



Interactions between top-down and stimulus-driven processes in visual feature integration

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Perception of visual scenes requires the brain to link local image features into global contexts. Contour integration is such an example grouping colinearly aligned edge elements to form coherent percepts. Theoretical and modeling studies demonstrated that purely stimulus-driven mechanisms, as implemented by feedforward or recurrent network architectures, are well suited to explain this cognitive function. However, recent empirical work showed that top-down attention can strongly modulate contour integration.

By combining psychophysical with electrophysiological methods, we studied how strongly prior expectations shape contour integration. These empirical techniques were complemented by model simulations to uncover the putative neural substrates and mechanisms underlying contour integration.

Subjects participated in two experiments with identical visual stimuli but different behavioural tasks: a detection task (A) and a discrimination task (B). Stimuli consisted of vertical or horizontal ellipses formed by colinearly aligned Gabor elements embedded in a field of Gabors with random orientations and positions. Each hemifield could contain either (i) one vertical, (ii) one horizontal, or (iii) no ellipse. All combinations of these three basic configurations were possible, resulting in nine stimulus categories. In experiment A participants replied 'yes' whenever one stimulus contained at least one ellipse, in experiment B observers replied 'yes' only when a target was present (either a horizontal or vertical ellipse). The psychophysical data demonstrate a pronounced influence of higher cognitive processes on contour integration: In the discrimination task, reaction times (RT) are consistently shorter for targets than for distractors. The presence of redundant targets (e.g. two horizontal ellipses instead of only one horizontal ellipse) also shortens RTs. These first two effects were consistent with our expectations. Moreover we discovered an additional bias in RT for horizontal ellipses (~70 ms shorter than for vertical ellipses).

In EEG recordings, we find pronounced differences in event-related potentials (ERPs) between stimulations with versus without the presence of contours. These differences appear at about 110-160 ms after stimulus onset in the occipital regions of the cortex. In the same regions the evoked potentials were substantially modulated by the number of contours present (~140 ms after stimulus onset) and depending on the behavioural task (~230 ms after stimulus onset). Psychophysical and electrophysiological results are qualitatively consistent: The larger the RT differences, the more dissimilar are ERPs in occipital regions. Moreover, phenomenological modeling reveals that the horizontal bias and task-induced effects either constructively or destructively combine in a multiplicative way. This may lead to much lower RTs when e.g. a horizontal bias combines with a horizontal target, or to a mutual cancellation of the different RT effects when e.g. a horizontal bias combines with a vertical target.

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