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Influence of prior expectations on contour integration: psychophysics and modeling

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Contour integration is a process linking oriented and colinearily aligned edge elements into coherent percepts. This process is thought to rely predominantly on feedforward and recurrent integration mechanisms, making its percepts very salient ("pop-out") and independent of top-down processes. However, recent studies have shown that attention can strongly modulate contour integration, suggesting the importance of the confluence of bottom-up (sensory input) and top-down (prior expectations) processes for this task. To uncover neural substrates and mechanisms underlying the influence of prior expectations on contour integration, we combine psychophysical with modeling studies. Participants had to carry out two experiments with identical visual stimuli but different behavioural tasks: a detection task (A) and a discrimination task (B). Stimuli consisted of vertical and horizontal ellipses formed by aligned Gabor elements, being embedded in a Gabor field with random orientations and positions. Each visual hemifield could contain one of a vertical, a horizontal or no ellipse. All combinations of these three basic configurations were possible, totalling to nine stimulus categories for the two hemifields. In experiment A, participants had to give a yes response whenever one stimulus contained at least one ellipse (contour); in experiment B only when a target was present (this target could be either a horizontal or a vertical ellipse, in any hemifield of the stimulus).

In the detection task, reaction times (RT) for horizontal ellipses are ~70 ms shorter than for vertical ellipses. In the discrimination task, RTs for targets are consistently shorter than for distractors, even if the bias for horizontal ellipses is taken into consideration. The presence of redundant targets (e.g. two horizontal ellipses instead of only one horizontal ellipse) also shortens RTs. Thus, the psychophysical data clearly demonstrate a pronounced influence of higher cognitive processes on contour integration.

In our contour integration model [1], we explore the hypothesis that top-down influences directly modulate the response characteristics of elementary feature detectors [2]. We first assume that the prevalence of horizontal lines in natural images leads to an increased activation of horizontal feature detectors. In a discrimination task, we provide a second bias either to horizontal or vertical feature detectors. When presenting a stimulus from the nine possible categories, any existing contour is integrated by the model and leads to a higher activation of edge detectors stimulated by contour elements. The mean amplitude of this activation is determined by the balance between the two different biases. In conjunction with fixed thresholds for contour detection and discrimination, these dynamics yield RTs that not only depend on the exact stimulus, but also on the top-down priming. The simulated RTs are in good qualitative agreement with our psychophysical experiments. We conclude that feature integration may serve as a mechanism to convert priors on single features into preferences for global Gestalt properties.

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