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# EFFECTS OF ORIENTATION ON SYMMETRIC OBJECTS DETECTION ON NOISY BACKGROUND

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## Abstract

Image contours correspond to objects' outlines, surface orientation changes, or texture features. Previous research indicates that detecting contours defined by separate elements depends on their closure and curvature. Closed contours are recognized more quickly, but this advantage diminishes when the contour curvature changes. However, more information is needed about how object recognition interacts with symmetry detection and the dynamics of this interaction. The present study aims to investigate the dynamics of detecting equilateral triangles embedded in noise, depending on their orientation. The stimuli consisted of 1,488 Gabor elements arranged in a hexagonal grid with 48 columns and 31 rows. The orientations of the elements were randomized, except for twelve elements aligned along the sides of an equilateral triangle, with a top element perpendicular to the triangle's base. The triangle was positioned randomly in successive trials, and its orientation could be left/right or up/down. Participants were required to identify the triangle's orientation by pressing a joystick button. Thirty-seven healthy observers (mean age 41 years, range 20-69 years; 23 males, 14 females) participated in the study. The temporal threshold for triangle detection was examined separately for the horizontal and vertical orientations. The results of our study revealed significant individual differences among subjects and a shorter detection time for left/right oriented triangles compared to those oriented up/down. The modeling results, obtained through a Bayesian hierarchical model, indicated significant differences in the probability of a correct response based on the orientation of the stimuli. The highest percentage of correct responses occurred when the triangle's apex pointed to the right, while the lowest - when the triangle's apex pointed downward. These results could not be explained by perceptual asymmetries related to the location of objects in the visual field or the orientation of the symmetry axis. They suggest that object recognition occurs in allocentric coordinates and precedes symmetry detection.

***Keywords:*** *Contour integration, object recognition, symmetry, perceptual biases.*

## 1. Introduction

According to Gestalt principles (Westheimer, 1999), detecting objects requires the perceptual organization of a visual scene to distinguish the object from its background. The contours in the image often correspond to the object outline. Their detection in clutter scenes depends on the ability to group or integrate local elements, their closeness, and alignment (Field et al., 1993). Research indicates that closed contours are detected more rapidly than open-ended contours, but this advantage disappears when the contour suddenly changes direction (Kovacs & Julesz, 1993).

Symmetry is a critical feature of our vision that enhances the recognition and reconstruction of shapes and objects. Both symmetry extraction and contour processing are essential for object representation (Kovacs et al., 1998). Some studies suggest (e.g., Rainville & Kingdom, 1999) that symmetry coding occurs at relatively low levels in the visual hierarchy. Others imply that symmetry information integration requires about 1 second (Tyler et al., 1995). Still, little is known about the interaction dynamics between contour integration and symmetry coding for object recognition.

## 2. Objectives

The present study aims to investigate the dynamics of detecting equilateral triangles embedded in noise depending on their orientation.

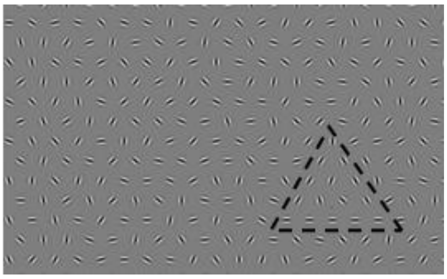
## 3. Methods and design

The stimuli were presented binocularly on a 20-inch NEC SpectraView 2090 computer screen, with a refresh rate of 60 Hz and a resolution of 1600 × 1200 pixels. They consisted of 1,488 Gabor elements arranged in a hexagonal grid with 48 columns and 31 rows. The orientation of the elements was randomized, except for twelve elements aligned along the sides of an equilateral triangle, with the apex element positioned perpendicular to the triangle's base (Figure 1). At the viewing distance of 57 cm, the sides of the triangle were four deg. long.

After a warning sound, a fixation point appeared in the center of the screen for 500 ms, followed by the stimulus. On every trial, the position of the embedded triangle appeared at randomly chosen positions, with its orientation either left/right or up/down. A custom program developed in Visual C++ and OpenGL controlled the experiments.

The initial stimulus duration was 1500 ms. It was decreased after two successive correct responses or increased after a wrong response by 10%, targeting a temporal threshold of 70.7% correct responses (a 2-down-1up staircase method). The experiment ended after 12 reversals or 100 trials.

*Figure 1. An example stimulus with a target triangle oriented upwards marked with a dashed line.*



### 3.1. Participants

Thirty-seven healthy observers (mean age: 41 years, range 20 - 69 years; 23 males and 14 females) with normal or corrected to normal vision participated in the study. They provided written consent for their participation. The experiments were conducted following the Declaration of Helsinki and approved by the Ethical Committee of the Institute of Neurobiology (protocol 48, June 6, 2023).

The participant's task was to detect the triangle and discriminate its orientation by pressing a joystick button. Each participant performed two experimental blocks depending on the triangle's orientation—horizontal (left/right) or vertical (up/down).

### 3.2. Statistical analyses

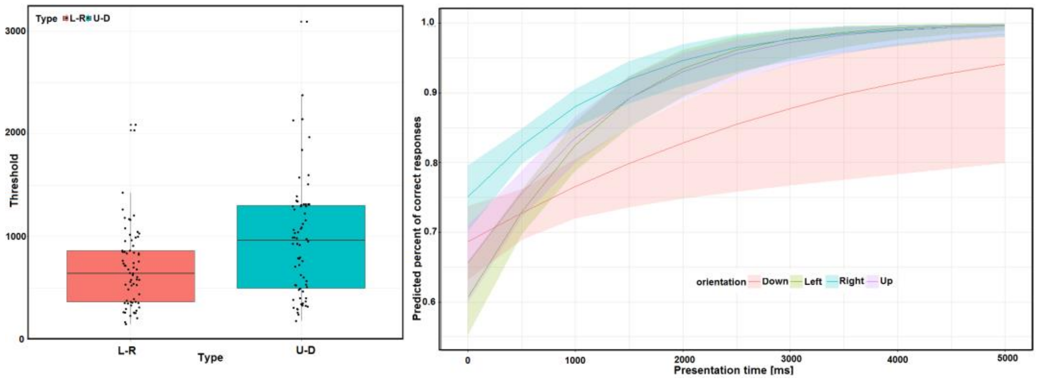
We used two approaches to analyze the data – the standard method of evaluating threshold in staircase methods based on reversal points and a Bayesian hierarchical model performed in R (R Core Team, 2021) and the brms package (Bürkner, 2017) to analyze the subjects' responses. The fixed factors in the model were the stimulus duration, the object orientation, and their interaction, while the subjects were regarded as random factors. We used a truncated normal distribution with a mean of 0 and a standard deviation of 10 as a prior distribution for the fixed factors and the Bernoulli distribution as the likelihood function since the subject responses were binary. We used Monte Carlo methods to estimate the posterior distribution, running 4 Markov chains with 6000 iterations (1000 warm-ups) each.

## 4. Results and discussion

The temporal threshold values showed a shorter detection time for left/right oriented triangles (median of 642 ms) than those oriented up/down (median of 965 ms) with significant individual differences in the threshold values (Figure 2, left). Applying a Bayesian hierarchical model to the responses allows us to evaluate whether there are not only differences between the horizontally and the vertically oriented triangles but also to obtain more detailed information on the effect of triangle orientation on its detection. The results show that the highest percentage of correct responses was observed when the triangle's apex pointed to the right, while the lowest percentage occurred when the apex pointed downward (Figure 2, right). Therefore, to achieve similar performance, the presentation time of the triangles significantly varies with their orientation.

The study results indicate that detecting an object embedded in noise precedes symmetry coding. If symmetry coding occurred first, we expect a performance advantage for the vertically oriented triangles since one of their symmetry axes is vertical and more prominent. Additionally, the symmetry axes of the two vertically oriented triangles and those of the two horizontally oriented ones are parallel. Therefore, we would not expect any differences between the upward and downward-oriented triangles nor between the leftward and rightward triangles.

*Figure 2. Left: Median temporal thresholds for the horizontal and vertical triangles. The individual data are also presented. Right: The predicted probability of correct responses depending on the stimulus orientation.*




However, we have observed significant differences in the time required to detect triangles based on their orientation. The target stimuli positions were random within the visual field, which should eliminate any visual-field differences relative to the observer. Our results contradict previous results that show that the left and the lower visual fields have an advantage in different spatial tasks. One reason for this discrepancy may be that our task required determining the vertex's location relative to the triangle's base, i.e., in an object-based (allocentric) coordinate system. The asymmetry in the time course of detecting the triangles in different orientations may arise from the interaction between the egocentric and allocentric coordinate frames. Recent studies (Zhou et al., 2012; Wang et al., 2016; Zhou et al., 2017) have shown that inconsistencies between these two reference frames result in slower response times on the left side compared to the right and in the lower visual field compared to the upper visual field during position judgment tasks. These effects have been attributed to lateralized communication and interconnectivity between the two hemispheres, as well as a functional imbalance in their ability to resolve conflicts (Wang et al., 2016).

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