

A SYNOPTIC ACCOUNT FOR TEXTURE SEGMENTATION: FROM EDGE- TO REGION-BASED MECHANISMS

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Abstract

Edge-based energy models predict that texture segmentation occurs at the locations where the output of local filters changes. However, statistical properties of texture-region are also quickly perceived and give an overall representation of texture surface. In this study we analyse different levels of explanation for texture segmentation processes: from the simplest edge-based to region-based accounts.

Introduction

Texture segmentation lead to recognise visual objects. Indeed, we can identify a natural surface for its own textural micro-structural properties (Julesz, 1981; Bergen & Adelson, 1988) and distinguish it from other surfaces when those properties change, perceiving a textural edge.

Two main families of texture segmentation accounts are present: the edge- and the region-based models (Landy & Graham, 2004). According to *edge-based models*, texture segmentation results from a non-linear transformation of the output of local spatial filters, followed by a 2nd-linear spatial filtering for enhancing activity at the texture defined contours where the local filters response changes. Generally, edge-based segregation is thought as resulting from both enhanced signal processing at the texture edge and local inhibitory activity in the uniform texture-region where filters response is weak (Malik & Perona, 1990; Sagi, 1991). Several data confirm nonetheless that the process of segmentation is not only resulting from *local* filtering response. Indeed, some *contextual properties* present at the edge, like collinearity between elements or their preferred orientation, can explain the filters response increment and the enhancement of segmentation (Wolfson & Landy, 1995).

However, the hypothesis of inhibition is difficult to conciliate with the phenomenological evidence that statistical region properties, like overall-orientation of texture surface, are still salient after segmentation. Indeed, we perceive the two zebra's coats, not just the edge between their bodies and this – in both artificial and in “natural” textures – can only result from holistic information (Oliva & Torralba, 2001). Differently, since *region-based models* predict that a texture edge is detected not explicitly, but rather implicitly when the “growing” of two different texture-regions causes their interaction (Caelli, 1985), these models would predict that the whole texture-region representation, on the basis of its statistical properties, can affect the process of segmentation (Wolfson & Landy, 1998).

In this study we will investigate the presence and the possible relationship between edge- and region-based mechanism in texture segmentation. We ask whether segmentation is resulting just on edge properties (orientation contrast as well as some contextual properties like collinearity between elements) or also on the bases of all the main output resulting from region analysis.

Materials and methods

Stimuli were generated using a VSG 2/3 Cambridge Research System graphic card with 12-bit luminance resolution and displayed on a gamma-corrected Sony Triniton monitor with a resolution of 1024*768 pixels refreshed at 100 Hz, at 57 cm viewing distance. In all Experiments (run in a dark room), we used textures composed of 8*8 (9.2*9.2 deg of visual angle) matrices of circular cosine-phase [even] Gabor-elements. Each Gabor-patch was defined as a sinusoidal-modulated carrier with a wavelength [λ] of .31deg (spatial-frequency of 3.2 cycles/deg) multiplied by a Gaussian envelope with deviation [σ] of .19 deg. Centre-to-centre elements distance was equal to 3.66λ . Mean luminance of a Gabor-element was equal to background luminance (49 cd/m²).

The *stimulus test* consisted of two sub-regions composed by elements iso-oriented (0, 45, 90 or 135 deg): a dominant texture-region (from here simply ‘*region*’) and one of the four more external stripes of elements, generating a textural *edge*. A texture *mask* was generated by randomising the orientation of all the Gabor-elements.

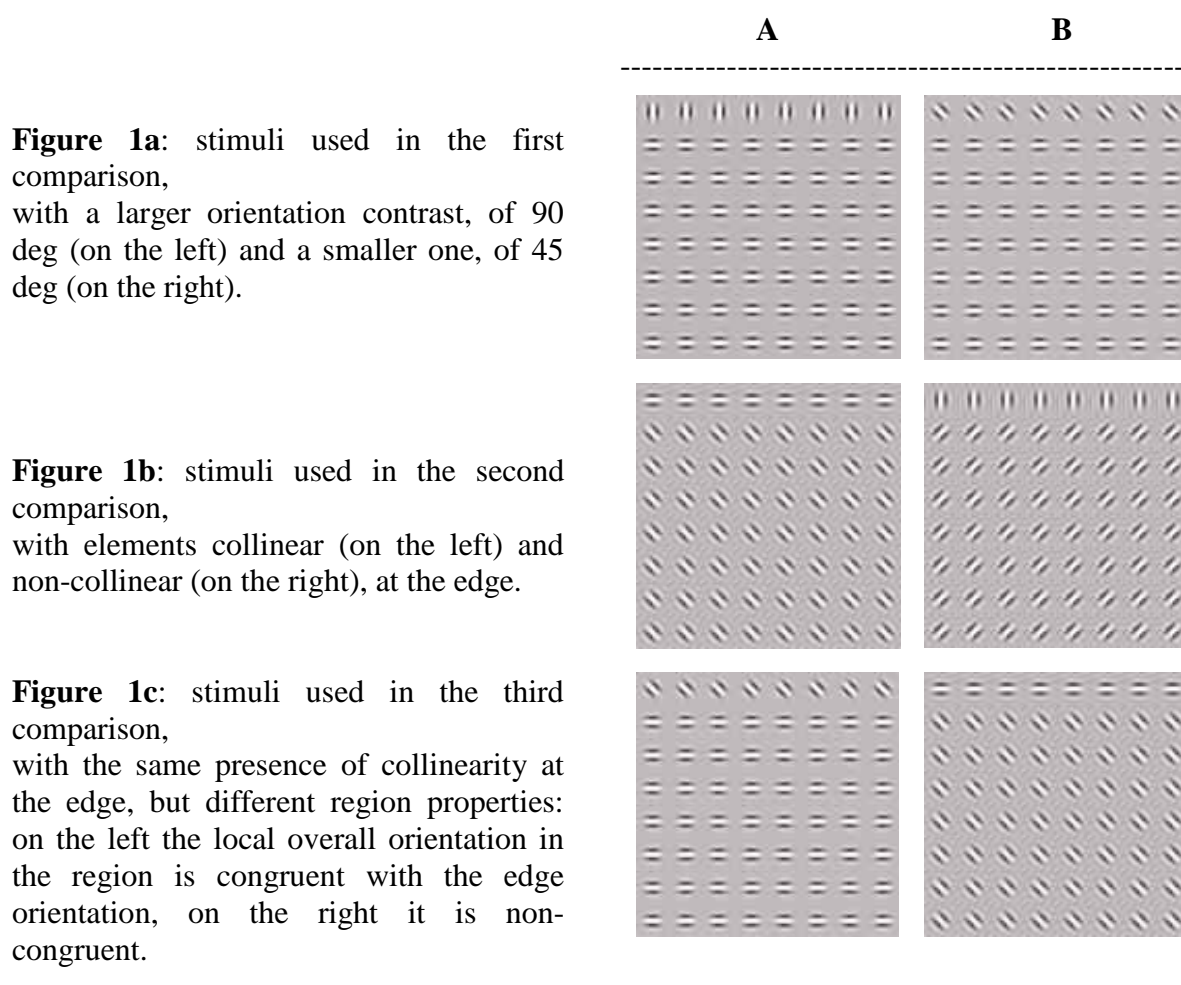


Figure 1a: stimuli used in the first comparison, with a larger orientation contrast, of 90 deg (on the left) and a smaller one, of 45 deg (on the right).

Figure 1b: stimuli used in the second comparison, with elements collinear (on the left) and non-collinear (on the right), at the edge.

Figure 1c: stimuli used in the third comparison, with the same presence of collinearity at the edge, but different region properties: on the left the local overall orientation in the region is congruent with the edge orientation, on the right it is non-congruent.

Procedure and task In each trial, firstly, a central fixation point was presented for 1000 ms on a grey background; this was followed by a mask, presented for 300 ms with no interval, and so the test matrix, whose variable duration (five equally-distant steps, from 20 to 100 ms) was interrupted by a new mask, briefly presented to break off the stimulus processing. Finally, the screen turned black until key press to start a new trial.

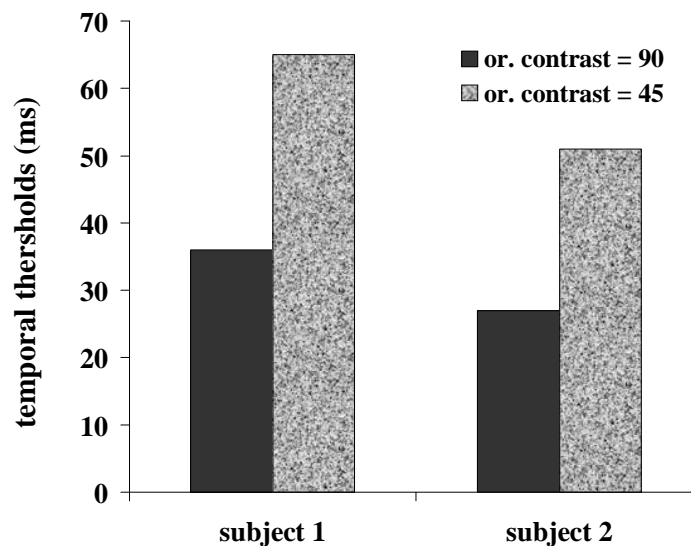
In the Experiments we tested six subjects (all volunteers and with normal or corrected to normal vision) in a texture-edge orientation discrimination task (horizontal vs. vertical). All the participants – except the first author – were naives about the purposes of the Experiments.

Repeated measures ANOVAs compared subjects' accuracy. Temporal thresholds (75% accuracy) were calculated by Probit analysis.

Experiments and discussion

In the **first Experiment [1]** we assessed the role of the difference in the segmentation output from local filters analysis.

To do it, we compared a pair of textures varying orientation contrast between elements present at the edge (stimuli presented in Fig. 1a). In 'A' the orientation contrast at the edge is larger (90 deg) than in 'B' (45 deg). A simple edge-based account would predict an easier segmentation with a larger orientation contrast. Indeed thresholds decreased when the orientation contrast was larger [thresholds were 36 vs. 65 ms for the first subject; 27 vs. 51 for the second].

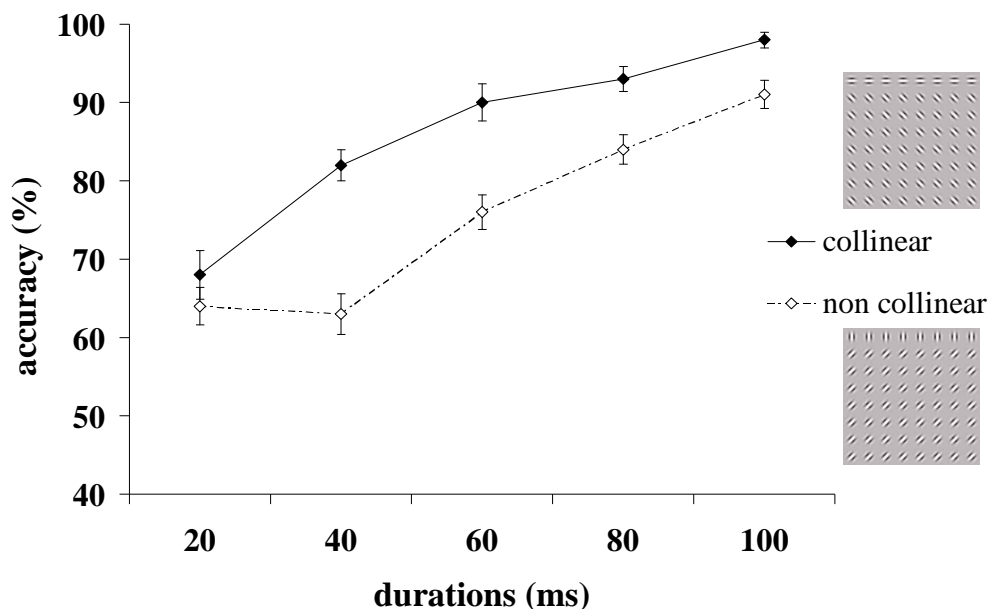


In the **second Experiment** we used stimuli showed in Fig. 1b and Fig. 1c. Each figure shows the mean accuracy as a function of stimuli durations (ms). Error-bars represent standard errors.

The **first comparison** tested the presence of contextual modulation according to an edge-based account. To do it, we compared [2] a pair of stimuli with identical

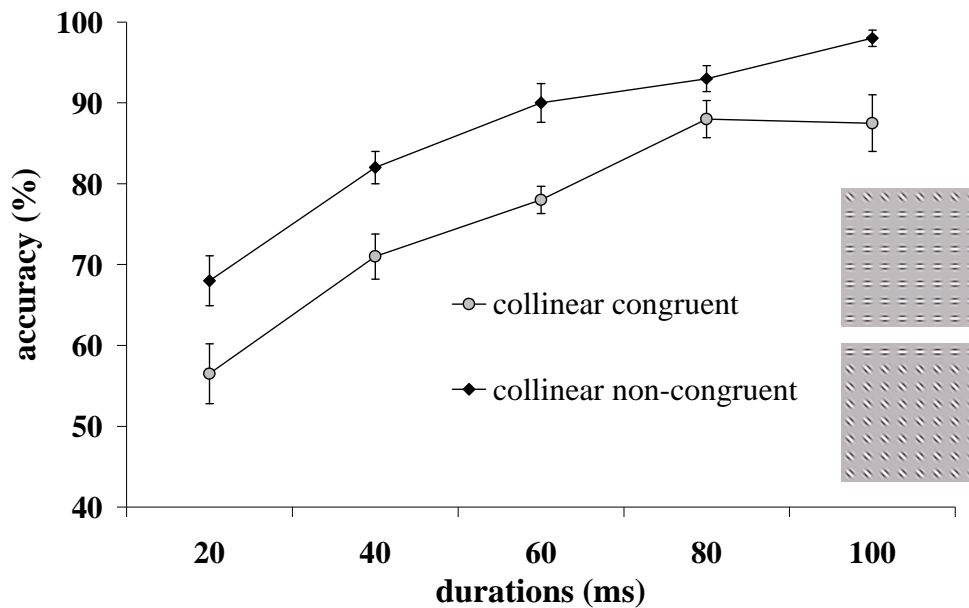
orientation contrast of 45 deg but different contextual properties at the edge (stimuli presented in Fig. 1b). In ‘A’ collinearity is present between elements at the more external of the two stripes producing the edge; in ‘B’ collinearity is not present. The role of the collinearity is well known to improve grouping and facilitate segmentation (Olson & Attneave, 1970), according to physiological explanations about the nature of lateral interactions (Li & Gilbert, 2002). In accord with this evidence, Wolfson & Landy (1995) proposed an integration of the simple edge-based model accounting for some configural effects found, like the enhancement of the performance with elements parallel (collinear) to the textural edge.

Results (see figure below) showed a significant difference between conditions [$F_{1,5} = 36$; $p < .005$]. Mean thresholds were 32 (standard error = 3.3) ms for the collinear and 58 (standard error = 4.3) ms for the non collinear stimulus.



These results confirm the presence of contextual modulation amongst collinear elements at the level of the edge. Next, we wanted to verify the presence of some contextual modulation in edge extraction from the overall region analysis [3]. To do it, in the **second comparison** we used two stimuli with identical properties at the edge (a same orientation contrast of 45 deg and collinearity in one of the two stripes belonging to the edge) but different contextual properties on the region (stimuli presented in Fig. 1c): the local orientation in the texture-region could be congruent or non-congruent with the edge orientation. If edge segmentation only depended on contextual characteristics at the edge, performance would be the same; otherwise a difference would indicate that segmentation was affected also by region analysis.

Our data (see figure below) showed a significant difference between conditions [$F_{1,5} = 6.9$; $p < .05$]. Mean thresholds were 32 (standard error = 3.3) ms for the non-congruent and 55 (standard error = 4.6) ms for the congruent pattern.



Conclusion

To summarize, firstly, our investigation confirmed that by increasing the orientation contrast between elements of a textural edge, segmentation performance improves [1], as predicted by a simple edge-based account. The presence of collinearity in one side of the edge can increase the saliency so to abolish the orientation contrast effect [2]. This and similar configural properties at the texture edge can be accounted by an integration of a classical edge-based model (Wolfson & Landy, 1995). Nonetheless we found that with identical configural properties at the edge, edge saliency was varied by manipulating the contextual properties of the region. In particular, we found that when the local orientation of the elements belonging to the region was non-congruent with the edge, the performance resulted significantly better than when their local orientation was congruent [3].

Accounting for this effect of configural properties between region and edge, *we propose that grouping by lateral interactions from region analysis can affect edge extraction.* The well known phenomenon of lateral interactions (see Albright & Stoner, 2002 – for a review) could be the physiological basis for such a mechanism.

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