The effect of 3-D shape on size perception
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Recent studies suggest that the shape of three-dimensional (3-D) objects causes the systematic distortion of their apparent size (Miura & Taya, 2001) and we have investigated which property of the objects may do this. The stimuli were stereograms defining four 3-D shapes: a pair of frontoparallel rectangles, a triangular ridge, a cylindrical ridge, and a trapezoidal ridge. The observer's task was to match the height of a line-drawing of a rectangle (comparison stimulus) to that of the stimuli. The results showed that the apparent height of the object decreased as the slant of their surface protruding from the background was increased. The results implied that our visual system takes account of the slant of a surface for size estimation.

**Key words:** size perception, surface slant, 3-D shape

Previous studies have reported that observers made systematic errors when they estimated size and depth in a 3-D space (Norman, Todd, Perotti, & Tittle, 1996). Most of these studies have attributed the errors to an incorrect estimation of the viewing distance. However, recently we demonstrated that the apparent width of cylindrical objects decreased as their depth increased, indicating that the 3-D shape causes a systematic error in size estimation (Miura & Taya, 2001).

The goal of the present study was to identify the factor causing the systematic decrement of the apparent size of 3-D objects. Whenever the depth of a cylinder changes its other 3-D properties (slant and curvature) also change. Therefore, it has not been clear which property critically affects size perception. In Experiment 1, we examined whether the depth itself affects apparent size. We measured the apparent height of differently shaped 3-D objects. The simulated depths of the objects were equivalently set across all shapes. Therefore, if the depth itself was the factor of the systematic error of size perception, the apparent height of the object would be dependent on its depth but independent of its shape.

**Experiment 1**

**Method** Eight observers participated. The test stimuli were random-dot stereograms depicting one of three 3-D shaped objects: a pair of frontoparallel rectangles, a triangular ridge, and a cylindrical ridge (Figure 1(a)–(c)). The test stimuli had the same horizontal width (5 cm) but either of two different heights (4 or 5 cm). The simulated depth was 2, 4, and 6 cm at the viewing distance of 60 cm. A line-drawing of a rectangle was presented below the test stimulus. An observer's task was to match the height of a rectangle to that of a test stimulus. To obtain the baseline for normalization a single random-dot rectangle of the same width and height as the test stimuli was presented in another session. The observers again used the same procedure in another eight trials of the height-matching task for this rectangle.

**Results and Discussion** Figure 1(e) shows how the apparent height varied as a function of depth for each of the three shapes. To normalize the large individual difference, the matched height for each stimulus is represented as the ratio against the baseline value. An analysis of variance revealed that the matched height of the cylinders decreased as their depth increased ($F(2,7)=27.3, p<.001$). A similar decrement of matched height was also observed with the deepest (i.e. depth = 6 cm) triangular ridge. However, the matched heights of the rectangular pairs were almost constant across all simulated depths.

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The results suggest that some properties of 3-D shape other than depth (e.g. slant or curvature) affected the apparent height. In this experiment, the depth of the objects was equivalent across all of the shapes. However, the decrement of height was only observed in cylindrical ridges and the deepest triangular ridge. Depth therefore, is not the main factor causing the decrement of the apparent height.

We presumed that the slant of a surface protruding from the background affects the apparent height (For the definition of “slant”, see Figure 1). The slant of the cylinder was much steeper than that of the triangular ridge or the pair of rectangles even if the depth of the objects was equivalent. Consequently, we hypothesized that a steeply slanted surface causes a decrement of the apparent height. We examined this hypothesis in Experiment 2.

**Experiment 2**

**Method** Five observers participated. The test stimuli were random-dot stereograms defining a trapezoidal ridge (Figure 1(d)). The depth-to-height ratio of the ridge was 1:1. The heights (and simulated depths) used were 4 and 5 cm. The horizontal width of the test stimuli was always 5 cm. The simulated slant of the surface against the frontoparallel background was selected from 74, 76, 80, 84, and 87 degrees. The observers participated in eight blocks of 10 trials. All other experimental conditions were the same as Experiment 1.

**Results and Discussion** Figure 1(f) illustrates how the apparent height varied as a function of the surface slant. An analysis of variance showed that the perceived heights of the 3-D stimuli decreased as their surface became steeper (F(4,4)=9.98, p<.001).

The results supported our hypothesis that the slant of the surface of the 3-D objects caused a decrement in the apparent height of them. Probably the reason why only cylinders and the deepest triangular ridge showed a height decrement in Experiment 1 was because the slant of their surface was much steeper than that of other stimuli. The results suggest therefore, that a slanted surface affects the perception of size, and especially when the slant has a certain steepness. The results suggest that the visual system may take account of the surface slant when size is estimated. This is likely because the size is the extent of the orthogonally projected image of a surface, and this can be varied depending on the surface slant.

**References**
