The Function and Fallibility of Feature Integration: A Dynamic Neural Field Model of Illusory Conjunctions

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1. Introduction
Illusory conjunctions (ICs) are failures of feature integration where features of distinct objects are combined into one percept [1]. For example, subjects presented with a blue ‘S’ and a red ‘X’ sometimes report having seen a blue ‘X’.

ICs in vision are more likely to occur between spatially close items [2], and between items having similar features [3]. Furthermore, the illusory percept tends to be located at the spatial midpoint between the involved items [4]. These findings set constraints on possible mechanisms of visual feature integration.

Here, we present a neurodynamic model of visual feature integration that captures this evidence. To test the model, we subjected it to a task similar to that used in [4] (see figure).

2. Dynamic Neural Fields
Dynamic Neural Fields (DNFs) describe neural activity patterns within cell populations as continuous distributions of activation over metric feature dimensions [5,6]. The continuous evolution of activity is governed by external inputs and lateral interactions within the DNF.

The interactions promote the formation of localized peaks of activity, which serve as units of representation. Peaks may reflect:

- Perceptual items, such as features or spatial locations.
- Memory items, in the form of self-sustained peaks.
- Motor parameters of upcoming actions.

Selection between competing percepts or actions may be forced by local or global inhibition.

3. Architecture
The model consists of a feature pathway and a spatial pathway, which interact through two shared low-level visual representations in a retinal frame. The feature pathway comprises two analogous layers, one for color and one for shape, which are linked solely via a spatial attention field.

4. Simulation

4.1. Pre-stimulus Phase
At the start of each trial, a cue item is presented (not shown), and the shape memory field is forced to build a peak by briefly boosting its resting level. The peak reflects the target shape and persists throughout the trial, causing an activity bias in favor of the target shape in the feature attention field and, consequently, the visual perception field.

4.2. Stimulus Display
For each item, a peak arises in each visual perception field. The preactivation enhances the target item’s shape peak, which projects to the corresponding location in the spatial attention field. In turn, the spatial attention field activates this region in the visual perception field for color. Peaks close to the center of this region are more strongly enhanced than distant ones.

4.3. Activity
Every peak, representing a feature or a location, is associated with activity. This activity is governed by lateral field interactions and external inputs. The activity can be positive (excitation) or negative (inhibition). The activity of a peak results from the weighted integration of lateral inputs.

4.4. Response
Perceptual items correspond to spatial peaks. Since a spatial peak is selective to the location of the target item, correspondence of a peak’s location and the target location characterizes a correct response. Non-target peaks being overly enhanced deviates the attentional focus, while peaks which more strongly indicate the target location are ICs.

5. Results
Response proportions accord well with those reported in [4] (see table) and are generally consistent with the behavioral evidence. As in [4], only the middle three stimuli were included in the analyses. Figures show data for ICs between adjacent items.

5.1. Spatial Locations
Consistent with [4], the model tends to localize ICs halfway between the target and the involved distractor, while estimates for correct responses are distributed around the target location.

6. Conclusion
Our neurodynamic model can account for several key effects reported in the behavioral literature. Namely, IC formation depends on the distance of items in both physical and feature space, and ICs are spatially localized halfway between the involved items. The model describes how visual features may be integrated into coherent objects by dynamically interfacing neural representations of low-level inputs, feature information, and physical space. It further provides an explicit neural mechanism for the formation of ICs, based on the coarse nature of spatial and feature representations.

The model thus complements existing theories that attribute ICs to the failure of feature integration. The model shows that a single mechanism can account for the behavioral evidence.

References

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