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The homogeneity effect on figure/ground perception in infancy

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Acknowledgements

This research was supported by PRESTO (Japan Science and Technology Agency), a Grant-in-Aid for Scientific Research (18300090) from Japan Society for the Promotion of Science and a Grant-in-Aid for Scientific Research (20119002) from Ministry of Education, Culture, Sports, Science and Technology. We thank Emi Nakato, Yuko Hibi, Aki Tsuruhara, Hiroko Ichikawa, Yumiko Otsuka, Jiale Yang, Megumi Kobayashi and Yuko Yamazaki for their help in collecting the data.

Abstract

We examined whether the homogeneity of the two profiles of *Rubin's goblet* affects figure/ground perception in infants. We modified the two profiles of *Rubin's goblet* in order to compare figure/ground perception under four test patterns: 1) two profiles painted with horizontal lines (horizontal-line condition), 2) two profiles painted middle gray (uni-color condition), 3) one profile painted light gray and the other dark gray (two-color condition), and 4) a goblet painted with concentric circles (concentric-circles condition). In the horizontal-line condition the homogeneity of the profile was strengthened, and in the two-color condition the homogeneity of the profile was weakened compared to the uni-color condition, which was an original *Rubin's goblet*. In the concentric-circles condition the homogeneity of the reversed areas of the horizontal-line were strengthened.

After infants were familiarized with each *Rubin's goblet*, the infants were tested on their discrimination between the two profiles and the goblet in the post-familiarization test. In horizontal-line condition, uni-color condition and concentric-circles condition infants showed a novelty preference for the two profiles in the post-familiarization test. On the other hand, in the two-color condition no preference was observed in the post-familiarization test. This means that infants perceived the goblet as figure and the two profiles as ground in the horizontal-line condition, the uni-color condition and the concentric-circles condition. We found that infants could not perceive the goblet area as figure when the homogeneity of the two profiles was weakened. It can be said that figure/ground perception in infancy is not affected by strengthened homogeneity, but is affected by weakened homogeneity.

Key words; figure/ground perception, Rubin's goblet, infancy

1. Introduction

Figure/ground perception is important for visual processing because it organizes a visual scene into figures and backgrounds. This perception is fundamental to the visual perception of objects.

Gestalt psychologists were the first to recognize the importance of figure/ground perception for distinguishing figures and grounds in terms of their phenomenal appearance (Rubin, 1921). *Rubin's goblet* (Rubin, 1921) is one of the classical demonstrations of a reversible pattern of figure and ground. We can perceive *Rubin's goblet* either as a white goblet on a black background or as two black profiles on a white background. *Rubin's goblet* illustrates two phenomenological characters of figure/ground perception: that figures appear to have a definite shape, and that their bounding contours are seen as belonging to them. The grounds are shapeless near the contours they share with the figures and appear to extend behind the figures near those contours.

Many studies on figure/ground perception have been concerned with identifying the properties that determine which regions will appear as figures. For example, smaller regions are more likely to be perceived as figures (Graham, 1929; Oyama, 1960), as are symmetrical regions (Bahnsen, 1928), same-width regions (Morinaga, 1941), convex regions (Hoffman & Singh, 1997; Kanizsa & Gerbino, 1976; Kanizsa & Luccio, 1986, Luccio, 2003), lower regions (Ehrenstein, 1930; Vecera, Vogel, & Woodman, 2002), regions with a wide base (Hulleman & Humphreys, 2004), and regions depicting familiar objects (Peterson & Gibson 1991, 1993, 1994).

Torii (1963) examined the figure/ground perception of *Rubin's goblet*. He presented a uni-color pattern in which the two profiles were the same color, and a two-color pattern in which

the each profiles was different in color. Observers were asked which area they perceived as figure, and Torii calculated the looking time for the two profiles and the goblet. The looking ratio for the two profiles was calculated by dividing the looking time for the two profiles by the total looking time. The looking time ratio for the two profiles was 50.9 percent in the uni-color pattern, while the looking time ratio was 75.3 percent for the two color pattern.

Takashima et al. (2012) presented these two patterns and a horizontal line pattern in which the two profiles were painted with horizontal lines, and recorded observers' perception (either a goblet or the two profiles). Results showed that in the two-color pattern was judged as two profiles by 92.5 percent of the observers, while the horizontal line pattern was judged as two profiles by only 11 percent of observers. The uni-color pattern was judged as two profiles by 50.4 percent of observers.

Torii (1963) and Takashima et al. (2012) showed that the two-color pattern was more likely to be perceived as two profiles and that the horizontal line pattern was more likely to be perceived as a goblet. From these phenomenological experiments with adults, it has been found that the color or texture of the two profiles affects perception of figure and ground. From these results we assume that the degree of homogeneity is controlled by changing color and texture. That is, in a horizontal-line pattern the homogeneity of the two profiles is strengthened, while in a two-color pattern the homogeneity of the two profiles is weakened.

Koffka (1935) and Morinaga (1969) showed that the weaker the homogeneity, the less we can perceive ground. Conversely, the stronger the homogeneity, the more we can perceive ground. In a two-color pattern the two profiles tend to be figure, and we are more likely to perceive two

profiles because the homogeneity of the two profiles is weakened. On the other hand, in a horizontal line pattern the two profiles tend to be ground, and we are more likely to perceive a goblet, because the homogeneity of the two profiles is strengthened. (This means that homogeneity affects figure/ground perception in adults.)

Many studies of figure/ground perception have been concerned with adults, but few studies have investigated figure/ground perception during infancy.

Because ground area extends behind the figure area (Rubin, 1921) amodal perception is necessary for figure and ground perception. This means that the occluded area was perceived as ground while the occluding area was perceived as figure in amodal perception (Kanizsa, 1980).

For infant studies about amodal completion in 2- dimensional pattern, Kellman and Spelke (1983) observed that 4-month-old infants perceived an object as connected when the object's ends moved in a common translation behind an occluder (motion condition). Yet infants did not perceive an object as connected when its visible parts were stationary (static condition). Otsuka, Kanazawa, and Yamaguchi (2006) used the partly occluded pattern to show that while 5-6 month-old infants could amodally complete this pattern like adults, 3-4 month-old infants could not. Kavšek (2004) used a center-occluded rod in a static rod-and-box display and suggested that the capability of perceiving object unity emerges after about 8 months of age. Condry, Smith and Spelke (2001) suggested that infants are able to use all the sources of information used by adults in perceiving object unity, including motion, contour alignment, and surface similarity (e.g., color, texture, and so on).

Recently, Braddick and Atkinson (2007) examined figure/ground perception in infancy. They

used the curved shape (“figure shape”) which was perceived as figure by adults and “ground shape”, which was the background region of “figure shape”. They measured infants’ preference between “figure shape” and “ground shape”. When these patterns were presented side by side, infants (7–21 weeks, mean 14 weeks) showed a significant preference for the “figure shape”. They concluded that 4-month-old infants are important age for developing an understanding of the attributes of the distinction between ground shapes and figure shapes.

Needham, Baillargeon, and Kaufman (1997) used a partly occluded pattern with a black rectangle, in which the left side of the display was red and rectangular, but the right was green and irregularly-shaped, and showed that 4.5-month-old infants failed to perceive the boundary between the objects. It is possible that infants, like adults, are less likely to perceive two pieces which have weakened homogeneity as ground. There is the possibility that 4-month-old infants can perceive figure and ground the same as adults. Needham et al. (1997) also tested a 3-dimensional pattern, but it is unclear whether the homogeneity of ground provides more effective information for infants in 3-dimensional patterns than in 2-dimensional patterns. We examined whether the homogeneity of ground affected figure/ground perception in infants.

We used the habituation paradigm to examine whether a goblet or two profiles were perceived as figure by infants. After the infants were habituated with *Rubin’s goblet*, they were tested for novelty preference between the profiles and the goblet. If infants perceived the two profiles as figure, they showed novelty preference for the goblet in the test pattern. If infants perceived the two profiles as ground, they showed novelty preference for profiles in the test pattern.

We modified two profiles of *Rubin's goblet* in order to compare the figure/ground perception under three test patterns; 1) two profiles painted with horizontal lines (horizontal-line condition), 2) two profiles painted middle gray (uni-color condition), 3) one profile painted light gray and the other painted dark gray (two-color condition). In 1) the homogeneity of the profile was strengthened, and in 3) the homogeneity of profile was weakened compared to 2), which was an original *Rubin's goblet*. And in 4) the homogeneity of the reversed area of 1) and 2) were strengthened.

2. Experiment 1

2.1. Method

Participants

Thirteen 7-8-month-old infants (seven male, six female, mean age = 234.00 days, ranging from 204 to 253 days) participated in the horizontal-line condition experiment. Thirteen 7-8-month-old infants (nine male, four female, mean age = 240.15 days, ranging from 214 to 253 days) participated in the uni-color condition experiment. Thirteen 7-8-month-old infants (eight male, five female, mean age = 220.85 days, ranging from 197 to 245 days) participated in the two-color condition experiment.

An additional forty-nine infants were tested, but were excluded from the analysis owing to a side-bias greater than 90% (eighteen), longer looking times in the first three trials than in the last three trials in the familiarization (twelve), or looking times over the two test trials less than 7.5 s (nineteen).

Apparatus

All stimuli were displayed on a MITSUBISHI Diamond Pro 2070SB 22-inch CRT monitor uni-colored by a computer. The infant and the CRT monitor were located inside an enclosure made of iron poles and covered with cloth. Each infant sat on his/her parent's lap in front of the CRT monitor. The infant's viewing distance was approximately 40 cm. There were two loudspeakers, one on either side of the CRT monitor. A CCD camera, just below the monitor screen, was used to videotape the infant's behavior throughout the experiment. The experimenter could observe the infant's behavior via a TV monitor connected to the CCD camera.

Stimuli

We used three types of *Rubin's goblet* as familiarization patterns (Figure 1), the uni-color patterns, the two-color patterns, and horizontal-line patterns. Generally, *Rubin's goblet* consisted of one "goblet" and two "profiles". In all familiarization patterns the goblet was painted blue (19.30 cd m^{-2}) and the two profiles were set as the three familiarization patterns. For the horizontal-line pattern, the two profiles were painted with horizontal-lines (Figure 1-A). The horizontal lines had achromatic gradation (from 4.10 to 57.00 cd m^{-2}). For the uni-color pattern (Figure 1-B) the two profiles were painted middle gray (22.20 cd m^{-2}). For the two-color pattern (Figure 1-C) the right profile was painted dark gray (4.10 m^{-2}) and the left profile was painted light gray (57.00 cd m^{-2}).

Test patterns consisted of the goblet shape (Figure 2-A) and two profiles shapes (Figure 2-B). In each shape the goblet or the two profiles were green (53.10 cd m^{-2}).

All *Rubin's goblets* were 380 pixels (21.26 deg) x 335 pixels (18.74 deg), and were drawn

against a white (90.33 cd m^{-2}) background. All stimuli were drawn at the centre of a 420 pixel (23.5 deg) $\times$ 420 pixel (23.5 deg) area, which was situated on both sides of the CRT monitor at a distance of 166 pixels (9.2 deg).

Insert Figure1 and Figure 2 around here

Procedure

The experiment consisted of three phases: the pre-test, the familiarization test, and the post-test. First, infants received two 10-second pre-test trials. Then, they received six 15-second familiarization trials, which were immediately followed by two 10-second post-test trials. Prior to each trial, a cartoon accompanied by a short sound was presented at the centre of the monitor. The experimenter initiated each trial as soon as the infant was paying attention to the cartoon.

In the pre-test and the post-test, the goblet and the profiles were presented side by side. The positions of the two shapes were counterbalanced across infants in the first test trial, and reversed in the second trial. For each infant, the pre-test and the post-test were the same in terms of stimuli and order of presentation. In these test trials, the presentation time of the stimuli was fixed regardless of whether or not the infants looked.

In the familiarization trials, the two identical familiarization patterns were presented side by side. The familiarization trial was terminated if the infant looked away from the CRT monitor for

at least 2 seconds, or if the trial lasted for 15 seconds. Two observers, who were unaware of the stimulus identity, measured the infants' fixations to the left and right sides of the display on the basis of video recordings. Only the infant's looking behavior was visible in the video. The interrater reliability was high ($r=.85, p<.01$).

2.2. Results

Familiarization trials

The individual looking times were summed over the two identical patterns, and then averaged across the first three and last three trials. The mean looking times for each condition are shown in Table 1. Decrements in looking time from the first to the second half of the familiarization test were observed for each condition. A two-way analysis of variance (ANOVA) of conditions (horizontal-line condition, uni-color condition and two-color condition) $\times$ trials (1-3 versus 4-6) revealed a significant effect of trials ($F(1, 76)=82.44, p<.01$) but no significant effect of conditions ($F(2,36)=0.03, n.s.$) and the interaction between conditions and trials ($F(2,36)=1.19, n.s.$). The result confirms that all conditions were habituated to the familiarization pattern.

Insert Table 1 around here

Test trials

The mean looking times during the pre-test and post-test are shown in Table 2. A preference score was calculated for each infant in the pre-test and post-test. This was done by dividing the infant's looking time for the profiles shape during the two test trials by the total looking time over the two test trials, and then multiplying this ratio by 100.

Figure 3 shows the mean preference score in all conditions. To determine whether infants had a different preference for each conditions, we conducted a two-way analysis of variance (ANOVA) of conditions (horizontal-line condition, uni-color condition and two-color condition) $\times$ test (pre-test versus post-test). This analysis revealed a significant effect of test ($F(1,76)=82.44$, $p<.01$) but no significant effect of conditions ($F(2,36)=0.41$, *n.s.*) and the interaction between conditions and test ($F(2,36)=0.82$, *n.s.*).

To determine whether infants had a spontaneous preference for either of the test patterns, we conducted two-tailed one-sample *t*-tests (versus chance) on the preference score in the pre-test. This analysis revealed no significant difference in any condition (horizontal-line condition: $t(12)=0.61$, *n.s.*, uni-color condition: $t(12)=0.90$, *n.s.*, two-color condition: $t(12)=0.14$, *n.s.*).

To determine whether infants had a spontaneous preference for either of the test patterns, we conducted two-tailed one-sample *t*-tests (versus chance) on the preference score in the post-test. This analysis revealed a significant difference in the horizontal-line condition ($t(12)=2.46$, $p<.05$) and the uni-color condition ($t(12)=2.37$, $p<.05$), but not in the two-color condition ($t(12)=0.50$, *n.s.*).

Infants in the horizontal-line and uni-color conditions could organize figure-ground, but

infants in the two-color conditions could not. These results suggest that infants are more likely to see the central area as figure, but that they preferred neither the goblet nor the profiles when the neighboring area has different characters, as with the two-color condition.

Insert Table 2 and Figure 3 around here

2.3. Discussion

We examined whether homogeneity of ground affects figure/ground perception in infants. We modified two profiles of *Rubin's goblet* in order to compare the figure/ground perception under three test patterns; 1) two profiles were painted with horizontal lines (horizontal-line condition), 2) two profiles were painted middle gray (uni-color condition), 3) one profile was painted light gray and the other dark gray (two-color condition). In 1) the homogeneity of the profile was strengthened, and in 3) the homogeneity of profile was weakened compared to 2), which was an original *Rubin's goblet*. And in 4) the homogeneity of the reversed area of 1) and 2) were strengthened.

The results of our experiments demonstrated that in the horizontal-line condition and the uni-color condition infants showed a novelty preference for the profiles in the post-familiarization test. In the two-color condition, no preference was observed in the post-familiarization test. That is, in the horizontal-line condition and the uni-color condition infants' novelty preference for profiles means that the goblet was figure and the two profiles were ground. In the two-color condition

infants preferred neither profiles nor goblets, which means that the infants could not discriminate figure and ground.

From this data, we can see that the infants were more likely to perceive two profiles as a ground in the horizontal line condition and the uni-color condition, and that they could not discriminate figure and ground in the two-color condition.

In the two-color condition the homogeneity of profiles was weaker than in the uni-color condition. The areas with weakened homogeneity were more likely to be perceived as figure. We expected that infants in the two-color condition would be less likely to perceive the goblet as a figure than in the uni-color condition.

Our results were positive. Infants in the uni-color condition perceived the goblet as figure, but infants in the two-color condition could not discriminate figure and ground. That means that infants were less likely to perceive the goblet as a figure in the two-color condition than in the uni-color condition. From these results it is possible to conclude that the figure/ground perception in infancy is affected by weakened homogeneity.

In the horizontal line condition the homogeneity of profiles was stronger than in the uni-color condition. The areas with strengthened homogeneity were more likely to be perceived as ground. We expected that infants in the horizontal condition were more likely to perceive the goblet as a figure than those in the uni-color condition.

Our results were negative. Infants in both the horizontal condition and the uni-color condition perceived the goblet as a figure. From these results it is possible to conclude that the figure/ground perception in infancy is not affected by strengthened the homogeneity.

We manipulated the homogeneity of profiles in Experiment 1. Takashima et al. (2012) manipulated the homogeneity of the goblet, ~~like~~ as profiles, and used the pattern in which the goblet area was painted with concentric circles (Figure 4). The results of Takashima et al. (2012) suggest that adults were more likely to perceive the profiles than the goblet. The homogeneity of the goblet area was strengthened by this pattern. We decided we must use this new pattern and examine whether the strengthened homogeneity affects infants' figure/ground perception in Experiment 2.

If figure/ground perception in infants is affected by strengthened homogeneity, infants would perceive the profiles as a figure. Or, if figure/ground perception in infants is not affected by strengthened homogeneity, infants would perceive the goblet as a figure.

 Insert Figure 4 around here

3 Experiment 2

3.1 Method

Participants

Thirteen 7-8-month-old infants (seven male, six female, mean age = 224.85 days, ranging from 197 to 253 days) participated in Experiment 2. An additional nine infants were tested, but were excluded from the analysis owing to a side-bias greater than 90% (two), longer looking

times in the first three trials than in the last three trials in the familiarization (four), or looking times over the two test trials less than 7.5 s (three).

Apparatus, Stimuli, and Procedure

Apparatus stimuli, and procedure were same as Experiment 1 except familiarization pattern (Figure 4). The familiarization pattern in Experiment 2 was *Rubin's goblet* which the two profiles were painted blue (19.30 cd m^{-2}) and the goblet were painted with concentric circles. The concentric circles had achromatic gradation (from 4.10 to 57.00 cd m^{-2}).

Two observers, who were unaware of the stimulus identity, measured the infants' fixations to the left and right sides of the display on the basis of video recordings. Only the infant's looking behavior was visible in the video. The interrater reliability was high ($r=.94$, $p<.01$).

3.2. Results

Familiarization trials

The individual looking times were summed over the two identical patterns, and then averaged across the first three and last three trials. The mean looking times for each condition are shown in Table 3. A two-tailed one-sample t -tests (1-3 versus 4-5) revealed a significant effect of trials ($t(12)=7.32$, $p<.001$). The result confirms that all conditions were habituated to the familiarization pattern.

Test trials

The mean looking times during the pre-test and post-test are shown in Table 4. A preference

score was calculated for each infant in the pre-test and post-test as same as Experience 1.

Figure 5 shows the mean preference score. To determine whether infants had a spontaneous preference for either of the test patterns, we conducted two-tailed one-sample *t*-tests (versus chance) on the preference score in the pre-test. This analysis revealed no significant difference ($t(12)=0.91, n.s.$). To determine whether infants had a spontaneous preference for either of the test patterns, we conducted two *t*-tests ; a two-tailed one-sample *t*-tests (post-test versus chance) revealed a significant difference ($t(12)=3.07, p<.001$) and a two-tailed one-sample *t*-tests (pre- versus post-test) revealed a significant difference ($t(12)=2.96, p<.05$). These results suggest that infants are more likely to see the central area as figure.

Insert Table 3, Table 4, and Figure 5 around here

3.3. Discussion

In Experiment 2, we used the pattern with the strengthened homogeneity of the goblet and examined whether infants perceive the goblet or the profiles in the new pattern.

The results of Experiment 2 demonstrated that in the concentric-circles condition infants showed a novelty preference for the profiles in the post- familiarization test. That is, in the concentric-circles condition infants' novelty preference for profiles means that the goblet was figure and the two profiles were ground. From this data we can say that figure/ground perception

in infancy is not affected by the strengthening homogeneity.

4. General Discussion

We used four type of Rubin's goblets in Experiments 1 and 2 to examine whether infants perceive the goblet or the profiles as figure.

The pattern in the uni-color condition was the ordinal Rubin's goblet and adults reported the reversal of figure and ground. In the horizontal line condition, the homogeneity of the profiles was strengthened and adults were more likely to perceive the goblet as a figure. In the two-color condition, the homogeneity of the profiles was weakened and adults were more likely to perceive the profiles as a figure. In the concentric-circles condition, the homogeneity of the goblet was strengthened and adults were more likely to perceive the profiles as a figure.

Infants perceive the goblet as a figure in the horizontal line condition, uni-color condition, and concentric-circles condition, while in the two-color condition infants could not discriminate figure and ground.

In the horizontal line condition the homogeneity of the profiles was stronger than in the uni-color condition and in the concentric-circles condition the homogeneity of the goblet was stronger than in the uni-color condition. If figure/ground perception in infancy is affected by strengthened homogeneity, the results would be different among these three conditions. But from our results infants in all these three conditions perceived the goblet as figure.

We must consider the common points among these three conditions. In all these conditions the two profiles have the same features. When the two profiles have the same features, infants

should perceive the goblet as figure. We can say that figure/ground perception in infancy is not affected by strengthened homogeneity, but by identical feature.

We also manipulated the weakened homogeneity. If figure/ground perception in infancy is affected by weakened homogeneity, the results in the two color condition would be different from other conditions. From our results, infants in the two color condition preferred neither the goblet nor profiles, while infants in the other conditions perceived the goblet as figure. That is, we can say that figure/ground perception in infancy is affected by weakened homogeneity.

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Tables and Figures Caption

Table 1 Mean looking time (seconds) and standard deviations (in parentheses) during the familiarization trials.

Table 2 Mean looking time (seconds) and standard deviations (in parentheses) during the test trials.

Table 3 Mean looking time (seconds) and standard deviations (in parentheses) during the familiarization trials

Table 4 Mean looking time (seconds) and standard deviations (in parentheses) during the test trials.

Figure 1 the familiarization patterns in horizontal-line condition (A), uni-color condition (B), and two-color condition (C). After pre-test trials, infants received six 15-second familiarization trials. In the familiarization trials, the two identical familiarization patterns were presented side by side.

Figure 2 the test pattern in all conditions; goblet shape (A) and profile shape (B). After infants were familiarized with each *Rubin's goblet* (Figure 1), the infants were tested for novelty preference between the two profiles and the goblet in the post-familiarization test.

Figure 3 Mean preference scores in each condition.

Figure 4 The familiarization pattern in concentric-circles condition

Figure 5 Mean preference scores in Experiment 2

Table 1 Mean looking time (seconds) and standard deviations (in parentheses) during the familiarization trials.

Condition	1,2,3 trials	4,5,6 trials
horizontal-line condition	6.72 (1.92)	5.05 (1.76)
uni-color condition	7.27 (2.09)	4.72 (2.29)
two-color condition	7.20 (1.88)	4.92 (1.92)

Table 2 Mean looking time (seconds) and standard deviations (in parentheses) during the test trials.

Condition	pre-test	post-test
horizontal-line condition	12.42 (2.36)	10.65 (2.70)
uni-color condition	11.30 (2.26)	11.24 (1.58)
two-color condition	12.65 (2.43)	10.74 (2.02)

Table 3 Mean looking time (seconds) and standard deviations (in parentheses) during the familiarization trials.

Condition	1,2,3 trials	4,5,6 trials
concentric-circles condition	10.84 (1.32)	6.78 (2.01)

Table 4 Mean looking time (seconds) and standard deviations (in parentheses) during the test trials.

Condition	pre-test	post-test
concentric-circles condition	13.98 (2.70)	12.50 (2.37)

Figure 1

Figure 2

(A) goblet shape

(B) profile shape

Figure 3

Figure 4

Figure 5