MEASURING THE VISUAL SALIENCE OF CURVES BY THEIR NON-ACCIDENTALNESS

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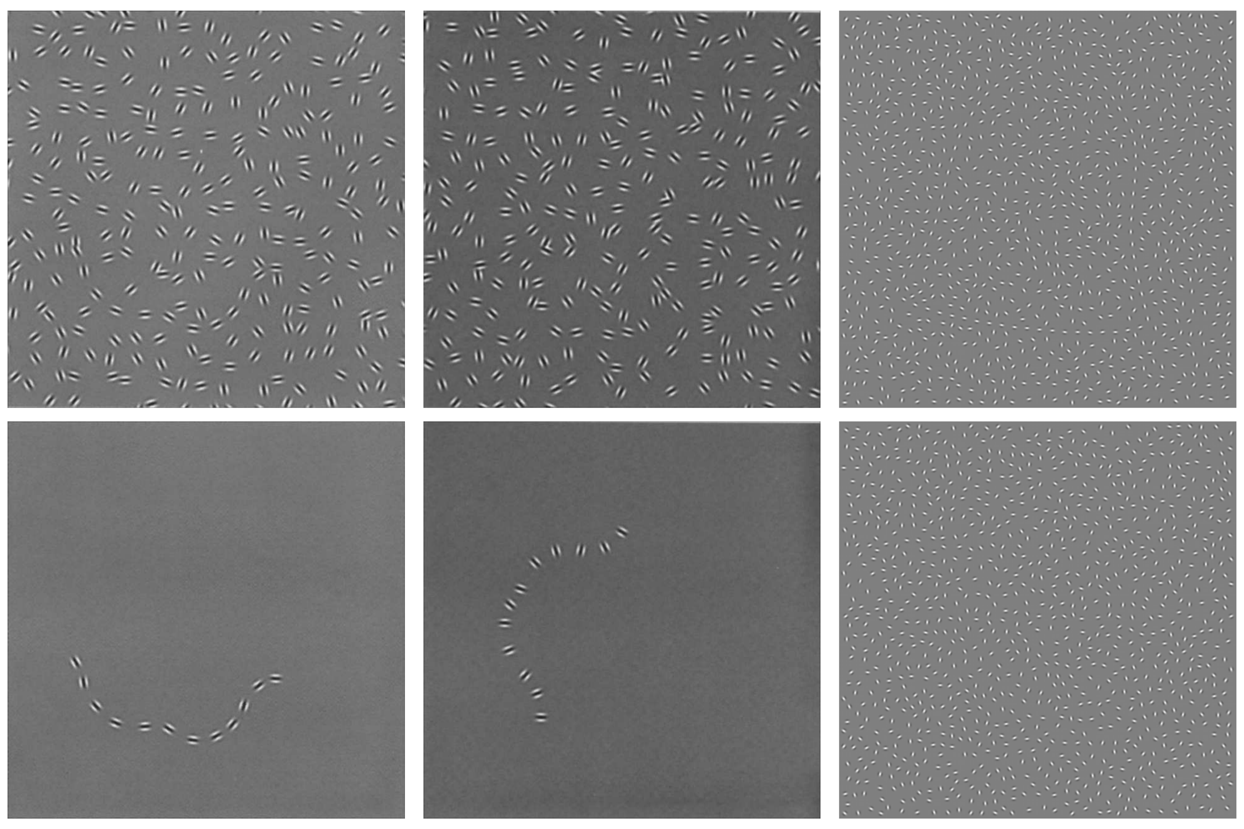
A well known result in psychophysical studies of good continuation in arrays of Gabor elements is that the visual system is better at detecting *smooth* paths rather than jagged ones, and all the more so as they are formed by elements that are roughly aligned to the local tangent of the contour (*association field* [3]). Here we present a similar experiment on contour detection, and a stochastic model that predicts and interprets the perceptual thresholds for this task, relying on the non-accidentalness principle. Generalizing [1], an artificial observer algorithm is compared to human subjects on every stimulus. We found that the algorithm's answers matched accurately those of subjects and that our measure of non-accidentalness, called NFA [2], strongly correlates with their detection performance.

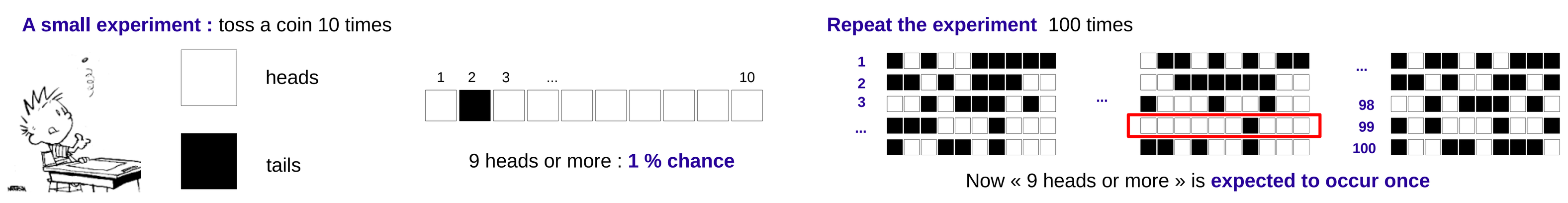
Introduction

Visual detection of smooth paths



Examples of arrays of Gabor elements used to study good continuation in [3] (first two columns) and [5] (third column). Whereas in the upper image of the first column most observers perceive the smooth path reproduced just below, this task becomes much harder in the second column, although the path represented in the bottom image is present in the top one. Similarly, the shape of a bell, visible in the upper image of the right hand column, vanishes in the bottom image although the same elements are present, but with random orientations.

Quantifying non-accidentalness



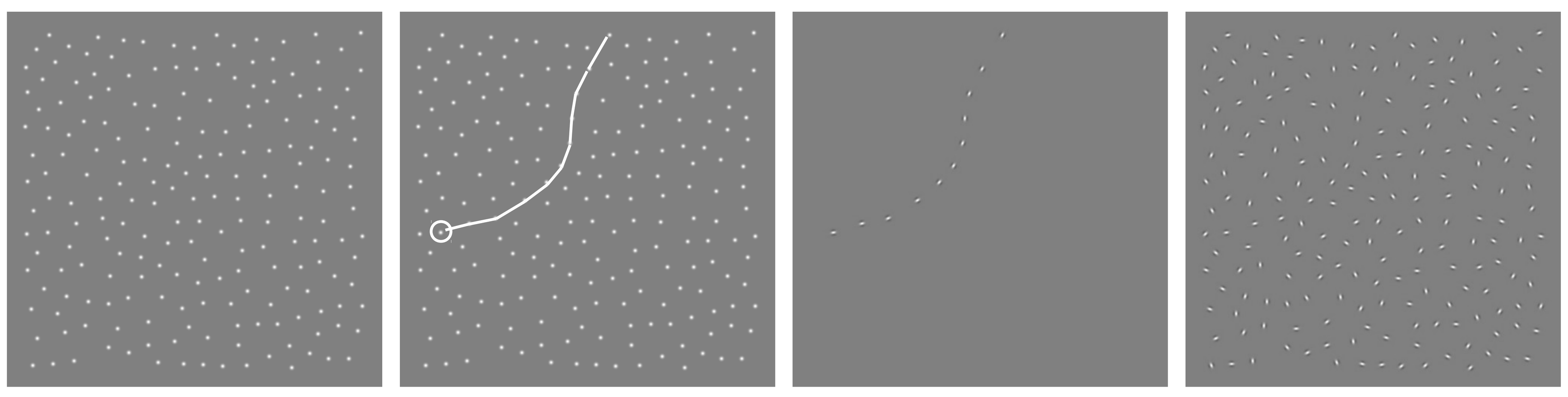
Non-accidental events are those we do not expect to observe in a set of random tests. They are surprisingly close to a configuration which seems special to us.

Perceptual task

Stimuli

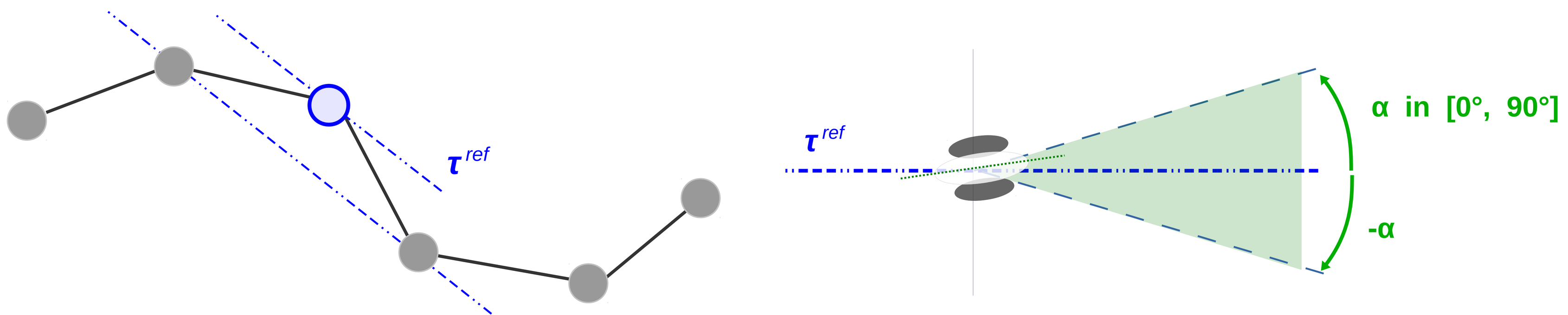
Arrays of Gabor elements of 500×500 pixels. Each stimulus is characterized by **3 parameters:**

- **N**: Total number of elements. $N = 100, 200$ or 600.
- **n**: Number of target elements. $4 \leq n \leq 12$.
- α: Angular jitter. $\alpha \in \{9°, 18°, 36°, 45°, 72°, 90°\}$.



$N = 200$ elements | $n = 11$ target elements | $\alpha = 9°$ (small jitter) | Stimulus

Whereas the background elements have random orientations among all possible angles, the target orientations are chosen randomly in a restricted interval $[\tau^{ref} - \alpha, \tau^{ref} + \alpha]$.



Protocol and subjects

- **16 subjects** (8 females); 20-40 years old; all naive except one.
- **Two versions**: online on their web browser `http://bit.ly/ac_curves` (9 subjects), or in a lab in more constrained conditions (7 subjects).
- **Trial**: the subjects were asked to **click on a Gabor element** they perceived as part of the target path.
- **Attentive task**: the stimulus remained on the screen until an answer was given.
- The **coordinates of the clicked point** and the **reaction time** were recorded.

References

[1] S. Blusseau, A. Carboni, A. Maiche, J.M. Morel, and R. Grompone von Gioi. Measuring the visual salience of alignments by their non-accidentalness. *Vision Research*, in press, available online 14 Sept. 2015.

[2] A. Desolneux, L. Moisan, and J.M. Morel. *From Gestalt Theory to Image Analysis, a Probabilistic Approach*, volume 34 of *Interdisciplinary Applied Mathematics*. Springer, 2008.

[3] D. J. Field, A. Hayes, and R. F. Hess. Contour integration by the human visual system: Evidence for a local "association field". *Vision Research*, 33(2):173 – 193, 1993.

[4] A. Gordon, G. Glazko, X. Qiu, and A. Yakovlev. Control of the mean number of false discoveries, bonferroni and stability of multiple testing. *The Annals of Applied Statistics*, pages 179–190, 2007.

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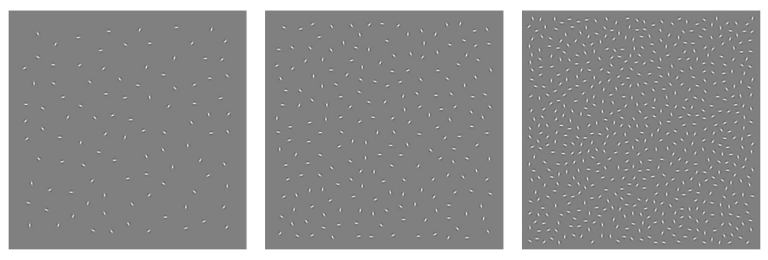
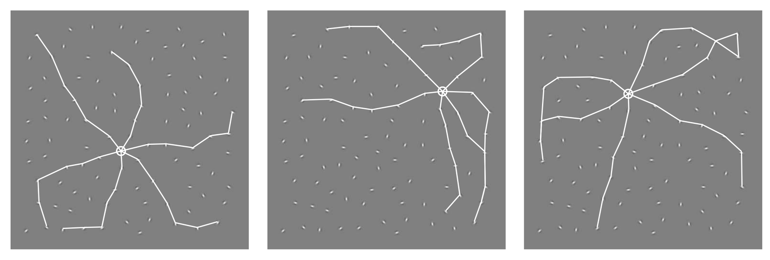
Algorithm

Probabilistic model



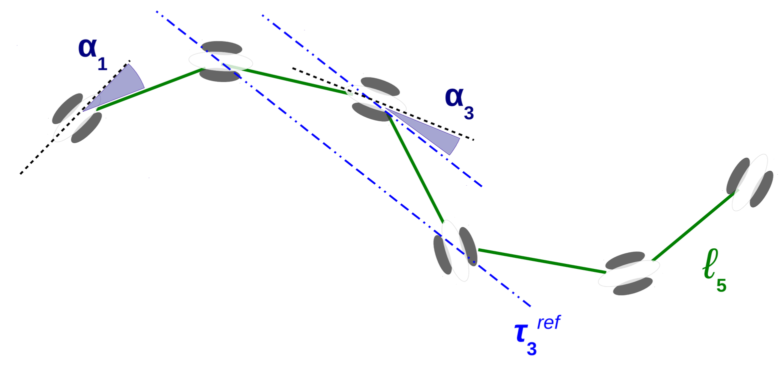
General configuration: randomly placed elements separated by a minimal distance and orientations uniformly distributed over all angles.

Set of tests



A number N_T of smooth chains are tested.

Geometric model



$$s = \sum_{i=1}^{n} \frac{2\alpha_i}{\pi} + \sum_{i=1}^{n-1} \tilde{F}_\ell(\ell_i). \tag{1}$$

The variable s is the sum of normalized versions of the angles α_i and the distances ℓ_i.

Target event: a chain with all $\alpha_i = 0$ and distances ℓ_i **as small as possible**.
This corresponds to a chain for which $s = 0$.

Non-accidentalness property

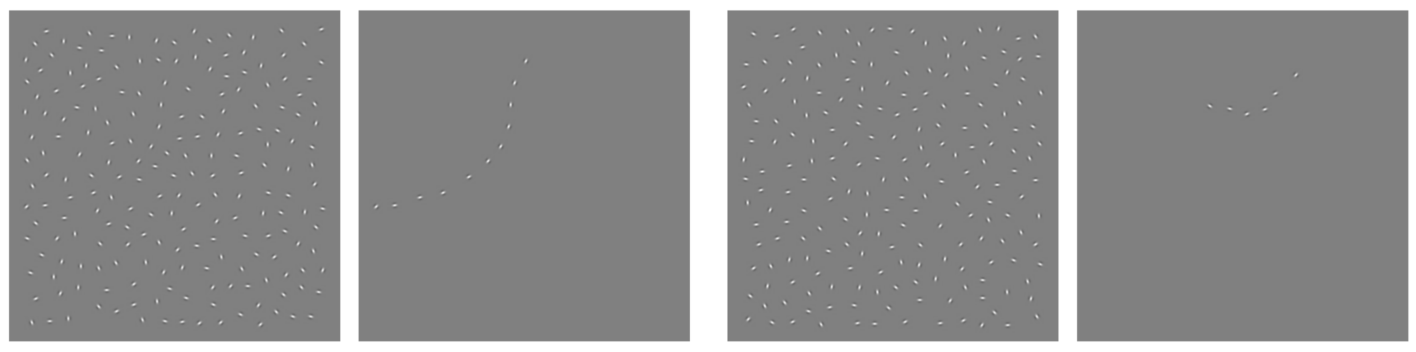
The algorithm associates to each tested chain c a quantity called **NFA** (Number of False Alarms):

$$\mathrm{NFA}(c) \overset{\mathrm{def}}{=} N_T \cdot \mathbb{P}(S_{2n-1} \leq s), \tag{2}$$

where the variable S_{2n-1} follows the Irwin-Hall distribution of order $2n-1$.

Non-accidentalness: a chain with $\mathrm{NFA}(c) << 1$ is unexpected under the probabilistic model. This comes from multiple hypothesis testing [4] and an empirical study.

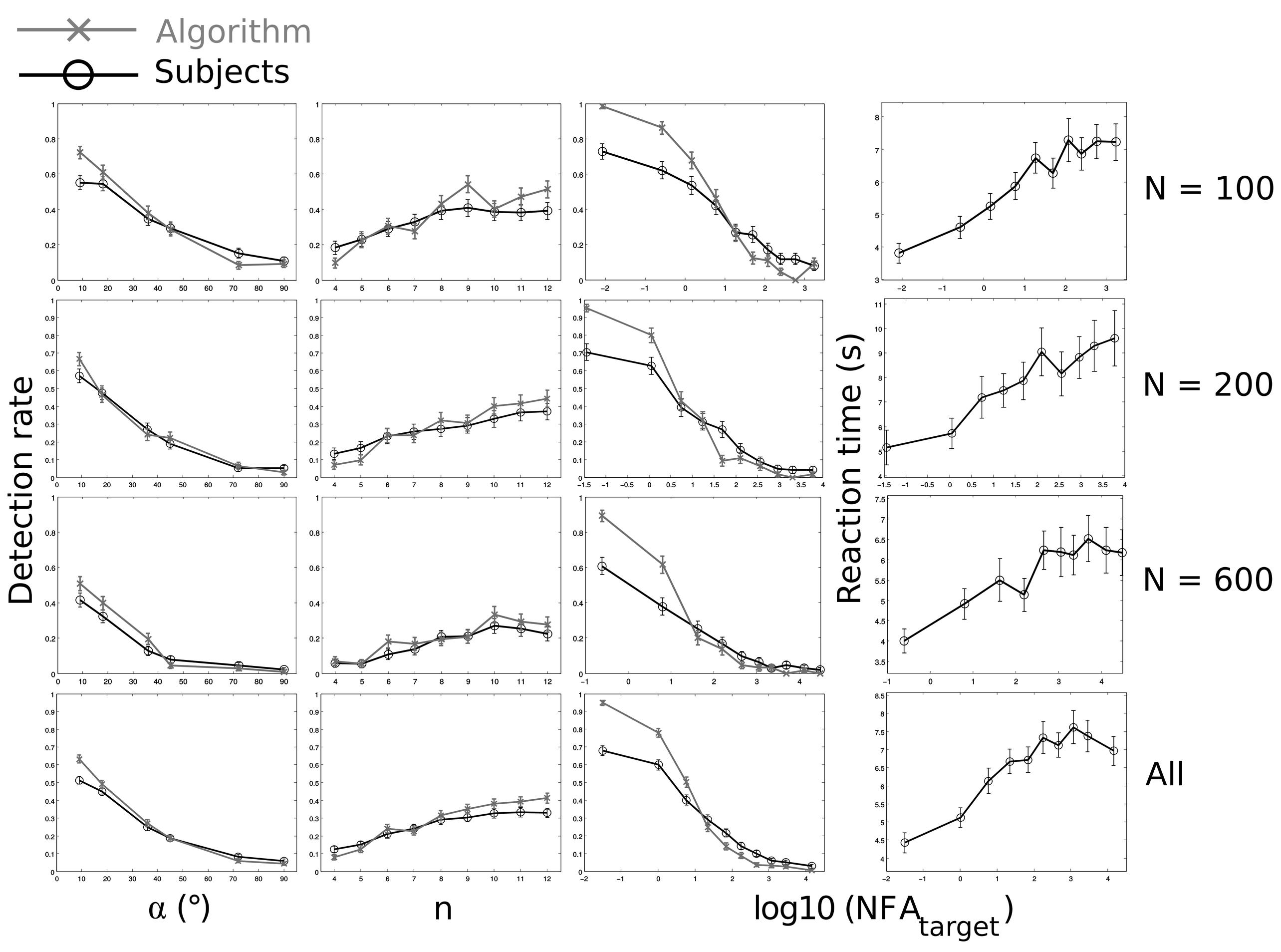
Output: the chain that achieves the lowest NFA.



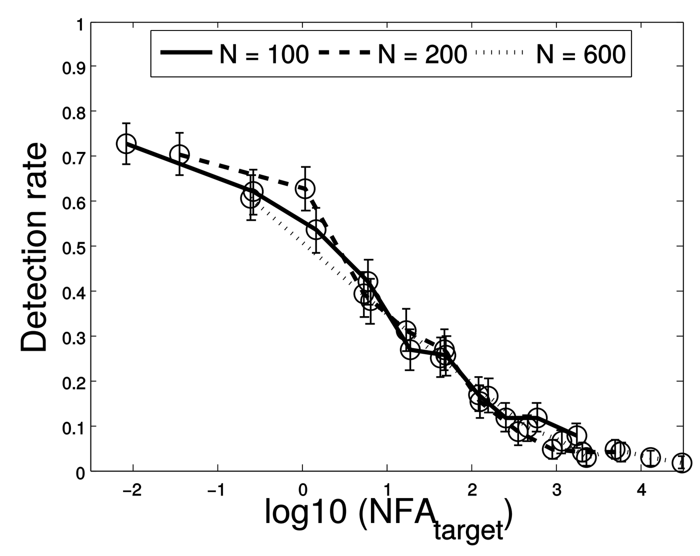
Input | Detection: $\mathrm{NFA} = 0.29$ | Input | Detection: $\mathrm{NFA} = 3.0$

Results

Subjects compared to the algorithm



NFA and salience



Detection rates achieved by the subjects, as functions of $\log_{10}(\mathrm{NFA})$ of the target paths, for three different values of the total number N of elements per image: $N = 100, 200$ and 600. The superimposition of the three curves indicates a perceptual equivalence among stimuli characterized by the same NFA: for a given NFA value, the detection rates are substantially the same, regardless of the value of N.

Conclusion

The overall results give credit to the non-accidentalness principle, as a way to interpret and predict the perceptual grouping in masking conditions. Future work will concentrate on predicting the salience of symmetry using the same framework.

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