DEVELOPMENTAL STUDIES ON SIZE CONSTANCY (I):
EXPERIMENTS ON SIZE CONSTANCY IN THE
PHOTOGRAPHS WITH SINGLE
COMPARISON METHOD1

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An experiment was conducted on the development of size constancy, after
the technique of Weinstein (1957), with controlled background of photographs,
which restrict cues for distance perception. With 86 Os from 5-yr. old children
to the adults, longitudinal method (2, 4 years' interval), single comparison
method, etc. were adopted. Size constancy was observed in the 5-yr. old
child when cues of distance were deleted in a photograph. Under these condi-
tions, size constancy changes with age, but it is not a linear change but one
with specific traits at each age level. There was no significant difference in
size constancy between children and adults when cues are abundant.

The problem of development in size
constancy, which can be traced back to
the philosophical argument between the
empiricism and nativism of cognition pre-
ised by Helmholtz and Hering, respecti-
vely, was for the first time studied ex-
perimentally by Frank (1925) and with
the aged accumulation of experimental
data it has become one of the most im-
portant subjects in the study of the de-
velopment of perception.

Frank (1925) and Beyrl (1926), the first
advocators of empiricism on size constan-
1 The present study is confined to the report of
experiment with single comparison method. The
next study will be on the experiment with serial
comparison method under the same experimental
conditions as this.

2 The author is grateful to Prof. Y. Akishige for
his advice on this study, and to Prof. T. Funatsu
of Kyushu Univ. and Prof. T. Kuroda of Kagoshima
Univ. for their critical reading of the manuscript.
The author also would like to thank to Assistant
Prof. T. Ozasa at the Department of English, School
of Education, Kagoshima Univ. for his help in the
English version of this paper.

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cy, experimented with single comparison
method and found that size constancy
develops with age. Piaget and Lambercier
(1943, 1951), Lambercier (1946), Kumé
(1956, 1961) etc. also reported that size
constancy develops with age. On the
contrary, Koffka (1935), Akishige (1937),
Locke (1937), Cruikshank (1941) and
Misumi (1951) maintained a nativistic
theory of size constancy, and reported that
size constancy can be observed in the
animals at the low level of evolutionary
ladder and congenital blind persons at
the time of temporary recovery of sight.
All of these psychologists experimented
with cross-sectional method controlling a
number of conditions such as an experi-
mental method, experimental situation,
stimulus objects, etc. and tried to clarify
the quantitative difference in size con-
stancy between children and adults.

However, as is pointed out by Gibson and
Olum (1960), it is impossible to draw a
general and persuasive conclusion on the
development of size constancy from the
findings obtained by the above-mentioned
scholars. One of the main reasons for this
lies, in the author's opinion, in that they all
approached to this problem from either of
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the two above-mentioned, mutually excluding viewpoints, nativism and empiricism. He thinks either of them is not valid as an experimental hypothesis for the solution of this problem. From a viewpoint such as the above, Shimada examined the change of the quantitative ratios of size constancy with age by a traditional method, then made an experiment controlling the factors which seem to regulate it, and, finally, investigated the process of the change of these factors with age in their functional role. The present paper, which deals with the problem of size constancy in the perception of objects in the photograph, makes a part of these studies.

It has been pointed out by not a few scholars that there is a close correlation between perceived size and apparent distance and that the cues for distance perception are important factors regulating size constancy (Ogasawara, 1935; Holway & Boring, 1941; Makino, 1956; Kuroda, 1965). Boring (1964) and Leibowitz, Bussey, and McGuire (1957) reported there is no size constancy observed when one sees a photograph since a photograph, reducing the cues of distance, inhibits the perception of depth. Gibson (1950) found that 'texture-gradient' in the visual field is an indispensable condition for the perception of distance and size and that depth is perceived and thus size constancy is observed as far as this factor exists.

Weinstein (1957) experimented on Gibson's theory with the photograph modified to delete the 'texture-gradient' and found that continual 'texture-gradient' is not an indispensable condition to regulate size constancy. Smith (1958), experimenting under the same experimental condition, found that there is not a striking difference between the apparent size perceived in the perfect photograph and the one perceived in the tri-dimensional space and that there is quite a high degree of size constancy in the artificially modified photograph to delete 'texture-gradient' although its degree is lower than the one obtained from unmodified perfect photograph.

Shimada (1968, 1971) compared the degree of size constancy in the tri-dimensional space and that of the photograph of the same space and found that in the latter case quite a high degree of size constancy is observed although its degree is slightly lower in the latter than in the former. Based on this basic research Shimada experimented on the development of size constancy with the composite photograph in which properly controlled are the factors regulating the perception of size and distance. The present study aims to make a cross-sectional and longitudinal study on the following points with 3 kinds of composite photographs.

(1) Is size constancy observed in the photograph in which 'texture-gradient' is completely deleted (Photograph A)?

(2) Is quantitative change of size constancy observed when the 'texture-gradient' is added to Photograph A (Photograph B) and further the 'perspective background' (Photograph C)?

(3) When the 'texture-gradient' deleted photograph is used, does the degree of size constancy change with age?

(4) How does the degree of size constancy change with age when background condition of a photograph is controlled?

METHOD

Apparatus

As a stand to present a stimulus object, black-painted steely pipes were used (diameter = 3.6 cm; height = 70.0 cm). A white-painted steely stake was inserted into the pipe and its length was adjusted by setting the stake ranging from 12.5 cm to 87.5 cm. These stakes were used as a standard stimulus (Ss) and a comparative stimulus (Sc).

Using this stimulus apparatus photographs were taken and negative film of arranged stimulus was prepared. The photographs were taken in the 16 m x 16 m playroom under the artificial illumination. A camera was set at
the height of 75.0 cm above the floor. Sc was set at the distance of 8.0 m from the camera, and Ss was set at the distance of 2.0 m from the camera at an angle of 4° to the right from the line between the camera and Sc. The camera lens was adjusted so that a point 4.0 m distant from the camera can be in focus and the bottom of Sc can be at the center of the finder. Twelve kinds of photographs were made, each containing a 50.0 cm white-painted stake as Ss and a white stake as Sc with its height ranging by the step of 2.5 cm from 45.0 cm to 72.5 cm. In processing the film we artificially deleted every background including the black-painted stand, and thus we prepared 12 exposures of negative film of the arranged stimuli containing only the Ss and Sc.

Next, we made 3 kinds of negative film of the background. Photo A (Background A) was taken of the grey paper on the vertical wall, Photo B (Background B) of grass at the golf course, Photo C (Background C) of a station yard. In each case, a picture of the background was taken under the natural light with a camera adjusted to focus a point 75.0 cm high above the ground and 16.0 m distant from the camera.

Then, we made 36 frames of composite film combining the 12 frames of stimulus negative film and the 3 frames of background negative film together. From this film 29.0 cm×33.5 cm photographs were enlarged with the lower end of Sc at the center. In these composite photographs the length of Ss was 4.0 cm. The 3 photographs of the background had the following characteristic.

Background A (Photo A) represents white Ss and Sc against the homogeniously grey background.

Background B (Photo B) represents flat, homogenous grass running approximately 400 m to some trees. This represents Gibson's regularly continual texture-gradient'.

Background C (Photo C) represents texture-gradient by means of sleepers and stones under the railway lines, and further represents a pair of lines and various buildings in perspective. (Hereafter, Background will be abbreviated to Bg.)

The followings are examples of the composite photographs copied on a reduced scale.

**Procedure**

A photograph of Bg. B was presented at the point 60.0—70.0 cm distant from O and slightly lower than the O's eye-level, and O was instructed to compare the objective size of Ss and Sc. The following was the instruction.

"Here are two white stakes; one (Ss) nearer to you than the other (Sc). Which do you think is the longer of the two if the two stakes are set at the same place?"

To each background, O was told to say the PSE of each of the ascending series and descending series. The 3 backgrounds were presented at random to each O. The same stimulus set and procedure were used in Experiment I and Experiment II.

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4 This comparative method, used by Weinstein, is the one by which Sonoda (1961) found that the degree of size constancy in the photographs is higher than by other methods.
Experiment I

Purpose. Experiment I (Exp. I) aims by the cross-sectional method, a generally adopted method in the developmental study on size constancy, to examine the existence and development of size constancy in the photograph.

Observer. Observers were (1) children at the age of 5-6 years (5-yrs. group), (2) children at the age of 7-8 years (7-yrs. group), (3) children at the age of 10-11 years (10-yrs. group), and (4) college students (adult group). The number of O was 16 in each of the 4 groups (8 boys, 8 girls) and 64 in total. The experiment was conducted in June, 1970.

Experiment II

Purpose. Experiment II (Exp. II) aims to examine the result of Experiment I (cross-sectional method) by a new approach, longitudinal method which has not been tried yet in the developmental study of size constancy, and also to elucidate the process of change in size constancy at the age level of 7-14 years, a hypothesis suggested by Piaget and Lambercier (1951), Kumé (1961), etc.

Observer. Observers were the same as those of Exp. I. In Exp. II-1, we retested two years after Exp. I with 12 children of the 7-yrs. group of Exp. I (9-yrs. group), and 4 years after Exp. I with 8 children of the same 7-yrs. group of Exp. I (11-yrs. group).

In Exp. II-2, the same experiment as Exp. II-1 was retested, two years after Exp. I with 12 children of 10-yrs. group and four years after Exp. I with 10 children of the same 10-yrs. group. At the time of Exp. II-2, therefore, Os were in the 12-yrs. group and 14-yrs. group, respectively.

Exp. II was conducted in June, 1972 and June, 1974. The stimuli and procedure of the experiment were the same as Exp. I. The difference of the number of Os between Exp. I and Exp. II was due to the fact that some of Os had moved out and it was impossible to follow them up.

RESULTS

The results of Exp. I and Exp. II are described in Result I and Result II, respectively.

Result I

Comparison of matched size (PSE) in Exp. I.
Each cell of Table 1-1 represents a mean of PSE by O in the ascending and descending series (converted score into real size) under the conditions of background and age. Table 1-2 is the results of analysis of variance of Table 1-1.

Table 1-2

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>34,733</td>
<td>3</td>
<td>11,577</td>
<td>6.291*</td>
</tr>
<tr>
<td>Bg.</td>
<td>86,972</td>
<td>2</td>
<td>43,486</td>
<td>23.633**</td>
</tr>
<tr>
<td>Error</td>
<td>11,042</td>
<td>6</td>
<td>1,840</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>132,747</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05  ** p < 0.01

Figure 1-1 indicates by Z-ratios of Thouless the change in the degree of size constancy with age under each of the 3 background conditions. In Fig. 1-2 the difference in the mean of PSE between the background conditions was presented for each age with an aim to evaluate the effect of the cues of each background. Table 1-2 shows that there were statistically significant differences both in the four age groups (p < 0.05) and in the 3 backgrounds (p < 0.01).

As for the data of Table 1-1 and Fig.
1-1 in terms of size constancy, in either of the age groups Bg. A showed the highest mean of PSE (M=63.5 cm), then Bg. B (M=59.6 cm), and Bg. C the lowest (56.8 cm). Z-ratios computed from those values were 0.83, 0.87, 0.91 for the Bg. A, B, C, respectively, and even in Bg. A, in which the degree of size constancy was generally low, 0.81, 0.83, 0.80, and 0.87 for the 5-yrs., 7-yrs., 10-yrs. and adult group, respectively. These data suggest the existence of a remarkably high size constancy in the photograph.

Figure 1-2 shows that there was a significant difference in the background conditions (F=16.835, df=6/2, p<0.01), in the age groups (F=5.164, df=6/3, p<0.05) and that when the condition of 'texture-gradient' was added to the condition of Bg. A (Bg. B—Bg. A), the degree of size constancy increased and when the background condition of various things arranged in perspective (Bg. C) was added to Bg. A (Bg. C—Bg. A), the degree of size constancy increased remarkably.

Next is the problem of the change of size constancy with age. As is shown in Fig. 1-1, size constancy changes with age but the process of the change is affected by the background conditions. Under Bg. A and B, the change in size constancy showed similar process: It increased a little at the age of 5 to 7, decreased from 8 to 10 showing the minimum value, and then, at the age of adult, increased remarkably. Under Bg. C, size constancy increased a little during a period from the age of 5 to adult, but between the minimum value of the 5-yr. old children and the maximum value of the adults, there was not such a significant difference as under the two above-mentioned background conditions.

As is shown in Fig. 1-1 and Fig. 1-2, the adult group already showed a high degree of size constancy under Bg. A, and even when another condition such as Bg. B and Bg. C was added, size constancy did not remarkably increase. On the contrary, however, the child group, when other conditions were added, showed a remarkable increase of size constancy.

Result II

Comparison of matched size (PSE) in Exp. II. In Exp. II, as we did in Exp. I, we computed and compared the means of matched size (PSE) as an indicator of size constancy. The results of Exp. II-1 and Exp. II-2 are shown in Table 2-1, and 2-2 respectively.

Table 2-1 contains the results of Exp. I as well as those of Exp. II. Table 2-1

![Fig. 1-1. Change of Z-ratios with age under the 3 backgrounds.](image1)

![Fig. 1-2. Change with age in the difference of mean of PSE under the 2 backgrounds. This figure indicates the degree of increase in the mean of PSE when 'texture-gradient' was added to Bg. A (Bg. B—Bg. A), and 'texture-gradient' and 'perspective background' were added at the same time to Bg. A (Bg. C—Bg. A).](image2)
reads the following. As for Bg. A, the mean of PSE by the 16 Os of the 7-yrs. group was 63.6 cm (See Table 1-1), and the mean of PSE by the 12 Os of the 9-yrs. group, who were followed up in Exp. II two years after Exp. I, was 64.1 cm (the mean of PSE by the 12 Os in Exp. I was 63.7 cm), and the mean of PSE by the 8 Os of the 11-yrs. group, who were followed up 4 years after Exp. I, was 65.0 cm. The mean of PSE by the same 8 Os who were followed up in Exp. II, was 64.0 cm and 63.5 cm at the age of 9 and 7 respectively. Bg. B and C of Table 2-1 and Table 2-2 read the same way as above.

As for Bg. A of Table 2-1, there were no statistically significant differences in the mean of PSE (at the age of 7) in the three groups, i.e., 16 Os of the 7-yrs. group (63.6 cm), the 12 Os out of the 7-yrs. group who were followed up at 9 (63.7 cm), and the 8 Os out of the 7-yrs. group who were followed up at 11 (63.5 cm). There were no significant differences in the mean of PSE (at the age of 9) between the 12 Os followed up at 9 (64.1 cm) and the 8 Os out of the 12 Os who were followed up at 11 (64.0 cm). The same trends were found under the other background conditions in Table 2-1 and under all of the background conditions in Table 2-2.

The analysis of variance computed from the mean of PSE (Table 2-2) of the 8 Os followed up for 4 years indicates that there were no significant differences in the age groups ($F=3.226, df=4/2$) but there were significant differences in the background conditions ($F=33.409, df=4/2, p<0.01$). The analysis of variance of the mean of PSE (Table 2-2) of the 10 Os followed up for 4 years indicates that there were significant differences in the age groups ($F=13.347, df=4/2, p<0.05$) and in the background conditions ($F=129.33, df=4/2, p<0.01$) respectively. Figure 2 is $\zeta$-ratios computed from the results of Exp. II and plotted, superposed on Fig. 1.

To sum up these results, in Exp. II-1 there was observed a high degree of constancy in each age group under Bg. A, and under Bg. B and C it remarkably increased. The same trends were observed in Exp. II-2 and they are quite similar to those of Exp. I. The analysis of variance indicates a general trend that under each
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of the background conditions, size constancy decreased from the age of 7 through 9 to 11 (Table 2-1, Fig. 2), although there were no significant differences.

In Exp. II-2, as indicated in Table 2-2 and Fig. 2, size constancy did not change with age under Bg. C but under Bg. A and B, it remarkably increased from 12 to 14. (From 10 to 12 it was unchanged.) The results of the retest of Exp. II not only reconfirm the results of Exp. I on the traits of size constancy under each background and the trends of its development with age, but, as is indicated in Fig. 2, show: (1) under Bg. C there was not a remarkable change in size constancy with age, but (2) under Bg. A and B, size constancy once decreased from the age of 7 to 10, remained unchanged from 10 to 12, and from 14 it remarkably increased approximating to that of the adult.

DISCUSSION

On the existence of size constancy in photograph. As mentioned above, it has been pointed out by many researchers that there is a close relationship between perceived size and distance (depth), and the relationship was formulated by Kilpatrick and Ittelson (1953), Kuroda, and others as 'size-distance invariance hypothesis' that the degree of size constancy is closely related to the cues for the perception of distance. Among many cues of distance, some specific cues are under restriction in the photograph, i.e., binocular convergence, disparity and accommodation, etc. In the present study, a high degree of size constancy was found in the artificial, 'texture-gradient' deleted photograph, which was stressed by Gibson as well as Weinstein, Smith, etc. Namely, in Photo. A the Z-ratio of the 10-yrs. group, whose size constancy was the lowest, was 0.80 in mean, and that of the adult group, whose size constancy highest, was 0.87 in mean.

These results support the views of Weinstein and Smith in which Leibowitz's view was criticized, and show that if there are cues of relative size and relationship of position of the objects compared, there exists perception of depth, and therefore size constancy even in the bi-dimentional plane in which, texture-gradient is completely deleted as well as binocular convergence and disparity, the necessary cues for distance perception, are restricted. Certainly these cues are not enough for perfect size constancy. When cues of 'texture-gradient' were added to 'relative size and relationship of position' of the objects, size constancy increased by 5.4% (Z-ratio was 0.827 under Bg. A, and 0.873 under Bg. B). Furthermore, when cues of 'texture-gradient' and 'perspective background' were added at the same time, the degree of size constancy was increased by 9.4% (Z-ratio was 0.827 under Bg. A, and 0.908 under Bg. C).

To conclude this, size constancy in a photograph approximates to the perfect degree with the existence of such cues as 'texture-gradient', 'perspective background' and 'relative size and relation-

FIG. 2. Change of Z-ratios in Exp. I and II with age under the 3 backgrounds.

● shows the change of Z-ratios by the same Os of the 7-yrs. group who were followed up at 9 and 11, and ▲ shows the change of those by the same Os of the 10-yrs. group who were followed up at 12 and 14.
ship of position' of the objects in the photograph.

On the development of size constancy with age.

It was Piaget and Lambrecht (1943) and Lambrecht (1946) who criticized Akishige's theory of differentiation of spatial structure (1937), in which he claimed the innateness of size constancy, and maintained its empiricism based on their unique experiments. They conducted their experiments with arranged 'système de référence' in front of the O between Ss and Sc on the apparatus and found that the 5 to 7-yr. old children cannot take advantage of the 'système de référence' arranged in perspective, and after a transition period of 7 to 9, at 9 to 11, they manage to relate directly or indirectly both stimuli (Ss and Sc) with 'système de référence' and thus hold a high degree of size constancy.

Shimada (1960, 1961, 1963) questioned their experimental method including the arrangement of 'système de référence', yet, as a suggestive developmental study on size constancy, restated and examined it. In the present study, instead of Piaget and Lambrecht's artificial type of 'système de référence' as perspective background, an experiment was conducted on the development of size constancy controlling the cues existing naturally in the familiar space such as 'texture-gradient', 'perspective background', etc.

Our results show that even the 5-yr. old children hold a high size constancy (\(\zeta = 0.798\)) as long as two objects are arranged in different distance, i.e., there exist 'relative size and relationship of position' of the objects even if binocular convergence and disparity for the depth perception are controlled, and texture-gradient and perspective background are deleted from a photograph. With a photograph modified to delete cues of distance (Bg. A), however, size constancy increases from 5 to 7, decreases for some period from 7 to 10 indicating the minimum value, and again rapidly increases from 12 to 14 approximating to the degree of the adult.

When texture-gradient is added to the photograph of Bg. A (Bg. B), the degree of size constancy increases more than under Bg. A in either age group, but the change with age shows the same tendency as that of Bg. A.

It has been pointed out by Lambrecht (1951), Kumé (1956), etc. that there is not linear relationship between size constancy and age. This was also confirmed by the results of our experiment with two photographs of different background condition, but as for its developmental trends, the results of the present study were slightly different from those of theirs. It is important to note here that there are some differences between the present experiments and theirs in experimental situation, stimulus objects, O, and, what is more important, in the experimental design. Theirs used only a cross-sectional method while the present study adopted both cross-sectional method and longitudinal method. In the author's opinion, the significance of the present study lies in that it reaffirmed by the longitudinal method the results obtained by the cross-sectional method.

As is stated earlier, when the conditions of 'texture-gradient' and 'perspective background' were added at the same time to Bg. A (Bg. C), the degree of size constancy was high in every age group, and under Bg. C, there was no significant difference between the child groups and adult groups. The adult can hold high degree of size constancy in a photograph without 'texture-gradient' and 'perspective background' if only he has cues of 'relative size and relationship of position' of the objects. In the child group, however, this is not the case; in the 7-yrs. group the effect of 'texture-gradient' is more significant than in the 5-yrs. group (the degree of size constancy increases); in the 10-yrs. group the effect of the 'perspective background' is much more significant than in the 5 and 7-yrs. group (the degree of size constancy decreases). From these findings it may safely be assumed that from
5 to 7 size constancy changes quantitatively, but the mechanism of perception is similar to the previous one, and that from 7 to 10 the mechanism of perception develops quantitatively and at about 10 the child comes to acquire a mechanism quantitatively similar to that of the adult though his size constancy is inferior in quantity to that of the adult.

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(Received Sept. 20, 1975)