieto-occipital regions. Electrodes were sorted by alpha power in descending order. We selected 29 electrodes with highest power and averaged their alpha power. The power values were log-transformed so the distribution of values approached the normal distribution.

3 Results

All other factors being equal, observers preferred vertical over horizontal dot groupings (Fig. 2). We estimated the strength of this *orientation bias* by measuring the difference in frequency of reports of “vertical” and “horizontal” groupings.

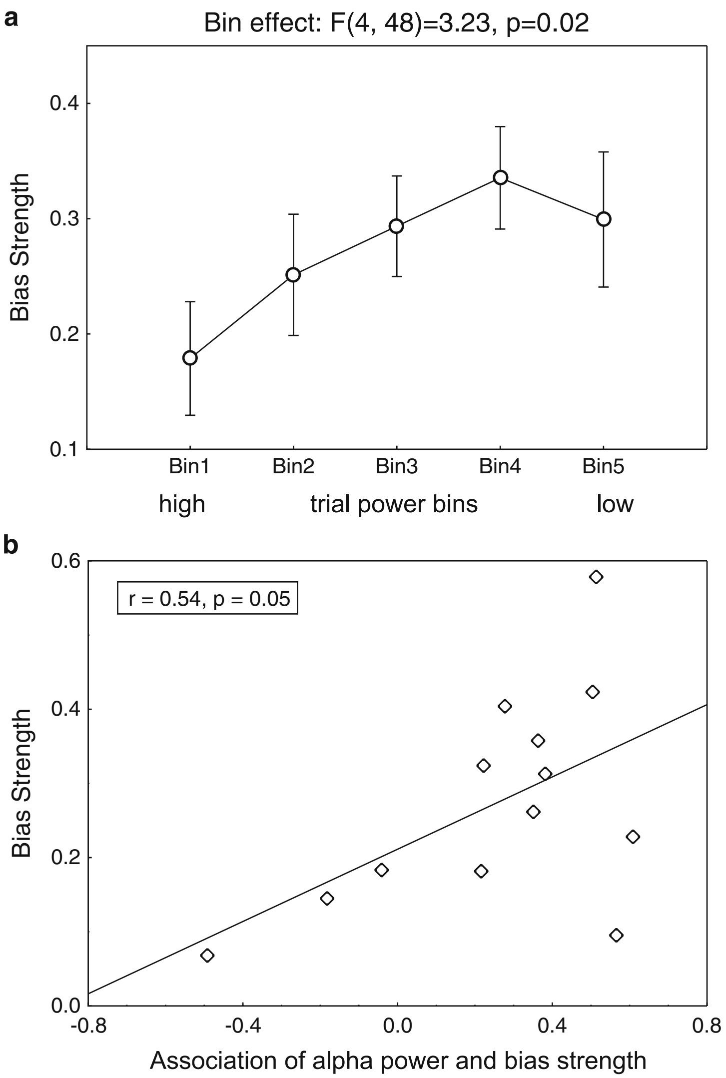

Fig. 3 (**a**) Strengths of orientation bias within bins of trials for different levels of pre-stimulus alpha power. Alpha power decreases from left to right. (**b**) Association of bias strength and pre-stimulus alpha power. Each point represents a different observer. The association of alpha power and bias strength was more pronounced in those trials where perception was dominated by bias

We sorted trials by alpha power in descending order, divided them into five bins, and calculated the strength of orientation bias for trials within each bin. Pre-stimulus alpha activity was associated with orientation bias: the bias for vertical orientation occurred more often in trials with low pre-stimulus alpha power (Fig. 3a). This effect was modulated by bias strength: the higher the bias the more it was associated with pre-stimulus alpha power (Fig. 3b).

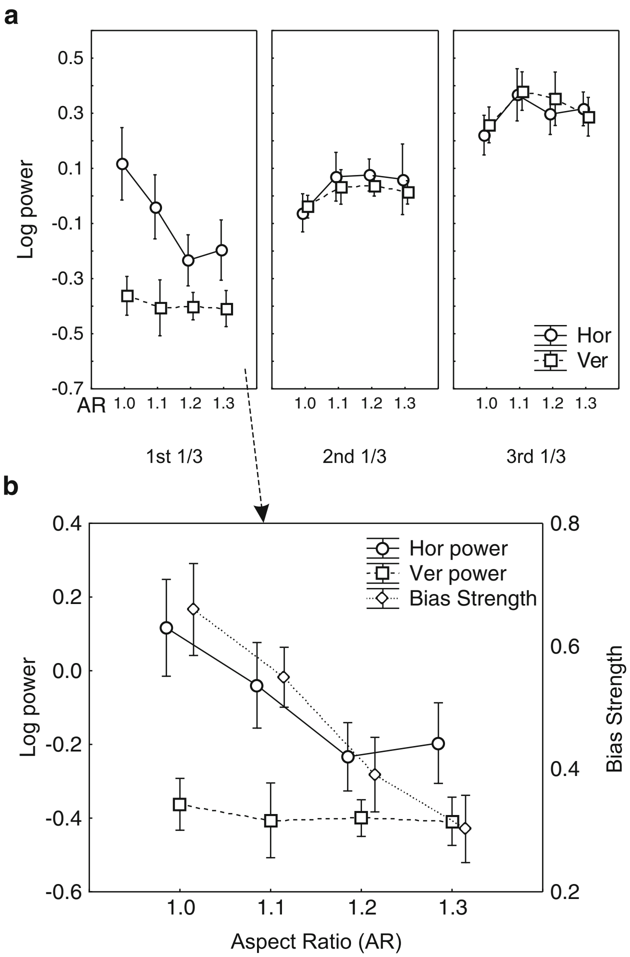

Fig. 4 (**a**) Log alpha power as a function of AR plotted separately for trials in which horizontal and vertical groupings were seen. The three panels represent three sequential parts a session, each part containing one third of trials. The association of alpha power and AR was present only in the first third of session, and only when horizontal groupings were reported. (**b**) Log alpha power for reports of horizontal and vertical grouping in the first third of session (*left ordinate*), and behavioral bias strength (*right ordinate*). Both alpha power and bias strength decreased with AR in trials where horizontal groupings were seen. The data are shown for ten observers whose performance was the highest

Next we asked whether the effect of alpha power depended on stimulus ambiguity (controlled by lattice aspect ratio, AR). We found that alpha power was not associated with AR when all trials were analyzed together. But when trials from different parts of experimental sessions were studied separately, it turned out that the strength of orientation bias was high in the beginning of the session, and gradually decreased toward the end. We therefore divided the session in three equal parts, each about 200 trials long, and studied associations of alpha power in each part separately. We found that alpha power significantly increased during session time course ($F(2,18) = 20.3$; $p = .00003$) (Fig. 4a), suggesting that observers became more relaxed toward the session's end.

Alpha power was significantly higher in trials with reports of horizontal than vertical grouping ($F(1, 9) = 8.1$, $p = .02$), consistent with an effect of alpha power on orientation bias (Fig. 3a). In the first third of trials, alpha power was associated with AR. Alpha power gradually decreased with AR in trials with reports of horizontal grouping ($F(3, 27) = 3.2$, $p = .039$). This decrease was consistent with the decrease of bias strength as a function of AR (Fig. 4b). That is, the association of pre-stimulus alpha power with perception was largest in the most ambiguous dot lattices (AR = 1.0).

4 Discussion

Studies of perceptual organization suggested that perception of ambiguous figures depends on two competing factors: extrinsic (stimulus support) and intrinsic (perceptual bias) to the brain [3]. Here, we found in ongoing electrical brain activity a correlate of the intrinsic bias in the perception of supra-threshold visual stimuli. Alpha power of pre-stimulus cortical activity correlated with the degree to which intrinsic bias affected perception (Fig. 3a). This relationship was most prominent in the trials where grouping was inconsistent with the proximity principle (Fig. 4b). Since high alpha power is considered an indicator of cortical inhibition [9], the association of low alpha power with large perceptual bias suggests that the bias is an intrinsic property of the visual system manifested during its active state. Previous studies showed that ongoing cortical activity can spontaneously generate patterns that correspond to certain stimulus orientations, in absence of stimulation [10]. Our results show how this spontaneous activity affects perception.

Analyzing the event-related potentials in the same data set we previously found that orientation of dot lattices is reflected in early C1 component of the stimulus-evoked activity: C1 amplitude gradually changes with orientation [8]. Alpha activity correlates with early components of the evoked potentials [9]. This may indicate the mechanism of influence of pre-stimulus brain state on subsequent perception of orientation.

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