
The influence of object size and surface shape on shape constancy from stereo

Rebecca A Champion, David R Simmons[¶], Pascal Mamassian

Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; e-mail: d.r.simmons@psy.gla.ac.uk

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Abstract. The failure of shape constancy from stereoscopic information is widely reported in the literature. In this study we investigate how shape constancy is influenced by the size of the object and by the shape of the object's surface. Participants performed a shape-judgment task on objects of five sizes with three different surface shapes. The shapes used were: a frontoparallel rectangle, a triangular ridge surface, and a cylindrical surface, all of which contained the same maximum depth information, but different variations in depth across the surface. The results showed that, generally, small objects appear stretched and large objects appear squashed along the depth dimension. We also found a larger variance in shape judgments for rectangular stimuli than for cylindrical and ridge-shaped stimuli, suggesting that, when performing shape judgments with cylindrical and ridge-shaped stimuli, observers rely on a higher-order shape representation.

1 Introduction

A representation of three-dimensional (3-D) shape is computed by the visual system from the combination of multiple sources of information. For example, binocular disparity, motion parallax, texture, and shading information must all be combined somehow to give an overall estimate of shape. Under natural viewing conditions, where some or all of these 3-D shape cues are available, human observers' subjective impression is most commonly that the perceived shape of an object remains constant, despite variations in conditions such as viewpoint or lighting. This is referred to as *shape constancy*. However, in experimental studies, failures in shape constancy are commonly reported (Foley 1985; Todd and Bressan 1990; Norman and Todd 1993; Glennerster et al 1996, 1998; Todd and Norman 2003).

In the case of binocular disparity, for the recovery of veridical shape information, disparities must be scaled inversely by the square of the viewing distance. Johnston (1991) proposed that the failure of shape constancy that is commonly found when binocular disparities are presented in isolation is caused by a misestimation of the viewing distance. Johnston demonstrated that observers made systematic errors when judging the shape of stereoscopically defined random-dot cylinders as viewing distance was varied. The errors were consistent with an intermediate value of viewing distance being used to scale the disparities, regardless of the actual viewing distance.

Another factor of interest in the study of shape constancy is the influence of object size. A uniform scaling of size should not affect the perceived shape of an object; however, evidence suggests that varying angular size does affect stereoscopic depth constancy (Collett et al 1991; Johnston 1991). In the study by Collett et al (1991), observers judged the depth between two stereoscopic rectangular textured surfaces. Stimuli had variable angular size and were displayed at variable viewing distance. Results showed that the angular size of the stimuli had a significant effect on depth judgments, with perceived depth decreasing as angular size increased. Collett et al proposed that this result was due to an increase in angular size being interpreted as a decrease in viewing distance. Johnston (1991), however, found an opposite effect to that found by Collett et al, with an increase in angular size generally leading to an

[¶] Author to whom correspondence should be addressed.

increase in perceived depth, although this effect was not consistent across all viewing distances tested.

There are a number of differences between the two studies which may have led to this discrepancy in findings. For example, the task in Johnston's study involved a judgment of the shape of an object, whereas the task in Collett et al's study involved the judgment of the depth difference between two independent surfaces. Also the shapes of the surfaces were different in each case. Collett et al's stimulus consisted of two frontoparallel rectangles, displaced in depth from a frontoparallel background. Johnston's stimulus, however, was a smooth surface with a continuous variation in depth. These two stimuli therefore differ not only in the relative disparity field, but also in the higher-order shape information available, such as the availability of second-order disparity information.

Hence, in the present study, we investigated the influence of angular size on shape constancy for objects with different surface shapes. Participants performed a shape-judgment task on objects of five sizes⁽¹⁾ with three different surface shapes. The shapes used were: a frontoparallel rectangle, a triangular ridge surface, and a cylindrical surface (see figure 1), all of which contained the same maximum depth information, but different variations in depth across the surface.

2 General methods

2.1 Stimuli

The stimuli were static random-dot stereograms, with a density of 5%, composed of white dots on a black background, defining one of three differently shaped objects. The objects portrayed were frontoparallel rectangles, triangular ridges, or elliptical cylinders, as shown in figure 1.

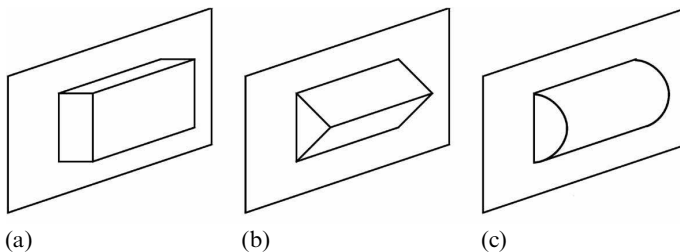


Figure 1. Schematic diagram of the three objects used: (a) frontoparallel rectangle, (b) triangular ridge, (c) cylinder.

Each image was 12.48 cm wide and 14.0 cm high. With a viewing distance of 80 cm, these images subtended visual angles of 8.92 deg and 10.0 deg.

The objects were presented protruding from the random-dot background and were all oriented horizontally in the frontoparallel plane. The objects and background were also situated behind a random-dot frame, at a disparity of 54.6 min of arc from the background, which rendered the top and bottom edges of the objects visible, but which occluded the left and right edges of the objects. The size of the aperture in the frame was constant at 8.48 cm by 10.0 cm (6.07 deg by 7.15 deg).

All objects had the same horizontal width of 8.48 cm (6.07 deg). The five object heights used were 1.00, 1.68, 2.83, 4.76, 8.00 cm (subtending visual angles ranging from 0.72 deg to 5.73 deg). Height was defined as the size of the base of the object in contact with the background. These were centred at the vertical midpoint of the image.

⁽¹⁾It should be noted that in the main experiment, when we refer to the variable of size, we were in fact only varying the dimension of height. This is based on the assumption that the effect of a change in height would be the same as the effect of a change in overall size. This assumption is tested explicitly in the second additional experiment.

The disparity maps were created by first calculating the depth represented by each pixel and then translating these depth values into disparities. The depths used ranged from 0 to 5.2 cm, for the largest object with the greatest ratio (corresponding to a disparity range of 0 to 17.9 min of arc at a viewing distance of 80 cm). Sub-pixel resolution techniques were used to represent disparities more accurately.

For each shape and each size, seven different stimuli were generated, each with a different depth : half-height ratio. The range of ratios varied depending on the shape, size, and participant. Pilot experimental runs were carried out for each participant to obtain a suitable range of ratios to allow a psychometric function to be fit to the data.

In total three sets of stimuli were generated, one for each of the three shapes. Each stimulus set consisted of 35 stimuli (5 heights \times 7 depth : half-height ratios).

2.2 Apparatus

Stimuli were generated on an Apple Power Mac G4 and presented on a Sony Trinitron 21 inch monitor set at a resolution of 1152 \times 870 pixels. The mean luminance was 4.8 cd m⁻². The room was painted matte black and lights were switched off during the experiment.

Participants viewed the stimuli from 80 cm, with their heads kept in place with a chin-rest and forehead-rest. A modified Wheatstone stereoscope was used to achieve independent presentation of the image to each eye. The stereoscope comprised two sets of two front-surfaced mirrors attached to adjustable mirror mounts, which were mounted on an optical bench. The outer two mirrors were angled at 45° to both screen and participant. The inner two mirrors were positioned at approximately 45° but adjusted to achieve the vergence state required for the viewing distance of 80 cm.

2.3 Procedure

We used the method of constant stimuli. An experimental block consisted of 35 trials (each of the stimuli from one stimulus set); 40 blocks were run. Within one block, stimuli were presented in a pseudo-random order, with a different pseudo-random order for each block. Stimuli from the cylinder stimulus set were presented within the same session as another set of stimuli used for the first additional experiment, which will be discussed in a later section. The stimuli in this other set were identical to the cylinder stimuli, except they had a lower texture-dot density. Trials from the two sets of stimuli were randomly interleaved. In the cases of the ridges and rectangles, trials from only one stimulus set were presented within a session. For the cylinder stimuli, one session consisted of 10 blocks of stimuli from each set, and each participant completed four sessions. For the ridges and rectangles, one session consisted of 20 blocks; hence each participant completed two sessions per shape. In all experiments, stimuli were generated and saved prior to an experimental session. Thus a given dot pattern appeared once per block throughout the session. A new set of stimuli was generated for each session. One session lasted approximately 30 min.

The participant's task was to decide, for each stimulus presentation, if the maximum depth of the object was less than or greater than its half-height. Participants were required to respond by a key-press. Stimuli were presented until the response was made.

Hence, this experiment had three independent variables: shape (3 levels), height (5 levels), and depth (7 levels). Two dependent variables were measured for each shape at each height: the accuracy or bias and the variability, σ , of the shape judgments. To obtain these measures, the data were plotted as the proportion of stretched responses as a function of depth (on a logarithmic scale) (see figure 2). A cumulative Gaussian was fit to the data with the *psignifit* software (Wichmann and Hill 2001a). From this fit the 50% threshold was obtained, which represents the depth that was perceived to be equal to the half-height. Dividing this by the actual half-height gives the depth-to-half-height ratio at the point of subjective equality (PSE). This measure represents

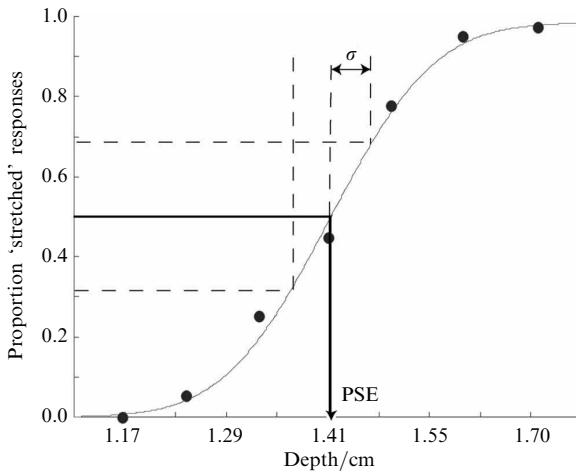


Figure 2. The proportion of 'stretched' responses was plotted as a function of depth. A cumulative Gaussian was then fit to the data. This figure shows an example of data from an object with a height of 2.83 cm. The point of subjective equality (PSE) was extracted from the depth at the 50% threshold and then scaled by the half-height to yield a depth-to-half-height ratio. The standard deviation, σ , gives a measure of the variability of the judgments.

the accuracy or bias in participants' shape judgments and is independent of size, hence allowing comparison of shape distortions across the different sizes. A PSE equal to 1 corresponds to shapes that are perceived veridically and without bias. Where a $PSE < 1$ was obtained, this means that an object with a depth less than its half-height was perceived to be circular. This indicates that the depth was being overestimated compared to the height or, rather, the shapes were perceived to be 'stretched' compared to the shape simulated. Where a $PSE > 1$ was obtained, then an object with a depth greater than its half-height was perceived to be circular, which indicates that the depth was being underestimated compared to the height or, rather, the shapes were perceived to be 'squashed' compared to the shape simulated. Also the standard deviation, σ , of the cumulative Gaussian was obtained. This gives a measure of the variability of the shape judgments. Confidence intervals on both the PSE and σ were obtained by a bootstrap resampling technique (Wichmann and Hill 2001b).

2.4 Participants

Four participants were used. Two participants were authors, RC and DS, and two were naïve participants, VL and RG. DS and VL both had corrected-to-normal vision. All four were experienced psychophysical observers.

3 Results

Figure 3 shows how the depth-to-half-height ratio at the PSE varied as a function of height for each participant for each of the three shapes. If size had no influence on perceived shape, we would expect, for each shape, all sizes to produce equal PSEs, and hence all points to lie along a horizontal line. Figure 3 demonstrates that size did affect perceived shape, but the pattern of errors varied between the different shapes. There was also a large amount of variability between participants, hence it is difficult to draw any conclusions about the general influence of size and shape on judgments. It is likely that there are many factors which could potentially be influencing the errors in judgment, one factor being the misestimation of viewing distance.

A subsequent analysis was performed in an attempt to remove some of the between-participants variability, and hence recover a systematic pattern of errors across size. In this analysis, we assumed that the errors found in the rectangle task, reflected factors which would have been consistent across all shapes, for example a misestimation of the viewing distance. By removing these errors from the results of the cylinder and ridge tasks, we obtain the residual errors in shape perception that occur for the cylinder and ridge stimuli. Hence, a new measure termed the adjusted PSE

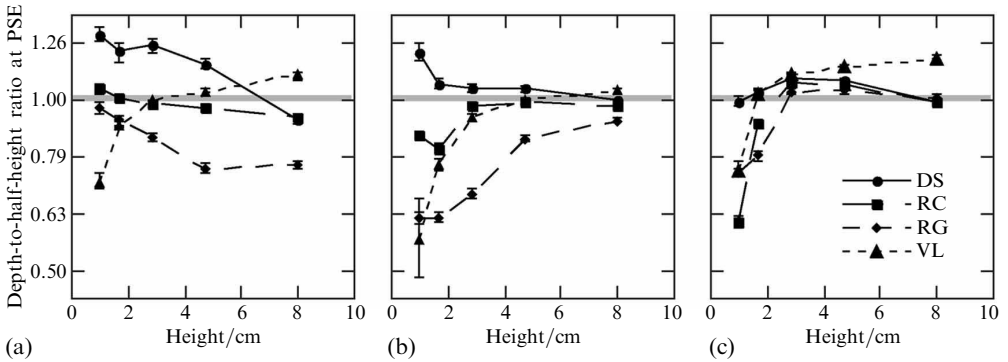


Figure 3. Variations in PSE with height, for each shape—(a) rectangles, (b) ridges, (c) cylinders—across the four participants: DS, RC, RG, VL. Error bars represent 95% confidence intervals.

was calculated, according to equation (1), from the cylinder and ridge results for each participant at each size.

$$\text{Adjusted PSE} = \frac{\text{PSE}_{\text{ridge or cylinder}}}{\text{PSE}_{\text{rectangle}}} . \quad (1)$$

This calculation is equivalent to obtaining an estimate of the perceived viewing distance being used to scale disparities in the rectangle condition at each size. This perceived viewing distance is computed for each participant by noting that the PSE is proportional to depth, which is itself proportional to the inverse of the squared viewing distance. If the viewing distance was correctly estimated, we would expect to obtain a PSE equal to 1, whereas for the perceived viewing distance we measured the $\text{PSE}_{\text{rectangle}}$.

Therefore we have:

$$\text{PSE}_{\text{rectangle}} = \frac{d_v^2}{d_p^2} \text{ or } d_p = \frac{d_v}{\sqrt{\text{PSE}_{\text{rectangle}}}} , \quad (2, 3)$$

where d_p is the perceived viewing distance and d_v the veridical viewing distance. We then use this estimate to remove any influence of a misestimate of viewing distance from the results of the cylinder and ridge stimuli to reveal any residual errors:

$$\text{Adjusted PSE} = \left(\frac{d_p^2}{d_v^2} \right) \times \text{PSE}_{\text{ridge or cylinder}} . \quad (4)$$

We found that this analysis removed most of the variability between participants, which allowed us to average performance across participants. Figure 4 shows how the

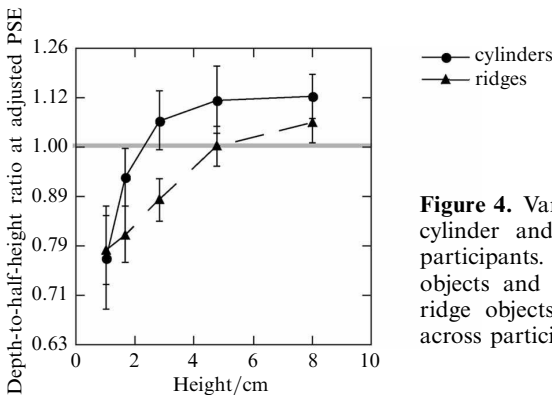


Figure 4. Variations in adjusted PSE with height, for cylinder and ridge shapes, averaged across the four participants. Circular symbols refer to the cylindrical objects and triangular symbols refer to the triangular ridge objects. Error bars represent ± 1 standard error across participants.

adjusted PSE varied as a function of height, for the cylinder and ridge shapes, averaged across participants.

Removal of the errors found in the rectangle condition from those of the cylinders and ridges resulted in greater consistency across participants. As demonstrated in figure 4, for both cylinders and ridges, the adjusted PSE was less than one at the smaller sizes, indicating that an object with a depth less than its half-height was perceived to be circular and therefore that the shape appeared stretched relative to the simulated object. At the larger sizes, the adjusted PSE was greater than one, indicating that an object with a depth greater than its half-height was perceived to be circular and therefore that the shape appeared squashed relative to the simulated object. However, at the largest size, for both cylinders and ridges, adjusted PSEs were closer to 1 than for the smaller sizes, indicating that perception was more veridical at the larger sizes.

For the cylinders, there is a steep increase in PSE with increasing size at the smaller sizes; however, some constancy was achieved at the larger sizes. With the ridges, however, there appears to be a steady increase in PSE with an increase in size for the whole range of sizes.

In general, the cylinders produced higher PSEs than the ridges, which indicates that the cylinders were perceived to be more squashed than the ridges. This may be explained by the texture cue, which was consistent with a flat frontoparallel surface, having a greater influence on the cylinders than the ridges.

Figure 5 shows how variability in shape judgments varied as a function of height for each shape, averaged over participants. These results demonstrate that there was a general increase in variability with an increase in height for all shapes. This is likely to be due to the increase in distance of the central portion of the stimulus from the background, also known as the disparity pedestal, with the increase in size. This explanation is supported by the previous finding that an increase in disparity pedestal causes a decrease in the precision of stereoscopic judgments (McKee et al 1990). Figure 5 further demonstrates that there was significantly more variability in judgments of rectangular shapes than of ridge or cylinder shapes. This is also reflected in the Weber fractions for the three shapes which were found to be 0.126, 0.074, and 0.078 for the rectangle, ridge, and cylinder conditions, respectively.

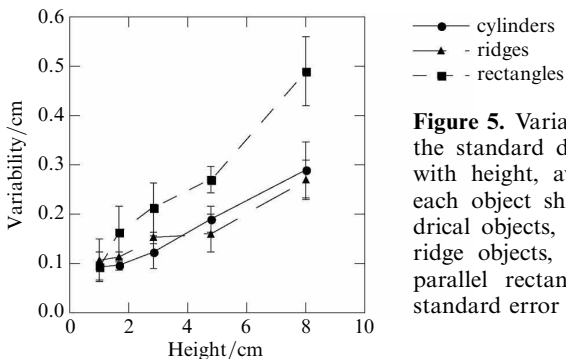


Figure 5. Variations in the variability (as measured by the standard deviation, σ , of the cumulative Gaussian), with height, averaged across the four participants, for each object shape. Circular symbols refer to the cylindrical objects, triangular symbols refer to the triangular ridge objects, and square symbols refer to the frontoparallel rectangular objects. Error bars represent ± 1 standard error across participants.

4 Additional experiments

The results shown in figure 4 demonstrated a failure in shape constancy for cylinder and ridge shapes that could not be accounted for by factors that were constant across all three shapes, such as a misestimation of the viewing distance. We identified two factors which could have contributed to the pattern of errors across size. First, as the height increased the amount of stereoscopic information defining the shape also

increased, the dot density being constant across all stimuli. This increase in stereoscopic information may have been the cause of the increase in veridicality with the increase in size. Hence, the factor of the number of dots defining the stimulus was investigated in an additional experiment by using stimuli with a lower dot density.

Second, the change in height with constant width meant that the height-to-width ratio varied with the height. To assess the influence of this factor on the results from the main experiment, a second additional experiment was carried out in which the height-to-width ratio was kept constant as the height varied.

5 Additional experiment 1: Varying texture density

5.1 Method

Stimuli were identical to the cylinder stimuli of the main experiment, except that the density of the dots was reduced to 0.62%. This new density was chosen so that the largest cylinder at this lower density contained the same number of texture dots as the smallest cylinder at the higher density in the main experiment.

The data for this experiment were collected within the same sessions as the data from the main experiment for the cylinder shapes. Trials from the two sets of stimuli were randomly interleaved. Only three participants were used in this additional experiment: RC, DS, and VL. All other methods were identical to those used in the main experiment.

5.2 Results

Figure 6 shows how the depth to half-height ratio at the PSE varied as a function of height for lower-density cylinders, in comparison with the data from the higher-density cylinders in the main experiment, averaged across the three participants. This figure demonstrates that, for both density conditions, the smallest stimuli were perceived to be stretched relative to the shape simulated, and the largest stimuli were perceived to be squashed relative to the shape simulated. Also, in both cases there is a steep increase in PSE with increasing height at the smaller heights, but some constancy is achieved at the larger heights. Hence the results of this experiment demonstrate that the number of texture dots defining the stimuli did not influence the pattern of results, even over an eight-fold change in dot density.

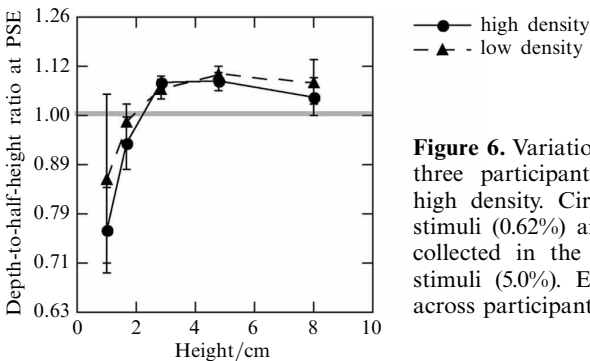


Figure 6. Variations in PSE with height, averaged across three participants, for cylindrical stimuli of low and high density. Circular symbols refer to the low-density stimuli (0.62%) and triangular symbols refer to the data collected in the main experiment for the high-density stimuli (5.0%). Error bars represent ± 1 standard error across participants.

6 Additional experiment 2: Constant height-to-width ratio

6.1 Method

Stimuli were similar to the cylinder stimuli of the main experiment, except for the following three factors. First, the aperture size was varied. For each stimulus, the width of the aperture was equal to double the height of the object, and the height of the aperture was equal to the height of the object plus 2 cm (in order to render 1 cm of the background visible above and below the object). Second, the range of object heights

was smaller, as the upper limit on height was constrained by the maximum possible width (8.5 cm). Hence the heights used were 1.00, 1.42, 2.00, 2.83, 4.00 cm (subtending visual angles ranging from 0.72 deg to 2.86 deg). Third, the depth of the frame from the background was reduced to a disparity of 10 min of arc. This change was implemented because pilot experiments demonstrated problems in fusing the stimuli at the smallest aperture size when the frame was presented at the disparity used in the main experiment. All other methods were identical to those of the main experiment.

6.2 Results

Figure 7 shows how the depth-to-half-height ratio at the PSE varied as a function of height for cylinders with constant height-to-width ratio, in comparison with the data for the cylindrical stimuli from the main experiment, which varied in height-to-width ratio. Results shown are the average across the four participants. This figure demonstrates that the two height-to-width ratio conditions produced very similar patterns of results, and therefore we conclude that the variability of the height-to-width ratio in the main experiment was not a factor in producing the pattern of results obtained. This justifies our generalisation of the effects of height to the effects of size.

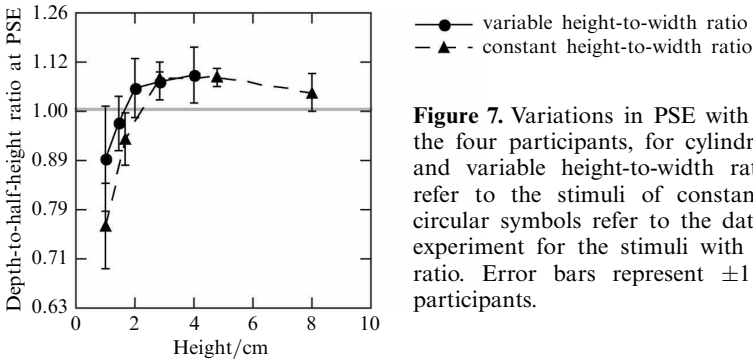


Figure 7. Variations in PSE with height, averaged across the four participants, for cylindrical stimuli of constant and variable height-to-width ratio. Triangular symbols refer to the stimuli of constant height-to-width ratio, circular symbols refer to the data collected in the main experiment for the stimuli with variable height-to-width ratio. Error bars represent ± 1 standard error across participants.

6.3 Discussion

This study was concerned with the issue of stereoscopic shape constancy. Our aims were, first, to investigate how stereoscopic shape constancy is affected by variations in the size of an object, and, second, to investigate the generality of any findings across different surface shapes. To investigate the effect of object size, observers' shape perception was measured for objects of five different heights. To investigate the effect of surface shape on depth constancy, three surfaces were chosen that each had the same maximum depth but different depth profiles.

Two salient aspects of the results obtained were the significant failures of stereoscopic shape constancy and also the large individual differences between participants, both of which are commonly reported in studies of stereoscopic shape perception (eg Johnston 1991; Todd et al 1995; Glennerster et al 1996; Todd and Norman 2003). In particular, these findings are consistent with those of the recent study by Todd and Norman (2003), who used a similar task and a stimulus similar to that of the ridge stimulus used in this study, and who demonstrated large errors in constancy and significant individual differences in the perception of both simulated stereoscopic and real-world stimuli.

With regard to the issue of size, we found that errors in shape perception varied across the five sizes, demonstrating that shape constancy was not achieved across size. We also found that the pattern of errors across size varied for the different shapes. For the cylinder and ridge shapes, the results revealed a decrease in perceived depth with an increase in size. For the rectangle shape, the pattern of errors was more variable

across participants. Hence the pattern of results across size obtained in the cylinder and ridge conditions is consistent with the results of Collett et al (1991), but is inconsistent with those reported by Johnston (1991). Collett et al proposed that the change in angular size affected perceived shape because of its influence on the perceived viewing distance. However, if this were the only factor influencing changes in shape perception with size in our study, we would expect a similar pattern of results across the three shapes. In an effort to put aside factors that were constant across all three shapes, such as a misestimation of the viewing distance, the errors found in the rectangle condition were removed from the results of the cylinder and ridge conditions, to reveal the residual errors in shape perception. This analysis revealed a pattern of errors across size which was consistent across all participants and demonstrated that, for cylinder-shaped and ridge-shaped objects, smaller shapes appeared stretched relative to the simulated objects, whereas larger shapes appeared squashed. We also found that, whereas for the cylinders there was a steep decrease in perceived depth with increasing size for the smaller sizes, at the larger sizes shape constancy was achieved. For the ridge stimuli, however, there was a steady decrease in depth with an increase in size for the whole range of sizes.

The reasons for these errors in shape perception are not clear. One difficulty in the interpretation of these results is that the causes of the misperception of shape could be due either to a misestimation of the depth or to a misestimation of the half-height. Two factors which could potentially have produced these results were the change in the amount of information (number of texture dots) in the stimulus, and a change in the height-to-width ratio of the object. However, these factors were ruled out by the additional experiments.

Another factor for consideration is the relative influence of other depth cues on the stimulus. The 3-D shape information provided by the binocular disparities was in conflict with the other depth cues present in the stimulus, such as texture, accommodation, and any residual motion cues through unintended eye or head movements. All these residual cues were consistent with a flat surface. It is widely accepted that when individual depth cues are integrated, the relative weighting of the cues is highly dependent on the viewing conditions and stimulus parameters (see Landy et al 1995). For example, it has been shown that the relative weighting of stereo and texture cues is affected by the viewing distance to the stimulus (Johnston et al 1993), the regularity of the texture elements (Cumming et al 1993), and also the orientation of the object (Buckley and Frisby 1993). With regard to the present study, it may be the case that the relative weighting of stereo and the residual depth cues, such as texture, was affected by the size of the object. For example, the residual cues indicating a flat surface may have had a greater influence on shape perception at the larger sizes than the smaller sizes. Another possible explanation for the pattern of results found concerns the influence of the frame through which the object is viewed. It has been shown that viewing an object through a frame reduces the amount of depth perceived in the scene (Eby and Braunstein 1995); this could potentially have a greater influence at the larger sizes than the smaller sizes. The influence of these factors would need to be tested empirically in further studies.

We were also interested in investigating how performance in this task was affected by the shape of the surface. We found differences in the pattern of errors across size for the rectangle shape compared to the ridge and cylinder shapes. We also found that the variability in shape judgments was significantly higher in the rectangle condition than in the ridge and cylinder conditions. This suggests that different information was being used to perform the task in the different conditions. Although all three surfaces contained the same maximum-depth information, they each contained different depth profiles. This meant that, for each shape, the task could be performed by

comparing the ratio of maximum depth to the half-height; however, for both the ridge and cylinder shapes, at least one alternative strategy could be used in each case. For the ridges, participants could rely on the angle between the two planes, and judge whether it is greater or less than 90° , and for the cylinders participants could judge the curvature of the surface and compare it to the degree of curvature of a circular cylinder. The extra information needed to use these alternative strategies could come from two sources. It could come from either the first-order and second-order derivatives of the disparity field, producing disparity gradient and disparity curvature information. Alternatively the first-order and second-order derivatives of the depth map (after the disparity field has been scaled by the viewing distance) could be used to produce an orientation map and a curvature map.

Whether the visual system uses these sources of higher-order information has been a matter of debate. Rogers and Cagenello (1989) claimed that the visual system does use mechanisms which compute disparity curvature for the representation of the shape of surfaces. While disparity curvature can be used in tasks where it is the only cue available, Lunn and Morgan (1997) claimed that the visual system is not as sensitive to disparity curvature as it is to relative disparity and disparity gradient, especially in tasks where precise discrimination of object surfaces is required. However, the difference in results found between shapes in this study suggests that the visual system is using more than just the depth map in the performance of the task.

The finding of lower variance in higher-order shape judgments has been reported previously (Johnston and Passmore 1994; Norman and Todd 1996). In the present case, one possible explanation why the rectangle might lead to higher levels of variability than the cylinder and ridge shapes is that the judgment requires accurate estimation of two dimensions: the depth and the half-height. For the other shapes, judgments could be dependent upon just one dimension—the slant or curvature of the surfaces. It is well known that both length and/or relative-position judgments and disparity-increment judgments show a Weber relation with the appropriate independent variable (see, eg, Morgan and Watt 1989; McKee et al 1990). With the rectangle stimulus, the judgment potentially introduces two Weber relations: that for relative position and that for relative disparity. Consequently, thresholds should increase more quickly with either depth or height as the independent variable than for a judgment such as that of relative angle or curvature for the ridge and cylinder shapes. Hence, it could be the necessity of estimating two dimensions which causes the increase in variance for the rectangle shapes, rather than it being due to a less reliable estimate of depth.

In summary, we have demonstrated that size does have an effect on stereoscopic shape constancy. Generally, small objects appear stretched and large objects appear squashed. We have also shown a larger variance in shape judgments for rectangular stimuli compared to cylindrical and ridge-shaped stimuli. These latter results suggest that, when performing shape judgments with cylindrical and ridge-shaped stimuli, participants rely on a higher-order shape representation, which integrates information across the surface of the shape, rather than simply relying on a depth map.

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