Rigid objects that appear to bend

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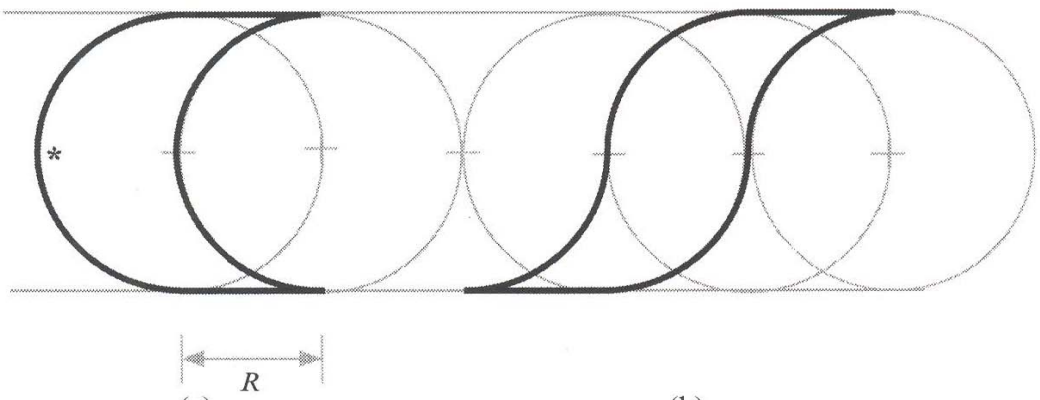
Abstract. Simple rigid objects are presented that appear to bend when viewed from certain angles. These illusions illustrate that perspective information is used by the stereo system, that projective distortions can override rigidity constraints in motion perception, and that touch only corrects the illusion for a local region.

1 Introduction

We present two simple objects that lead to illusory percepts in a manner that nicely illustrates many properties of the human visual system. In a previous study (Griffiths and Zaidi 1998), we used parallelogram objects to demonstrate the kinds of shape inferences that the visual system makes in response to ambiguously projected stimuli. When these objects were presented above the line of sight, the internal angles seemed closer to right angles and the objects appeared tilted from the horizontal. In this paper we present two examples of curved forms (figure 1) that can result in illusory percepts. These objects are physically flat, but when held level and viewed monocularly and elevated relative to the observer they appear to be curled in a dimension orthogonal to the plane of the surface. Many observers find this illusion of curl more compelling than the tilt illusion.

2 Objects

The objects shown in figure 1 are simple to construct, and are based on arcs of a circle with radius, R. In figure 1a, two semicircles are drawn parallel to one another, one radius apart, and joined by two straight lines. In figure 1b, two 90° arcs are joined to form an S-shaped curve; two such curves are placed one radius apart and joined at the ends by two straight lines (whose length is equal to R). In order to better view the illusion at arm's length, we suggest values of R of approximately 3 to 5 inches. We have used balsa wood $\frac{1}{4}$ inch thick and foam-core poster board to construct solid, three-dimensional forms from these templates. However, any rigid material will suffice.



3 Viewing the illusion

In order to view the illusion, first cover one eye. Grasp the shape between thumb and forefinger, at the point indicated by the asterisk in figure 1a. Hold the object at eye level, approximately 1 foot (30 cm) in front of you. The object should be held so that it is level, your line of sight is parallel to the two straight edges, and the curved edge is oriented so that the pointed ends are towards you. Raise the object straight up by 1 to 2 feet (0.5 m) to an elevation of approximately 45°, while keeping it level, ie parallel to the floor, as shown in figure 2. The hitherto rigid object now appears to have an upward (shallow U-shaped) curl. If the object is lowered below eye level, the illusion is reversed, and the object now appears to have a downward curl. Alternatively, hold the object at eye level as before, but tilt it slowly about the horizontal axis, ie the axis that is parallel to the eyes and orthogonal to the line of sight. Once again, the object will appear to curl up or down, according to the direction of rotation. A third alternative is to hold the object at eye level but oriented so that the two straight edges are in the vertical plane, and to move it from side to side.

The procedure for viewing the second object is similar to that described above. Hold the object in front of you at eye level, oriented so that one of the S-shaped edges is facing you and your line of sight is parallel to the straight edges. Close one eye, and raise the object. The left and right sides of the object will appear to curl up or down, in opposite directions to one another. Edges which curve towards you, relative to the midline, will appear to curl up; edges which curve away from you will appear to curl down. These illusions are reversed when the stimulus is viewed below eye level. As before, tilting the object about the horizontal axis will also evoke an illusory curl.

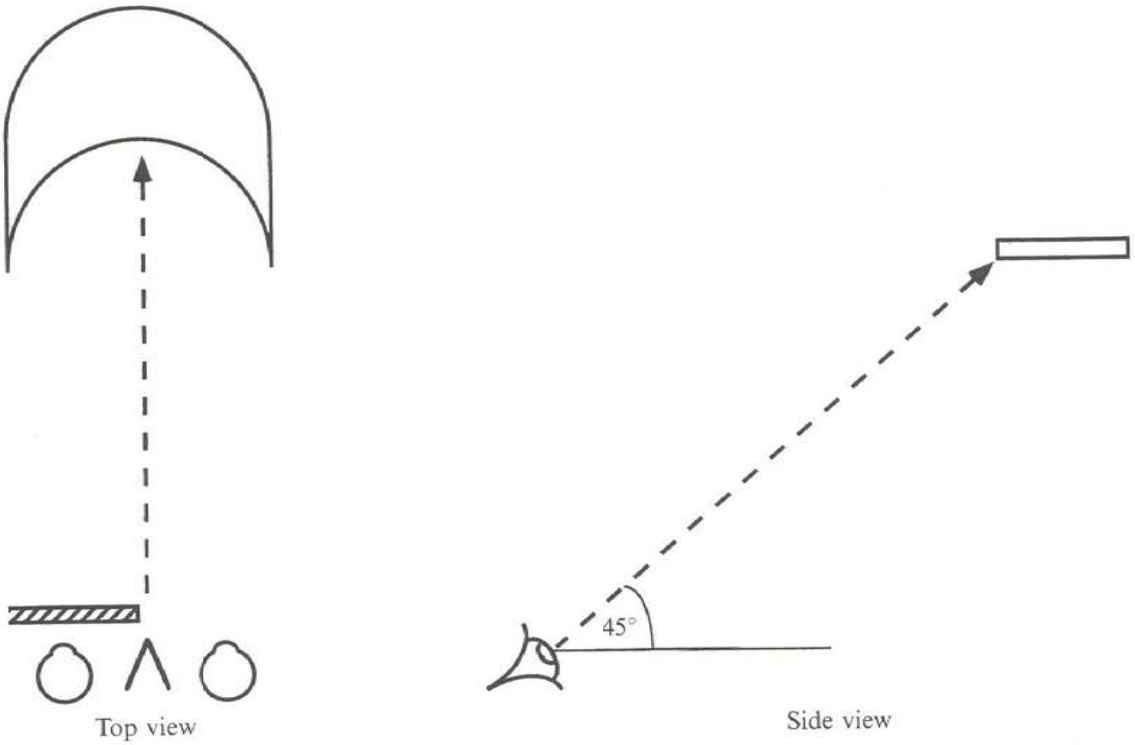


Figure 2. Viewing the illusion. With one eye covered, the shape is held directly in front of the observer, with the straight edges parallel to the line of sight (shown as the dashed line in the left-hand figure). The shape is then slowly raised until the line of sight is elevated from the horizontal by approximately 45°.

4 Demonstrations

4.1 *Shape*

We describe a number of informal observations using objects like the one shown

object in figure 1a appears to curl up or down, its shape appears to approximate a curled rectangle. Even though there is an infinite number of curve–curl pairs which can yield a particular projected image, the percept tends towards one of two shapes: the veridical shape (flat with curved edges) and an illusory approximately rectangular shape (which appears to curl up or down). The consistency of percepts across observations and observers suggests that the perceptual assumptions involved in making shape inferences are highly consistent.

We have also constructed other objects that are similar, but where the separation between the two curves is very small, leading to a C-shape, or where the outer curve is an elongated parabola. Neither of these shapes can share a projected image with that of a curled rectangle, yet both shapes appear to be curled. The perceptual assumptions involved in the three-dimensional reconstruction of an image seem to concern local features rather than global shapes. This is also true for the case of parallelogram objects (Griffiths and Zaidi 1998).

4.2 *Stereo*

If you uncover both eyes after the illusory percept has been obtained, the illusion will immediately disappear. Fixate on the center of the closer curved edge, and notice that it appears to curve towards or away from the observer, but still appears flat. Close one eye, and the ends of the object appear to curl, one end slightly more than the other. Open just the other eye. Once again, both ends of the object appear to curl, in the same direction as before, but the opposite end now appears slightly more curled. Both monocular views yield a percept of a curled surface, but when both eyes are opened the combination of the views from the two eyes results in the perception of a flat, planar surface. Since the stereo percept is not related to simple horizontal or vertical differences between the monocular percepts, this demonstration indicates that monocular projections and stereoscopic percepts are related by the rules of perspective geometry.

4.3 *Motion*

In this demonstration, the object is viewed monocularly and is gradually raised and lowered in front of the monocular observer. The object now appears more or less curled as the elevation above eye level is increased or decreased. Specifically, the object appears to flex and change shape, and this results in nonrigid motion. The motion is highly implausible, since the material out of which the object is constructed is not perceived as flexible, but the illusion is strong.

This demonstration works best if the object is translated slowly. If the object is moved too quickly, the shape illusion instantly disappears, and the object appears flat once again. In addition, many observers report a brief delay between the initial presentation of the object and the appearance of the illusory curl. Whereas the illusory percept can almost be seen as it develops, it is lost almost instantaneously. This asymmetry suggests that a hysteresis-type process is not at work, and also that the illusory percept is lost with rapid movements because it simply does not get a chance to develop.

4.4 *Touch and proprioception*

While viewing the illusion monocularly, if the observer holds the object at the tips of the curved edge with both hands, the strength of the illusory percept is reduced. It seems that proprioceptive depth information interacts with visual cues. In addition, it is possible to break the illusion by running a finger along the closest edge of the object. If an observer touches one end of the closer curved edge, it is still possible to see the opposite end of

4.5 *Binocular illusion*

When this object is presented at larger viewing distances (greater than 10 feet, for an object constructed from arcs of radius 3 inches), the illusory percept can still be obtained when the object is viewed binocularly. At larger viewing distances the monocular illusions from the two eyes are similar and the differences between the two retinal images are not sufficient to overcome the illusion. As a result, this illusion can be used to help a moving observer line up with a channel. If three lights or other identifying features are placed at the center and tips of this type of object (ie the center light at a different depth from the flanking lights), an observer would see the three lights as collinear only if the observer was in the same plane as that formed by the three lights. This would work for planes of any three-dimensional orientation.

5 Summary

A curved planar object can appear curled when viewed monocularly. Even though an infinite number of three-dimensional objects could be consistent with the retinal projection from a particular viewpoint, a stable illusory curl is seen, consistent with the straightening of the curve. The illusory curl can literally be seen to develop, but can be instantly smoothed out by stereo, motion, or proprioceptive information.

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Reference

Griffiths A F, Zaidi Q, 1998 "Perceptual assumptions and projective distortions in a three-dimensional shape illusion" *Perception* (submitted)