Available online at www.sciencedirect.com
SCIENCE DIRECT®
Vision Research 45 (2005) 91–102
Vision Research
www.elsevier.com/locate/visres

# Differences in real and illusory shape perception revealed by backward masking

Michelle L. Imber [a,b,c,*], Robert M. Shapley [b], Nava Rubin [b]

[a] *Department of Psychology, New York University, United States*
[b] *The Center for Neural Science, New York University, 4 Washington Place, New York, NY 10003, United States*
[c] *Department of Psychiatry, Massachusetts General Hospital, Harvard Medical School, Boston, MA 02115, United States*

Received 4 July 2003; received in revised form 12 July 2004

**Abstract**

Illusory contours (ICs) are thought to be a result of processes involved in the perceptual recovery of occluded surfaces. Here, we investigate the relationship between real and illusory contour perception using a shape discrimination task and backward masking paradigm. ICs can mask other ICs when times between mask onset and stimulus onset, or SOAs, are very long (~300 ms), but real contours (RCs) are not similarly effective. Masking is absent for RC masks at perceptually salient contrasts, as well as for those with contrast lowered to match the perceived brightness of the illusory surface. We also find that RCs are not masked at long SOAs, either by ICs or by other RCs. Finally, the masking seen between ICs can occur for different sizes of target and mask. The cross-size masking would not be expected if the masking were at a level sensitive to retinal contour location. The late masking therefore may be related to a higher level of processing of shape categories and surfaces, the level at which shapes defined by ICs and RCs are differentially represented.


*Keywords:* Illusory contours; Boundary interpolation; Real contours; Size invariance; Shape discrimination

## 1. Introduction

Neuroscientists have long tried to understand the normal processes of the brain by studying what is abnormal or unusual. In attempts to dissect the complex computations that result in visual recognition of objects, researchers have studied a perceptual illusion known as the illusory contour (Kanizsa, 1955; Kanizsa, 1976; Petry & Meyer, 1987; Schumann, 1987), or IC. This phenomenon, illustrated in Fig. 1, results when observers perceive a surface occluding a set of inducing elements (inducers, or pac-men) over an otherwise homogeneous background. A portion of the bounding contour is not supported by a luminance-defined gradient. It is thought that illusory contours result from processes responsible for segmentation. These processes are believed to underlie contour completion of occluded and illusory surfaces (Kellman & Shipley, 1991). In order to understand these segmentation processes we have studied the perception of shapes bounded by illusory contours and real contours.

Numerous psychophysical studies point to perceptual interactions between real and illusory contours. For example, there are interactions between real and illusory lines in a task of vernier acuity (Greene & Brown, 1997) and in versions of famous perceptual phenomena such as the Poggendorff (Beckett, 1989, 1990) and Bourdon (Walker & Shank, 1988) illusions. Studies have been made of common aftereffects involving tilt and

* Corresponding author. Address: Brigham Behavioral Neurology Group, Brigham and Women's Hospital, 221 Longwood Avenue, M-Level, Boston, MA 02115, United States.
*E-mail address:* michelle_imber@hms.harvard.edu (M.L. Imber).

0042-6989/$ - see front matter 
doi:10.1016/j.visres.2004.07.034

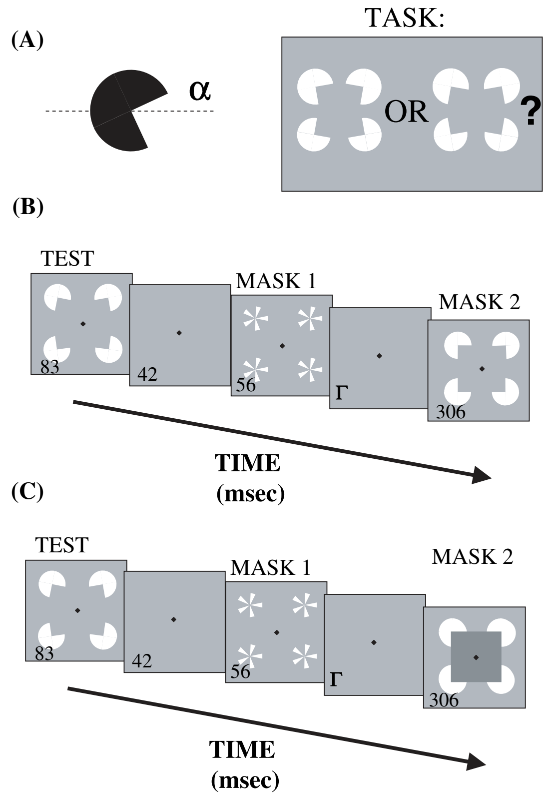


Fig. 1. (A) At right, the shape discrimination task used in all experiments (after Ringach and Shapley, 1996). At left, α represents the degrees rotation of the top left inducer. (B) Experiment 1: The sequence of events within a trial, for an Illusory Contour (IC) mask. Each trial was composed of five frames: stimulus, fixation point, "pinwheels" (local orientation) mask, fixation point, and illusory square mask. The IC stimuli shown here are not drawn to scale; in our experiment, the support ratio (between the inducer diameter and the illusory square side) was only 25%. The duration of each frame in ms is shown in the lower left-hand corner. The duration of the fourth frame, Γ, was varied across trials. (C) Sequence of events for trials in which Mask 2 was a real square.

orientation masking (Paradiso, Shimojo, & Nakayama, 1989; Smith & Over, 1976, 1977, 1979); results were always comparable for real and illusory contours. Other researchers have found evidence of binocular rivalry between real and illusory shapes (Bradley, 1982). In these cases, it appears that the brain treats illusory contours like real contours.

In order to analyze the subprocesses that lead to the perception of an illusory contour, researchers have employed visual masking techniques (Gellatly, 1980; Muise, LeBlanc, Blanchard, & de Warnaffe, 1993; Parks, 1994; Reynolds, 1981; Ringach & Shapley, 1996; Weisstein & Matthews, 1974) in which the processing of a target shape is interrupted or impaired by the presentation of a second figure. Masking is thought to enable the investigator to disrupt the stream of visual processes, and to query the system about its current state at the time of the disruption. Such paradigms can be useful for elucidating the temporal evolution of the illusory percept. Reynolds (1981) applied such a backward masking technique to the study of illusory contour "microgenesis" (time course of evolution). Reynolds presented Kanizsa-type triangles for a duration of 50 ms. After various stimulus onset asynchronies (SOAs, the duration between onset of the target and onset of the mask), observers were asked to discriminate between a straight-sided triangle, a curved triangle, or no triangle at all. In some stimulus displays, the triangle was intercepted by a brick-wall pattern that was logically incompatible with the depth information that would correspond with a perceived illusory triangle. Reynolds found that IC perception could take place by 100 ms but that the percept disintegrated 50–100 ms later when the brick overlay was present. He interpreted his results to mean that top-down processes were responsible for the disappearance of the illusory surface at relatively late durations (50–100 ms), consistent with a hypothesis-testing model of IC perception. However, the top-down interpretation has been questioned in subsequent research on this subject (see Parks, 1994, 1995; Petry & Meyer, 1987; Rubin, 2001 for discussion).

Ringach & Shapley (1996) devised a shape discrimination task to study properties of IC perception (Fig. 1(A)). They and others have shown with a variety of methods, including spatial masking remote from the inducers, that good performance in this task (i.e., discrimination of shapes with small curvature; see Section 3.1) depends on the ability to perceive ICs (Gold, Murray, Bennett, & Sekuler, 2000; Kellman, Yin, & Shipley, 1998; Ringach & Shapley, 1996; Rubin, Nakayama, & Shapley, 1996, 1997).

To investigate the time-evolution of IC formation, Ringach & Shapley (1996) double-masked the illusory-shape targets. The first mask contained local orientation information that interfered with the local inducers' elements, but that did not have a globally defined shape. This mask reduced performance on IC-defined shape discrimination when flashed at an SOA of less than 117 ms. At longer SOAs the local mask became less and less effective. The second mask in their double-mask experiment consisted of a Kanizsa-type illusory square that overlapped in position and size with the target IC shape (except that its bounding ICs were straight, not curved; see Fig. 1(B)). The second ('global') mask interfered with task performance at latencies as long as ~250–300 ms (140–200 ms after the presentation of the first, 'local' mask). A no-contour (NC) control, with all inducers facing outwards, failed to mask the illusory shape at this latency. Based on their findings, Ringach and Shapley conjectured the existence of two stages in the processing of ICs. In the first stage, local luminance features are detected; in the second, the illusory boundary is interpolated into a global percept of a shape.