Perception, 1997, volume 26, pages 17–27

Perceived angular and linear size: the role of binocular disparity and visual surround

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Received 7 August 1995, in revised form 4 November 1996

Abstract. An experiment was conducted to investigate the effects of perspective cue and binocular disparity on perceived angular and linear size. Following the 'angular' and 'linear' instructions, subjects matched the size of two squares, for which the binocular disparity between the centers of the squares and the configuration of the stimulus surrounding the squares were manipulated. Results showed that angular-size matches depended on the retinal-image size and the binocular disparity, and not on the visual-surround stimulus. Linear-size matches, on the other hand, depended on the visual-surround stimulus as well as on the image size and the binocular disparity. The visual-surround stimulus also affects the perceived depth between the test squares. These findings indicate that perceived angular and linear size depend on different processes that use different cues, and suggest that there is a causal relationship between perceived depth and perceived linear size.

1 Introduction

The traditional size–distance-invariance hypothesis (SDIH) states that for a given size of a retinal image the perceived size of an object is proportional to its perceived distance (Epstein et al 1961; Kilpatrick and Ittelson 1953). Although the size–distance-invariance process has often been applied to explain the size illusions such as of the moon (Dees 1966; Kaufman and Rock 1962; King and Gruber 1962; Rock and Kaufman 1962), distance responses and size responses are not always consistent with predictions from the hypothesis. For example, many people report that the moon at the horizon appears to be larger in size but closer to the viewer than the moon at the zenith (Hershenson 1989; McCready 1986). This discrepancy is called the size–distance paradox (Epstein et al 1961; Ono et al 1974). To fit the size–distance paradox into the size–distance-invariance process, it was proposed that either perceived (seen) distance or registered (indicated) distance could be used in the process (Rock and Kaufman 1962).

Several writers have stated that the size–distance paradox is due to ambiguity of the instructions for the size responses (Joynson 1949; McCready 1965, 1985; Ono 1970; Rock and McDermott 1964). They claimed that observers could perceive both linear size and angular size for an object [see Plug and Ross (1994) to obtain clear definitions of perceptual terms for size] and that the single word for size experience used in many of the past studies, such as "perceived size" or "apparent size", could elicit either the linear size or the angular size. McCready (1985) stated that observers simultaneously, not alternatively, had both linear-size and angular-size perceptions and that application of perceived angular size instead of physical visual angle in the traditional SDIH, including the case of the moon illusion (McCready 1986), could resolve the size–distance paradox. The perceived angular size in McCready's theory is a 'primitive', and therefore it should be independent of perceived distance or registered distance and have its own cues. McCready mentioned the two types of explanation for shifts of perceived angular size away from physical visual angle: contour interactions and oculomotor factors.

Some other writers (Enright 1989a; Ono et al 1974; Plug and Ross 1994) also suggested that the change in the perceived size with oculomotor adjustments, which had been shown experimentally in many studies (Biersdorf et al 1963; Komoda and Ono 1974; Leibowitz and Moore 1966; Leibowitz et al 1972; Ono et al 1974; Oyama 1974), was a change in perceived 'angular' size.

Although many studies have demonstrated phenomenally that the size responses under the 'linear' and 'angular' instructions differ from each other (see Carlson 1977 for a review), the observations do not conclusively confirm McCready's notion that linear and angular sizes are processed differently. This is because there is a possibility that both angular-size and linear-size responses are based on a single perceived size.

The purpose of this study was to examine experimentally whether perceptions of linear and angular size are processed differently, or whether both size responses depend on a single process. For this purpose, we measured the linear size, the angular size, and the depth responses for stimuli while manipulating two kinds of depth cue: binocular disparity and visual perspective. If any changes in the cues affect both the linear-size and the depth response but not the angular size, the hypothesis that the two types of size response depend on two different processes would be supported. In this case, McCready's SDIH is suitable for describing the relationship among the three perceptual quantities. On the other hand, if the linear-size and angular-size responses always vary together with any change of the cue condition and of the perceived distance, then it follows that either the linear-size and angular-size responses are dependent on a single function of cues or that the independent processes responsible for each size response cannot be separated through manipulation of the binocular disparity and perspective.

2 Method

2.1 *Subjects*

Eight male subjects, aged between 22 and 30 years, participated. They were students or staff of Tokyo Institute of Technology. Five of them wore their own glasses during the experiment. All subjects had normal stereo acuity. All were naive regarding the purpose of this experiment, except one of the authors. Their interocular distances were between 63 mm and 72 mm and the average was 66 mm.

2.2 *Apparatus and stimulus*

The standard stimulus was presented in a stereoscope, and the comparison stimulus was located at a fixed distance from the subject and observed binocularly. The binocular disparity between the centers of the stimuli and the perspective configuration surrounding the stimuli were manipulated. The apparatus, shown schematically in figure 1, consisted of three parts, which generated the standard stimulus, the comparison stimulus, and the surround stimulus. The apparatus was in total darkness so that nothing was visible other than those stimuli.

The standard stimulus consisted of two square apertures back-illuminated by small fluorescent lights in boxes attached to the apertures. These stimuli were presented dichoptically by means of two half-silvered mirrors and two pairs of polarizing filters, which were placed directly in front of the apertures and the subject's eyes. The standard stimuli were mounted on tracks and their positions were controlled by stepping motors and a microcomputer, thus varying the binocular disparity. The linear size of each standard stimulus was 36 mm, and the distance between the subject and the standard stimuli was 100 cm. Therefore, this subtended a visual angle of 2.1 deg. Neutral-density filters were placed in front of the stimuli to reduce extraneous illumination resulting from incomplete polarization. The luminance of the standard stimulus was 0.1 cd m^{-2}.

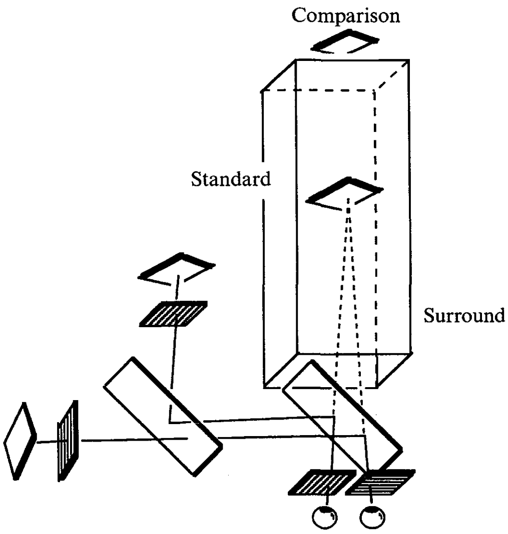

Figure 1. Schematic diagram of the apparatus.

The comparison stimulus consisted of a set of two triangular-shaped apertures which were movable in opposite directions by means of a DC motor and gear system. By using this device, the size of the comparison stimulus could be varied without changing its shape (square) and center position. This stimulus was back-illuminated by a fluorescent light. The linear size of the comparison stimulus was between 7 mm and 149 mm, and the viewing distance was 326 cm. Therefore, it subtended a visual angle from 0.1 deg to 2.6 deg. The comparison stimulus was located just above the standard stimulus with their centers 4 deg apart. The center of the comparison stimulus was at the same height as the subject's eyes. The luminance of the comparison stimulus was reduced to 0.1 cd m^{-2}, which was equal to that of the standard stimulus, by means of neutral-density filters.

The binocular disparity between the centers of the standard and comparison squares was adjusted to be either 0, +0.60, or +1.15 deg, which corresponded to an effective distance between the standard and comparison squares of 0, 110, and 162 cm, respectively, for an interocular distance of 66 mm. The zero value was defined as the position of the standard square where both the standard and the comparison square appeared to be the same distance from the subject. Positive values indicated that the standard square was closer than the comparison square.

The surround stimulus was used to manipulate the perspective cue, which could change the perceived depth between the standard and comparison squares while keeping the binocular disparity constant. There were three surround conditions, designated 'long', 'middle', and 'short'. These stimuli consisted of two lines of LEDs arranged on both of the side walls flanking the standard and comparison squares. These stimulus arrangements are shown schematically in figure 2. In the 'long' condition (figure 2a), the spaces between the side walls and between the LEDs on each wall narrowed with increasing distance from the subject (filled circles and solid lines). The distribution of LEDs simulated a scene in which the LEDs were arranged on the parallel walls of a long corridor (open circles and dotted lines). In the 'middle' condition (figure 2b), the LEDs were arranged on the walls of a cubic corridor in a straight manner (filled circles and dotted lines). In the 'short' condition (figure 2c), the spaces between the side walls and between the LEDs on each wall became wider with increasing distance from the subject (filled circles and solid lines). This distribution of LEDs simulated a scene in which the LEDs were arranged inside a short corridor (open circles and dotted lines).

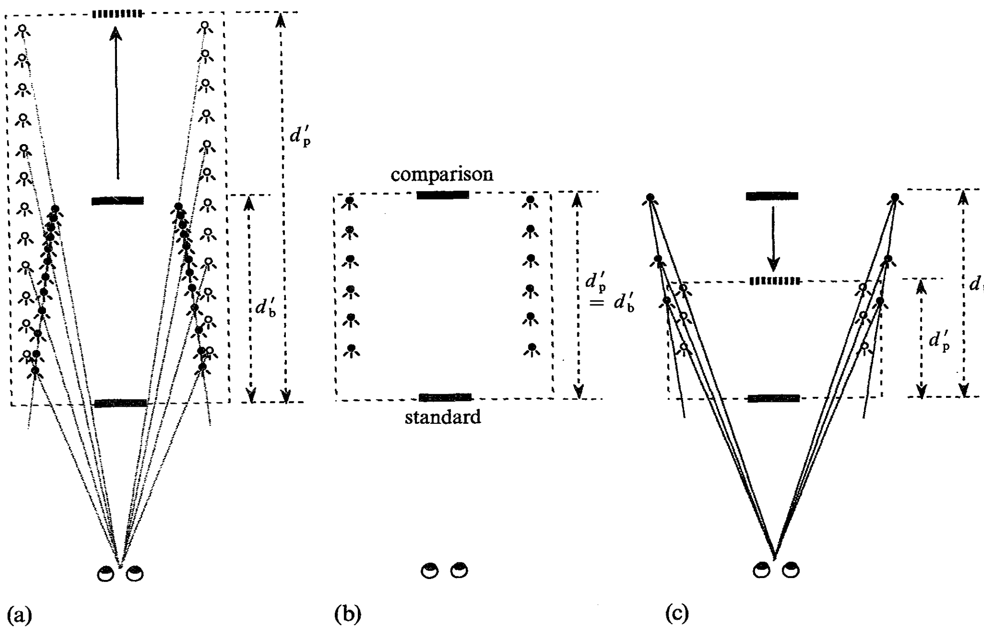

Figure 2. Schematic top view of the surround stimuli. The filled and open circles show the real and predicted positions of the LEDs, respectively. d'_p and d'_b indicate the depths between the standard and comparison stimuli predicted from perspective cue and from binocular disparity, respectively. (a) 'Long', (b) 'middle', and (c) 'short' condition.

These three arrangements of LEDs simulated the LEDs uniformly distributed inside the cubic corridors (dotted lines), in which the right and left walls, the parallel lines of LEDs on each wall, and the LEDs in a line were separated by 36 cm, 13 cm, and 26 cm, respectively. There were twelve LEDs in a line for the 'long' condition, six for the 'middle', and three for the 'short' condition, so that the predicted positions of these stimuli from the subject were 170 – 456 cm, 170 – 300 cm, and 170 – 222 cm, respectively. The real positions of the stimuli (LEDs) were 163 – 300 cm for the 'long', 170 – 300 cm for the 'middle', and 186 – 300 cm for the 'short' condition. This kind of manipulation of perspective cue was previously made in the studies of Blessing et al (1967) and of Vogel and Teghtsoonian (1972).

2.3 *Instructions*

We used the following two different instructions to elicit linear-size and angular-size responses.

Under the 'linear-size' instruction, subjects were asked to match the size of the upper square (comparison stimulus) to that of the lower square (standard stimulus) *as objects.* We asked the subjects to mentally move (imagery) one square to the position (distance) of the other square, or to imagine using a ruler to measure both square sizes. Subsequently, the subjects had to make a linear-size match.

Under the 'angular-size' instruction, the subjects were asked to match the size of the upper square (comparison stimulus) to that of the lower square (standard stimulus) *as extents.* We asked the subjects to mentally displace (imagery) the closer square so that its representation would appear to be located between the eyes and the farther square, keeping the distance between the two squares constant, or to imagine taking a picture from their eye position. Subsequently, the subject had to make an angular-size match to allow the borders of both squares to overlap.

2.4 *Procedure*

The subjects adjusted the size of the comparison square to match that of the standard square for each combination of binocular disparity and surround stimulus under the linear-size and the angular-size instructions in a simultaneous-viewing condition. The subjects were instructed to observe the stimuli binocularly. The observation time was not limited. For each subject, each of nine stimulus conditions (three binocular disparities × three surround conditions, 'long', 'middle', and 'short') was presented eight times under each size instruction. These trials were divided into four experimental sessions. In each session, the size instruction was either 'linear size' or 'angular size'. The order of instructions was balanced among the subjects. At the beginning of each session, the zero adjustment for the binocular disparity setting was performed. Each session, including the adjustment, lasted about one hour. The subject's head was fixed with an adjustable chin-and-head rest.

All of the subjects also made depth judgments about the stimuli in other experimental sessions. The subjects reported verbally the perceived depth between the standard and comparison squares. For tactile reference, the subjects used a wooden bar, which was 90 cm long and had grooves every 10 cm on it. For each subject, there were thirty-six trials (three binocular disparities × three surrounding conditions: 'long', 'middle', and 'short' × four repetitions). In this experiment, the visual angle of the comparison square was kept constant at 2.1 deg (117 mm), which corresponded to that of the standard square.

3 Results

Figure 3 shows the averaged size of the comparison square matched in size with the standard square as a function of the binocular disparity under each instruction and surround condition across the eight subjects. Each symbol indicates each combination of surround stimulus and instruction, and the error bars represent standard errors. The horizontal dashed line represents the perfect angular-size match, which is the linear-size match corresponding to the visual angle of the standard square. The three curved dashed lines are based on the prediction from perfect linear-size constancy, on the assumption that perceived linear size varies according to the depth calculated

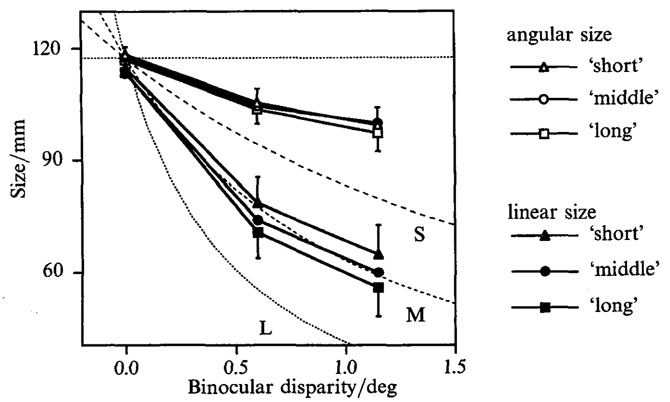

Figure 3. Averaged size of a comparison stimulus matched to a standard stimulus under the angular and linear size instruction as a function of binocular disparity across eight subjects. Symbol shapes indicate the surround conditions. The horizontal dashed line represents the perfect angular match. The curved dashed lines represent the linear matches predicted from the surrounding conditions (S, 'short', M, 'middle', and L, 'long'). One of the lines designated as M also represents the linear match predicted from the binocular disparity. Error bars represent standard errors (for clarity, only the positive error bars for the 'short' condition and the negative error bars for the 'long' condition are plotted).

for the surrounding condition of 'short', 'middle', and 'long'. One of the curves for 'middle' also represents the perfect linear-size match according to the depth calculated for the binocular disparity.

The size of the comparison square matched with the standard square decreased with increasing binocular disparity between the centers of the comparison and standard squares. This effect was clear for both the angular-size and the linear-size response. The binocular-disparity – size-response functions of the linear size and of the angular size were clearly different from each other. The linear-size responses were close to linear-size constancy (the curved dashed lines) and the angular-size responses, in contrast, were close to visual-angle match (the horizontal dashed line) but diverged clearly from the true angle in the direction of linear-size constancy. These results are consistent with previous studies (Gilinsky 1955; Kaneko and Uchikawa 1992). A three-way ANOVA (instructions × binocular disparity × visual surround) with repeated measures confirmed the results. The main effects of binocular disparity and of instruction were significant [$F_{2,14} = 77.1$, $p < 0.01$ (binocular disparity); $F_{1,7} = 28.3$, $p < 0.01$ (instruction)]. The binocular disparity × instruction interaction was significant ($F_{2,14} = 23.2$, $p < 0.01$).

The results also show that the surround stimulus used in the experiment affected the linear-size responses (filled symbols), although this effect was smaller than that of the binocular disparity. For the stimuli which had the same amount of binocular disparity, the comparison-stimulus size under the linear-size match decreased as the perceived depth between the standard and comparison squares predicted from the surround stimulus increased. The angular-size responses, on the other hand, were unchanged or only slightly changed for different surround stimuli. The main effect of the visual-surround stimuli was significant ($F_{2,14} = 19.1$, $p < 0.001$). The visual-surround stimuli × instruction interaction was significant ($F_{2,14} = 7.3$, $p < 0.01$). The interaction of visual-surround stimuli × instruction × binocular disparity was significant ($F_{4,28} = 2.9$, $p < 0.04$). These ANOVA results show that the effects of the visual-surround stimuli on the linear-size response and on the angular-size response were significantly different.

Figure 4 shows the averaged depth responses between the standard and comparison squares as a function of binocular disparity across the eight subjects. Each symbol shape indicates each condition of surround stimulus. The results show that the binocular disparity clearly affected the depth responses. It is also shown that the surround stimulus affected the depth responses for the squares. As the predicted length of the surround stimulus increased, the depth responses also increased. A two-way

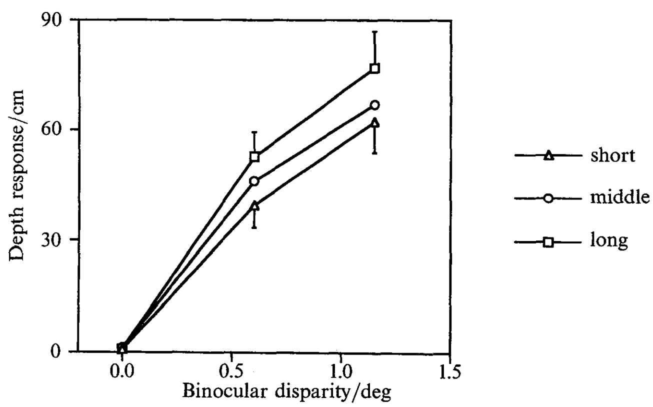

Figure 4. Averaged verbal depth responses for the stimulus squares as a function of binocular disparity across eight subjects. Symbol shapes indicate the surround conditions. Error bars represent standard errors.

ANOVA (binocular disparity × visual surround) with repeated measures confirmed the results. The main effects of the binocular disparity and of the visual-surround stimuli were significant [$F_{2,14} = 59.5$, $p < 0.01$ (binocular disparity); $F_{2,14} = 6.5$, $p < 0.02$ (visual-surround stimuli)]. The visual-surround stimuli × binocular-disparity interaction was significant ($F_{4,28} = 5.2$, $p < 0.01$).

To display the effects of the visual-surround stimuli on the size and depth responses separately, response ratios, defined as the response values for the 'long' and 'short' conditions relative to those for the 'middle', were calculated. Figure 5 shows the averaged response ratios of linear size, angular size, and depth across the eight subjects as a function of the surround condition for binocular disparity values of 1.15 and 0.60 deg.

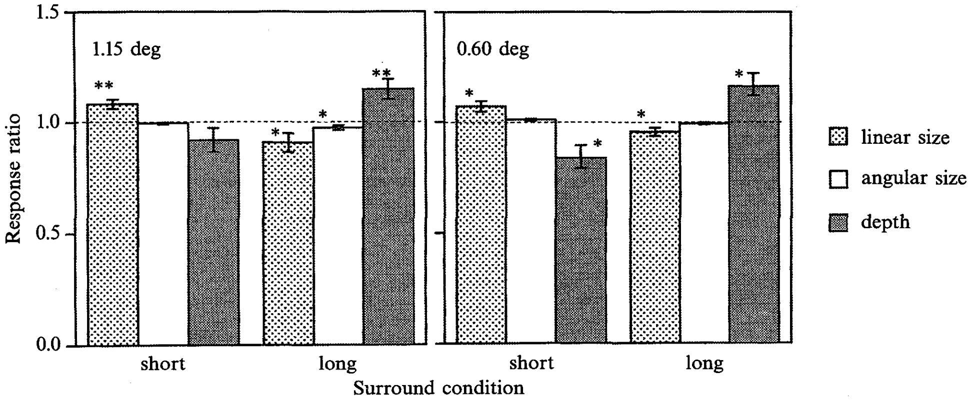

Figure 5. The mean ratios of linear-size, angular-size, and depth responses in the 'short' and 'long' surround conditions to those in the 'middle' condition for binocular disparities of 1.15 deg and 0.60 deg. The symbols * and ** indicate significant levels of difference of the value from 1.0 of $p < 0.05$ and $p < 0.01$, respectively. Error bars represent standard errors.

The linear size and depth response ratios for the 'long' and 'short' conditions are clearly different from 1.0, which indicates that the surround stimulus affected the responses. The angular-size-response ratios for the 'long' and 'short' conditions, on the other hand, are much closer to 1.0 than are the linear-size responses. A one-tailed t-test confirmed the results.

As a summary of the results, we can state that the perspective cue manipulated by the surround stimulus in this experiment affects both the linear-size responses and the depth responses for test squares, but does not affect or only slightly affects the angular-size responses. In other words, the linear-size responses always vary together with the depth responses in each condition, but the angular-size responses do not always change with the depth responses. Although we did not control the accommodation for the size responses in the experiment, we suppose the effect was relatively small. This is because we found that the effect of the stimulus distance for the linear-size and angular-size matches under monocular viewing was very small in our previous study with the same apparatus as used in this study (Kaneko and Uchikawa 1992).

4 Discussion

The size responses under the linear and angular instructions were clearly different from each other, which was consistent with previous studies (see Carlson 1977 for a review). The linear-size responses were close to linear-size constancy, while the angular-size responses were close to visual-angle match with a divergence from the true angle in the direction of linear-size match. These trends of the size responses were consistent with the results of previous reports (Gilinsky 1955; Kaneko and Uchikawa 1992).

We also found that there is an interaction between the type of cue and the type of size response. Binocular disparity clearly affected the linear-size, angular-size, and depth responses in a manner consistent with the SDIH, at least as to the directions of the response changes. However, the visual-surround stimuli used in the experiment affected the linear-size responses and the depth responses in the same manner, but did not affect the angular-size responses. This result indicates that linear-size and angular-size responses depend on different processes which use different sources of information, and suggests that depth responses are causally related to linear-size responses but not to angular-size responses.

There could be three explanations for the difference between the linear-size and angular-size responses. The first explanation is that we simultaneously have two kinds of size perceptions for an object (McCready 1985). In this case, the angular-size and linear-size responses obtained in this experiment correspond to each size perception. The second explanation is that we have only one perceived size and the single perceived size corresponds to the linear-size response obtained in this study. In this case, the angular-size responses might be the outputs of a process in which the subject attempts to ignore all information for depth. In other words, the subject imagines the objects to be equidistant, taking depth into account cognitively. The third explanation is that we have only one perceived size and the single perceived size corresponds to the angular-size response obtained in this study. In this case, the linear-size responses might be the outputs of a process in which the subject attempts to use all available information for depth cognitively. The processes for the size responses in this explanation may correspond to the outputs of the primary (perceptual) process and of the secondary (cognitive) process, which were defined in the two-process theory proposed by Gogel and Da Silva (1987). The second and third processes might be used alternatively according to the viewing distances. For example, at near distances the only perceived size corresponds to linear-size responses and at far distances it corresponds to angular-size responses.

Although we cannot obtain conclusive evidence from the results, we would like to support the first notion that there are two kinds of size perceptions simultaneously corresponding to linear-size and angular-size responses. This is because the two size responses obtained in this study are not completely cognitive. The size responses did not correspond to the perfect cognitive angular-size matches or linear-size matches in the surround conditions of 'long' and 'short', which the subject could theoretically make using the depth information of the surround context. Specifically, the size ratios between the stimuli and the adjacent marks on the surrounding walls (under the assumption of uniform spaces between the marks) provide cognitive depth information, but the size responses were very different from the values calculated according to the depth predicted from the surround context (figure 3). This fact is inconsistent with the notion implied in the second and third explanations stated above in the point that one of the two size responses depends on the other size and a cognitive process. However, we should note that these observations cannot provide proof for the notion that the linear-size and angular-size responses correspond to linear and angular perceptions, respectively. More studies on this subject are required.

Many researchers have reported that size and distance responses were inconsistent with the traditional SDIH in some cases. This phenomenon is called the size–distance paradox. It has been reported that the moon at the horizon appears to be larger in size but closer to the viewer than the moon at the zenith (Hershenson 1989; McCready 1986). Ono et al (1974) presented subjects with two different-sized coins at different distances so as to subtend the same visual angle and found that the closer stimulus was judged to be farther away and smaller. We (Kaneko and Uchikawa 1993) found that slower objects arranged in two rows with different velocities were always perceived as being larger but were not always perceived as being farther than those moving faster.

In some other reports, the degrees of the perceived size and distance changes were inconsistent with the SDIH, although the directions of the changes were consistent with the SDIH. Vogel and Teghtsoonian (1972) manipulated the perspective cue in a way similar to our experiment and found that the relations between the size and distance responses in each perspective condition were linear but that the slopes of the functions were different for each perspective condition. Oyama (1974) investigated the effects of convergence on both perceived size and distance and concluded from the results of causal analysis by means of partial correlation that the observed relation between the perceived size and distance was not based on a direct causal relation between them.

We think there are two reasons for the inconsistency of the size and distance responses in previous studies with the SDIH. One reason is the ambiguity in the instruction for the size responses in those studies, as stated in section 1. The single word for size experience used in many of the past studies, such as "perceived size" or "apparent size", could elicit either linear-size or angular-size responses. The other reason is that the effects of the perceived angular size on the perceived linear size and perceived distance were overlooked. From McCready's theory, which states that perceived angular size determines the ratio of a perceived linear size to perceived distance, the perceived linear size could be affected by changing the perceived angular size as well as by changing the perceived distance, and perceived distance could change with a change of perceived angular size. If perceived angular size and perceived linear size depend on different processes which use different cues, as suggested by the present results, it would be possible to produce a size–distance paradox by manipulating the cue condition and by controlling the size instruction. At this point, we can not conclude from the results that there are two perceived sizes simultaneously and that McCready's theory is valid to describe the relationship among perceived linear size, angular size, and distance. But, in any event, perceived angular size and perceived linear size should be distinguished when we discuss the interaction of size and distance (depth) perceptions. In addition, it is important to specify the cues and the information responsible for angular-size and linear-size perceptions.

We think that the size responses obtained under the angular instruction represent our experience of the extent of an object, because the notion that we have a sense of angular size offers an advantage in explaining the effects of perceived size on perceived distance. It has been reported that a relative 'perceived' size, not a relative 'retinal' size, is a cue for the relative distance (Higashiyama 1979; Kaneko et al 1991; Komoda and Ono 1974; Ono et al 1974). If the perceived size of an object were a cue for the perceived distance, any change in the perceived size should be interpreted as a change of the angular size with the assumption of a rigid object. The other reason to support the idea is that when visual targets are viewed monocularly, observers can make retinal-image-size matches accurately (Kaneko and Uchikawa 1992). The fact that we cannot make angular-size matches according to the retinal-image size when viewing binocularly is consistent with the conclusion of the previous study by McKee and Welch (1992) that all retinal signals are affected by some noise in cortical binocular units.

Several writers have mentioned the roles of some factors, which have been recognized as cues for distance and/or depth perception, in the determination of perceived angular size. Vergence and/or accommodation changes have been suggested to cause perceived angular-size changes, as mentioned above (Enright 1989a; McCready 1985; Ono et al 1974; Plug and Ross 1994). Enright (1987) has shown that perspective illustrations on a flat surface can evoke vergence changes during monocular inspection, such that some perceived size changes for illustrations can be explained by convergence micropsia and can be perceived angular-size changes. Some other writers have suggested the following factors as explanations or cues for the shifts of perceived angular size from the actual visual angle: contour (neural) interactions or size contrast

(McCready 1985; Plug and Ross 1994), which are usually applied to geometrical size illusions (Oyama 1977), the relative velocity of objects (Kaneko and Uchikawa 1993), and aerial perspective and color (Plug and Ross 1994). Visual surround might affect perceived angular size, although the surround stimulus used in our experiments did not. Enright (1989a, 1989b) performed a study in which the subjects were required to make size estimates for a binocularly presented moon-like stimulus superimposed on the binocular view of an outdoor landscape. He found that the changes in apparent size known as convergence micropsia varied as a function of the surround context. He noted that this size perception must be perceived angular size, as mentioned previously. At first sight, his results seem to be inconsistent with ours, in which the surround context did not affect the angular size responses. But a close comparison suggests this is not the case. When a simultaneous-matching method is used, as in our experiments, the matching (comparison) stimulus is a kind of visual-surround stimulus for the matched (standard) stimulus. Results from our previous study indicated that the binocular disparity between the standard and comparison stimuli had additional effects on the perceived angular size to the effects predicted solely from the convergence changes (Kaneko and Uchikawa 1992), and thus the perceived angular size can be affected by a variety of visual-surround features. Namely, surround context might affect the perceived angular size of an object by changing the binocular disparities between the elements in the surround stimuli and the object. Enright (1989b) stated that the parametric investigation of structures in visual-surround stimuli deserves further study. In addition to this suggestion, the results of our studies suggest that the analysis of visual-surround stimuli in terms of binocular disparity is important for understanding the process for perceived angular size.

The distinction between perceived linear size and perceived angular size is similar to that between lightness and brightness. In the achromatic-perception domain, it has been suggested that lightness and brightness are two distinct 'simultaneously' available dimensions of experience for a surface (Arend and Goldstein 1987; Evans 1974). Lightness refers to perceived reflectance and brightness refers to perceived luminance. Linear size is comparable to lightness, because both of them represent the features of the object. Angular size, on the other hand, is comparable to brightness, because both of them represent the features of the retinal image of the object. In addition, it should be noted that subjects can not make angular-size and brightness matches perfectly, even though the information for the matches is available on the retinas. This correspondence of features between the two different perceptual phenomena suggests that there is a common process underlying the distinction between the perception representing the features of the object and the perception representing the features of the retinal image of the object.

Acknowledgements. We thank Hiroshi Ono, Byron Pierce, Masao Ohmi, and Ian P Howard for reading and providing helpful comments on this paper, and we thank Antonie Howard for her help in preparing the manuscript in English.

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