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Articles

Effects of Aspect-ratio and Size of Photographs upon the Depth Impression and the Depth Perception on their Scenes[1)]

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Although the panoramic impression of photographs increased with the increment in either the horizontal to vertical aspect-ratios (h/v) or sizes of photographs, the perceived lateral distance in the same photographs did not increase (Ohnaka, 2005). From this viewpoint, the present study examined the relationship between the depth impression and the depth perception by the use of the same photographic scenes. In the experiment, 20 participants evaluated the depth impression of 9 photographs varying in either aspect-ratios or sizes, and another 20 participants estimated the apparent depth distances to a disk which varied in 15 to 90m from camera. Results showed that the depth impression decreased with the increment in aspect-ratios of both h/v and v/h though not influenced by the sizes in h=v. On the other hand, the apparent depth distances decreased as either the aspect-ratio or the size increased. Although these findings were somewhat contrary to Ohnaka (2005), the present study suggested again that the impression and the perception in photographs might differ in their qualities.

Key words：aspect-ratio and size of photograph, depth impression, depth perception

The impressions of photographic scenes are variously affected by the horizontal to vertical aspect-ratio and the size of photographs even though those scenes are exactly the same. For example, the so-called panoramic photograph familiar to amateurs is a pseudo-panoramic one which is only more rectangular than a normal-shaped photograph. Nevertheless, such a photograph gives us the impression of a wide view of the scene. Recently Ohnaka, Takezawa, & Matsuda (2003) examined the relations of the horizontal/vertical aspect-ratio and the size of photographs to some kinds of impressions including the panoramic view and the depth impression by means of 7-point rating scale, and they found in the horizontally elongated photographs that the impression of panoramic view increased significantly with the increment in the aspect-ratio and/or the size, but that the depth impression decreased as the aspect-ratio increased. Ohnaka (2005) also investigated the relationship between the impression of a panoramic view and the perception of lateral

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distances in photographs. Her special concern was whether or not the aspect-ratio and the size influenced the perceived lateral distance between two targets along x-axis in photographic scenes in the same manner as they influenced the panoramic impression. The results of her experiment showed again that the panoramic impression increased as either aspect-ratio or size increased. The perceived lateral distances, however, were not influenced by the aspect-ratio, and they decreased with the increment in the size in the photograph. These findings suggested that the panoramic impression might differ from the perception of the lateral expansion in their qualities.

Main purpose of the present study was to clarify the following question : When the depth impression of photographic scenes decreases with the increment in the horizontal to vertical aspect-ratio of the photographs (Ohnaka *et al.*, 2003), how is the perceived absolute distance (perceived depth between the camera and a single target along z-axis) in the same photographic scene influenced by the aspect-ratios? In addition, the effect of the size of photographs on both the depth impression and the absolute distance perception was also examined in this study.

There have been several studies on the depth perception in the photographs. For example, Bengston, Stergios, Ward, & Jester (1980), Kraft, Patterson, & Mitchell (1986), Kraft & Green (1989), Matsuda (2002) and Takezawa (2007) examined the effect of the lens focal lengths, Smith (1958a, 1958b) and Smith & Gruber (1958) the effect of the viewing distances, and Hagan, Jones, & Reed (1978) the effect of the truncation of the visual field. The findings in these studies suggested that the depth perception in photographs was affected more or less by such factors as the angle of view, magnification and trimming of the photographs. These studies, however, were not concerned about the relationship between the distance perception and its related impression.

As mentioned above, Ohnaka (2005) has already suggested that the impression of panoramic view of photographic scenes might be different in quality from the perception of lateral distance in the same photographs. Why are the impression of wide view and the perception of lateral distance different in their qualities? It might be considered for one possible reason that the information relating to the quadrilateral shape of plane surface of photographs will be available for the impression evaluation with first priority, whereas the pictorial information of scenic configuration in photographs will be utilized predominantly in the distance perception. If then, the difference must be also found between the depth impression and the absolute distance perception, that is, the effect of the aspect-ratio and the size of photographs on the depth impression of scenes must be different from those on the absolute distance perception to the objects in the same scenes.

To verify the above assumption in the present study, the aspect-ratios of the same photographs were manipulated in two ways, horizontally elongated ($h \geqq v$) and vertically elongated ($h \leqq v$) as shown in Figure 1. And the photograph in $h = v$ were changed to be small, middle and large in their sizes. More concretely speaking, the goals of this study were: (1) to confirm again that the depth impression would gradually decrease with the increment of the aspect-ratios as shown in Ohnaka *et al.* (2003), (2) to examine the hypothesis that the depth impression ought not to change with the sizes so far as the aspect-ratio would remain in h = v, and (3) also to examine the hypothesis that the perceived absolute distances along z-axis might be affected by both aspect-ratio and the size as considered from many preceding studies mentioned above.

Method

Participants

Forty undergraduate and graduate students at Ritsumeikan University with normal vision participated in the experiment on a volunteer basis without financial compensation. They were divided into two equal groups, each of which participating in the evaluation of the depth impression or the estimation of the absolute distance.

Materials and design

The photographs used in the experiment were taken at open space of a shrine in Kyoto and were treated to correspond to such experimental conditions as described later. This place was covered with lawn grass and surrounded with a few shrubs. All participants were not familiar to this place. The photographs for the estimation of the absolute distance were taken as follows: A white disk of 1m in diameter was set at 50cm above the ground with every distance of 15m, 30m, 45m, 60m, 75m and 90m from digital camera (6 distance-conditions in all), and each time the scene was taken one by one with 43° in both horizontal and vertical angles of view. Position of camera was exactly kept at the eye level, and a disk in every photographic scene was kept in the center of photographs. Photographs without a disk were also prepared for the impression evaluation. All photographs were printed in color.

The aspect-ratios of photographs were manipulated as shown in Figure 1. That is, in horizontally elongated photographs, horizontal aspect vs. vertical aspect (h : v) were 1.0 : 1.0, 1.4 : 1.0, 2.0 : 1.0 and 2.8 : 1.0 (h≧v; for convenience, H1.0, H1.4, H2.0 and H2.8, respectively), and in vertically elongated ones, h : v were 1.0 : 1.0, 1.0 : 1.4, 1.0 : 2.0 and 1.0 :

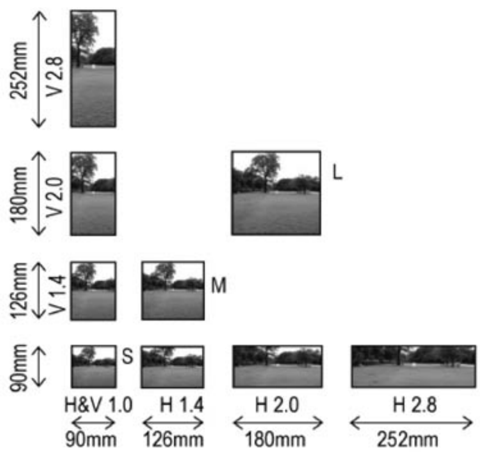

Figure 1. The aspect-ratios and the sizes of photographs used in the experiment. H1.2 to 2.8 means the aspect-ratios of h/v in horizontally elongated photographs, and V1.2 to 2.8 means those of v/h in vertically elongated ones. S, M and L mean small, middle and large in their sizes with h=v. In the distance estimation, 54 photographs including a white disk were used, and in the impression evaluation, 9 photographs without a disk were used.

2.8 (h≦v; for convenience, V1.0, V1.4, V2.0 and V2.8, respectively). Since H1.0 and V1.0 were the same, there were 7 aspect-ratio conditions in all.

The way to make the elongated photographs was as follows: Taking a case of H2.0 (180mm × 90mm) as an example, the photographic scene of H1.0 or V1.0 (90mm × 90mm) was enlarged in double size (180mm × 180mm), and then for H2.0, one quarter each in the upper and lower sides was trimmed at the time of printing. In this case, when one quarter each in left and right sides of double-sized photograph was trimmed, V2.0 (90mm × 180mm) was resulted. Other elongated photographs shown in Figure 1 were prepared in the same way. So, the height of photographs in h≧v and the width of photographs in h≦v were equal in each other. The horizontal extent of scenic views in h≧v was exactly the same, and the vertical extent of those in h≦v was also the same each other, though the degrees of enlargement (enlargement ratios) were different according to the aspect-ratios.

The sizes of photographs in h = v varied in 3 ways; small (S : 90mm × 90mm), middle (M : 126mm × 126mm) and large (L : 180mm × 180mm), in which S was common to either H1.0 or V1.0. After all, as shown in Figure 1, there were 9 different-shaped photographs varying in either the aspect-ratio or the size.

In the experiment of the absolute distance estimation, 54 photographs (6 distance-conditions by 9 different-shapes) were used, and in the impression evaluation, 9 different-shaped photographs without a disk were used.

Procedure

The evaluation of the depth impression and the estimation of the absolute distance were designed as the between-pariticipant factors. Other factors were treated as the within-pariticipant.

In the impression evaluation, 9 photographs were presented one by one to participants twice in random order, and each time they were asked to evaluate the depth impression by means of 7-point rating scale, in which "1 to 7" meant "weak to strong" in the depth impression. In the distance estimation, 54 photographs were presented to another participants twice in the same manner as the impression evaluation, and they were asked to estimate the apparent absolute distance to a white disk in each photographic scene with use of the metric unit (in meter).

Both in the impression evaluation and in the distance estimation, the photographs were observed binocularly under natural daylight in the room, and the viewing distance was kept constant in 40cm.

Results

Although the evaluations of the depth impression and the estimations of the absolute distances were recorded twice for every photograph, the first half trials were regarded as the practical ones, and the data obtained from the second half trials were analyzed in this study.

The impression evaluation

Results of the ratings for the depth impression were summarized in Figure 2(a) in relation to the aspect-ratios and also in Figure 2(b) in relation to the sizes. The two-way analysis of variance applied to the data in Figure 2(a) showed significant main effects of the aspect-ratios (F (3,57) = 17.22, p<.01) and the direction of elongation (F (1,19) = 7.44, p<.05). These results ascertained that the depth impressions decreased significantly as the aspect-ratios increased, and its tendency was more remarkable in a condition of h≧v than a condition of h≦v. On the other hand, as easily understood from Figure 2(b), the one-way analysis of variance did not reveal significant main effect of the sizes. This result meant that the enlargement of the photographs up to double size did not cause any change in the depth impressions so far as the aspect-ratio remained in h = v.

The distance estimation

Relations between the aspect-ratios and the mean estimated absolute distances to a target (a single disk in every photographs) were summarized in the left panel (a) of Figure 3, in which the parameters were the real distances of a disk from camera. To make a visual inspection easier, h/v = 1.0 was placed in the center of the axis of abscissa in Figure 3(a), and then H1.4, H2.0 and H2.8 were located toward the left direction from the center and V1.4, V2.0 and V2.8 were also located toward the right direction from the center. Although the SDs in every condition varied widely from 8.32 to 32.19, Figure 3(a) showed that the mean estimated distances decreased as the aspect-ratios increased 1.0 to 2.8 in both horizontally and vertically elongated photographs. The three-way analysis of variance for the directions of elongation (2) × the aspect ratios (4) × the real distances (6) showed significant main effects for all 3 factors: for the directions of elongation, F(1,19) = 8.22, p<.01; for the aspect ratios, F (3,57) = 20.96, p<.01; for the real distances, F(5,95) = 71.26, p<.01. The interaction of the aspect-ratios × the real distances was also significant (F (15,285) = 5.83, p<.01).

Significant main effect of the direction of elongation suggested that the absolute distances were estimated to be shorter in the horizontally elongated photographs than in

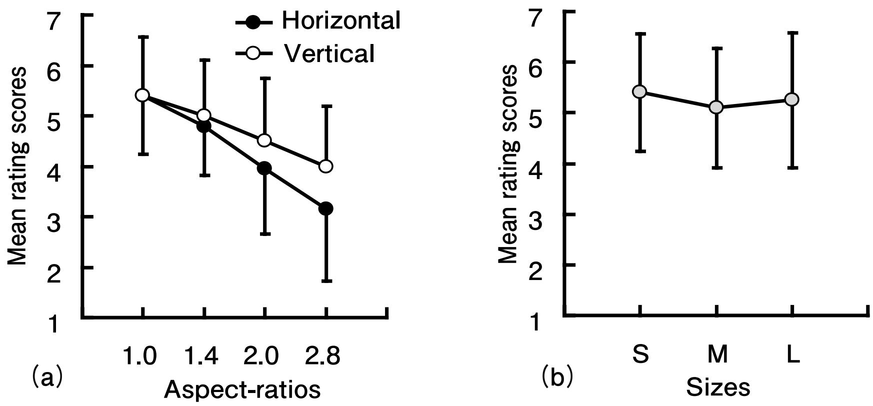

Figure 2. Mean ratings of depth impression in relation to the aspect-ratios in the left panel (a), and those in relation to the sizes in the right panel (b). Bars show the standard deviations.

the vertically elongated ones. Since a main effect of aspect-ratios was also significant, the multiple comparison tests were applied between adjacent aspect-ratios (6 pairs in all) in each of 6 real distance conditions, and then it was ascertained that the estimated distances decreased significantly with the increment of the aspect-ratios in 26 paired comparisons out of 36 ($p<.05$). The other 10 pairs showed the same tendencies though not significant. Although the interaction of aspect-ratios × real distances was significant as described above, further analyses showed as a matter of course that the estimated distances increased with the increment of the real distances in all aspect-ratio conditions ($p<.05$).

The mean estimated distances to a disk in S, M and L were summarized in the right panel (b) of Figure 3. The two-way analysis of variance showed the significant main effect of the sizes ($F(2,38)=12.96$, $p<.01$). Of course the estimated distances were significantly affected by the real distances ($F(5,95)=55.34$, $p<.01$). The interaction between two factors was also significant ($F(10,190)=2.52$, $p<.01$). The multiple comparison tests among S, M and L in each of 6 distance-conditions showed that the estimated distances in S-condition were longer than those in L-condition without exception ($p<.01$), and only in two conditions of 75m and 90m, the estimated distances in M-condition were significantly longer than those in L ($p<.01$).

As previously described, the present study showed on the whole that the estimated distances decreased with the increment in aspect-ratios. In this study, however, as the aspect-ratios of photographs increased, the enlargement ratios also increased as shown in Figure 1. In other words, the effect of enlargement ratios might be possibly compounded with the effect of aspect-ratios.

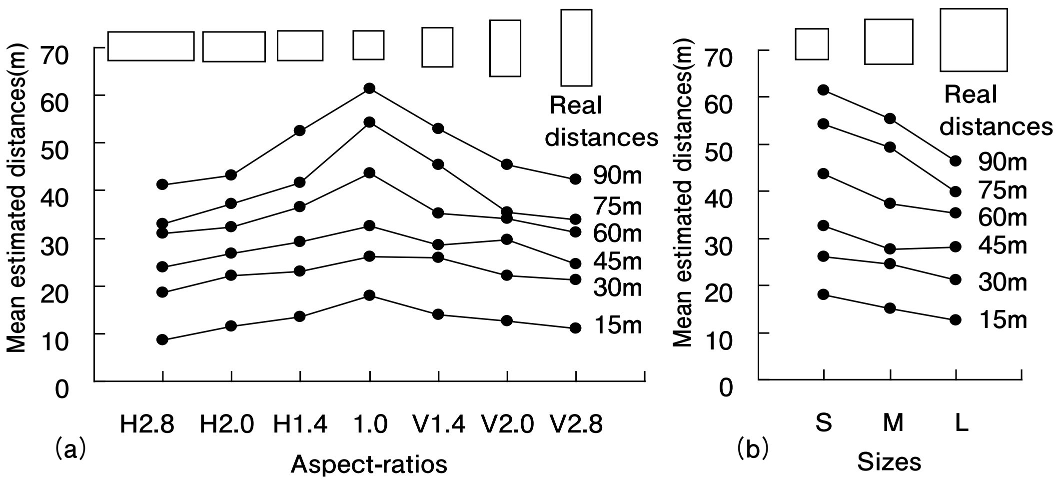

Figure 3. Mean estimated distances to a disk in photographs in relation to the aspect-ratios in the left panel (a) and those in relation to the sizes in the right panel (b). Parameters in both panels are the real distances to a disk from camera. Quadrangles in the upper part correspond to the aspect-ratios and the sizes shown in abscissa axes in (a) and (b).

So, for the purpose of ascertaining the single effect of the aspect-ratios within the same enlargement ratio condition, the estimated distances shown in Figure 3 were compared between H1.4 and M, between H2.0 and L, between V1.4 and M and between V2.0 and L by the use of two-way analyses of variances (aspect-ratio : 2 × real distance : 6). Speaking of the main effect of aspect-ratios, the estimated distances were significantly smaller in H1.4 than M ($F(1,19)=4.42$, $p<.05$), and also in H2.0 than L ($F(1,19)=6.23$, $p<.05$). These results suggest that, although the enlargement ratio was the same, the aspect-ratio could influence the distance perception in horizontally elongated photographs. In vertically elongated photographs, however, there seemed to be no single effect of aspect-ratios because of no significant differences between V1.4 and M and between V2.0 and L. To clarify the single effect of aspect-ratios more exactly, further examination will be needed.

Now, based on the data shown in Figure 3(a) and Figure 3(b), the linear relationship between the perceived distances and the real distances was examined in every condition of the aspect-ratios as well as in every condition of the sizes. The slopes obtained from the linear regression were as follows : 0.49, 0.40 and 0.41 for H1.4, H2.0 and H2.8, respectively ; 0.50, 0.40 and 0.38 for V1.4, V2.0 and V2.8, respectively ; 0.60, 0.54 and 0.44 for S, M and L, respectively (in every case, $r^2>.97$). These results suggested that, although the absolute distances were remarkably underestimated in all conditions, the estimated distances were linearly approximated in high degree of fitness as a function of the real distances.

Discussion

Main results of the present study were summarized in (1) to (5) as follows: (1) The depth impression of photographic scenes decreased significantly with the increment in aspect-ratios 1.0 to 2.8, and this decreasing tendency was more remarkable in horizontally elongated photographs ($h \geqq v$) than vertically elongated photographs ($h \leqq v$). (2) The depth impression did not change with the increment of the size S to L so far as the aspect-ratio remained in $h=v$. (3) The perceived absolute distance in photographs decreased with the increment of aspect-ratios both in $h \geqq v$ and in $h \leqq v$. This tendency was recognized as the single effect of aspect-ratios in horizontally rectangular photographs. (4) The perceived distance also decreased with increment in the size. (5) The perceived distances were linearly approximated to the real distances with high degree of fitness though extremely underestimated in all conditions.

A finding of (1) agreed with Ohnaka *et al.* (2003), and considering together with (2), a powerful determinant in depth impression of photographs seemed to be the aspect-ratio, not the enlargement of photographic scene itself. The increment in aspect-ratios also caused the decrement in the perceived distances as described in (3). Be that as it may, why did the increment in aspect-ratio cause the decrement in not only the depth impression evaluation but also the distance estimation along z-axis?

To manipulate the aspect-ratios to be up to 2.8 in the present study, either the upper and lower sides (in $h>v$) or the left and right sides (in h<v) of the enlarged square-shaped photographs were trimmed according to the aspect-ratios. It meant that the depth cues in photographic scenes became less available according as the aspect-ratio increased. It seems to be natural that the less available the depth cues became, the less the depth impression and the distance estimation along z-axis became. Consequently, the results (1) and (3) might be obtained in this study. Regarding the depth cues in the photographic scenes, a further suggestion will be added here. As summarized in (1), the present study showed that the depth impression of photographic scenes decreased with the increment in aspect-ratios more remarkably in horizontally elongated photographs (h>v) than vertically elongated ones (h<v). The estimated distances were also significantly shorter in h>v than in h<v. Considering the way to make the elongated photographs, these results might suggest that the depth cues represented in upper and lower sides of photographs seemed to be more important than those represented in left and right sides of photographs in both the depth impression evaluation and the depth perception.

Result (2) on the depth impression could be also explained for such a reason as the depth cues in S, M and L were exactly the same regardless of their sizes. However, the result (5) showed that, even if the depth cues were the same, the absolute distances were underestimated with the increment in the sizes of photographs. These findings suggest that the effect of sizes on the impression evaluation might differ in quality from those on the distance estimation.

On the contrary to the depth impression along z-axis, Ohnaka *et al.* (2003) and Ohnaka (2005) had ascertained that the panoramic impression along x-axis increased with the increment in the aspect-ratio in horizontally elongated photographs. Their results seem to be natural if the information relating the shape of plane surface of the photographs itself (the elongation along x-axis) could be utilized predominantly in the evaluation of the panoramic impression along x-axis. By contrast in the present study, the increment in the aspect-ratio diminished the depth impression along z-axis as shown in Figure 2(a). Why did the effects of aspect-ratios on the depth impression appear to be quite contrary to those on the panoramic impression? It might be considered for a reason that the horizontal and vertical elongations of photographs along the x- and y-axes could not be in accord with the z-axis of the depth impression evaluation in the present study. It might be also considered here that the two-dimensional factor such as the aspect-ratio could affect positively on the photographic impression relating to the front-parallel dimensions along the x- and y-axes. If the impression of expansion along y-axis is examined by the use of the vertically elongated photographs in the future, the impression evaluation might increase as the aspect-ratios in h<v (that is, the degree of elongation along y-axis) increases.

Differences between x-axis and z-axis could be also found in the distance perception. Using the horizontally elongated photographs, Ohnaka (2005) showed that the perceived lateral distances along x-axis were not influenced by both the aspect-ratio and the size.

This finding differed from the present results (3) and (4), which showed that the perceived absolute distances along z-axis decreased with the increment in either the aspect-ratio or the size.

For one possible reason on this discrepancy between the absolute distance perception and the lateral distance perception, it might be pointed out that all photographs in Ohnaka (2005) were exactly the same in the extent of photographic scenes along x-axis regardless of their aspect-ratios, and therefore, the aspect-ratios might be no longer effective on the estimation of lateral distances. Another possible reason is that the effects of many factors at photographing and/or observing the photographs upon the distance estimation might be extremely different among axes of three-dimensional space represented in two-dimensional photographic space. For example, the perceived absolute distances along z-axis decreased with the increment in the lens focal length (Kraft, Patterson, & Mitchell, 1986 ; Kraft & Green, 1989 ; Matsuda, 2002 ; Takezawa, 2007), but the lateral distances along x-axis were not influenced by the lens focal length (Kraft, Patterson, & Mitchell, 1986; Takezawa, 2007). Regarding another factor at observing the photographs, the perceived absolute distance increased as the viewing distances increased (Smith, 1958a, 1958b ; Smith & Gruber, 1958), but then the perceived height along y-axis was not influenced by the viewing distance (Smith, 1958b). Considering these findings as a whole, it might be hypothesized that the effects of various factors in photographs upon the distance perception along z-axis seem to be distinctively different from those along x-axis and y-axis. However, there have been few studies that focused on the difference among the x-, y- and z-axes. For the present, we cannot but recognize that many problems remain in the future studies to deepen our understanding on the nature of three-dimensional space perception in photographic displays.

Finally, the relation between the perceived and the real absolute distances to an object in photographs will be discussed in brief. As already mentioned above, the perceived absolute distances are significantly affected by many kinds of experimental variables; nevertheless, the perceived distances could be approximated linearly as a function of the real distances so far as the real distances were up to 100m or so (Matsuda & Takezawa, 2002 ; Takezawa, 2005). The present study also showed the same linear relationship with high degree of fitness though the perceived distances were extremely underestimated. As a reason of this underestimation, it will be considered that the perceived distances might be highly dependent on what kind of target was used. In studies of Matsuda & Takezawa (2002) and Takezawa (2005), they used an adult human figure as a target and showed that the perceived distances were almost the same as the real distances. Every participant in their studies seems to be able to estimate the physical size of adult human figure almost precisely. On the other hand, an artificial disk was used as a target in the present study and the participants didn't know its physical size. In this respect, there is some suggestion: When trapezoidal boards and adult females were used as targets in photographs, the estimated absolute distances to trapezoidal boards were significantly nearer than those to females though their physical heights (160cm) and all other experimental conditions were exactly the same (Takezawa & Matsuda, 2004). To clarify the relationship between the nature of targets and the perceived distance, further examination will be needed.

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