Research report

Visual texture segregation by the chimpanzee (*Pan troglodytes*)

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Abstract

One adult male chimpanzee (*Pan troglodytes*) was trained to detect a target area consisting of texture elements from the background texture made of the different elements from the target area. The subject was given eight different stimulus conditions. In Condition 1, segregation was based on the difference of local feature of elements but not on global similarity. Conditions 2–3 investigated the effects of the number of terminators, which was considered as ‘textons’ in human texture perception. The chimpanzee showed better performance when the discrimination can be based on the difference of the number of terminators. This tendency, however, was reversed when the local salient feature (length of shorter lines) was enhanced, as in Enns’ [15] study with humans as subjects. The subject showed asymmetries in segregation performance when discriminating based on gap (Conditions 4–5), line length (Condition 6), and regularity of line arrangement (Condition 7). Observed asymmetries were consistent with humans and with visual search asymmetries. The performance of texture segregation by the chimpanzee was consistent with humans, and the texture segregation is one of the useful tasks for comparative study of early vision as well as visual search task.

Keywords: Texture segregation; Visual processing; Asymmetry; Comparison; Chimpanzee

Recent advance revealed various aspects of visual perception in chimpanzees. Researchers found similarity and difference in basic properties of visual perception between chimpanzees and humans [16–19,22–24,28–30,37–45]. Among these studies, Tomonaga [37,39] investigated parallel and serial processing of visual information in chimpanzees by using visual search tasks [46]. He found that the chimpanzees showed search asymmetries during visual search performance as well as in humans [47,48]. For some stimuli (such as lozenge versus lozenge with horizontal line or vertical versus tilted lines) the chimpanzees showed significant asymmetry in performance when changing the target and distractors (for example, vertical among tilted was more difficult to find than tilted among vertical). This asymmetry was considered as evidence for parallel processing of ‘features’ during the early processes of vision and serial processing of feature integration in the late phase of visual processing. In the area of human visual perception, texture segregation task is also used as frequently as visual search task. In the texture segregation task, subjects are required to detect a textured area consisted of small elements from the background consisted of different elements. Texture segregation has been frequently studied in humans since Julesz [25,26] or Beck’s [3,4] classical studies. They found that humans showed difficulty in detecting the target area when using specific elements but not when using different types of elements. Texture segregation is also governed by the two types of visual processing.

As noted above, texture segregation is frequently used in human subjects. In addition, there are some behavioral and neurophysiological studies with nonhu-
man animals such as pigeons [6, 8–12], cats [13, 14, 49–52], and macaques [27]. Unfortunately very little behavioral experiments are reported using nonhuman primates, especially chimpanzees. The behavioral study with chimpanzees on visual perception is one of the most important areas in comparative perception and cognition. Chimpanzees are the closest living relatives of humans. Investigating their visual perception will tell us the origin and evolution of our human visual perceptual systems. It is also useful for testing the validity of nonhuman primates as human models. Furthermore, since chimpanzees have adapted rather different environments than humans. Therefore, comparing chimpanzees and humans will also shed light on the species differences as well as similarities. In these senses, the study with chimpanzees then will play the role of the bridge between behavioral or neuropsychological studies in humans and neurophysiological studies in macaques, and will give some suggestions on the evolution of human visual system.

In the present paper, I attempted to verify the basic characteristics of the chimpanzee’s visual texture segregation. In the first condition, I explored the relationship between perceptual similarity among texture elements and perceptual grouping. Using humans as subjects, Beck [3, 4] reported dissociation between these two factors in texture segregation. For example, upright T is more similar to tilted T than to upright L for humans when judging their global similarity. However, they showed more difficulty in segregating an area consisted of upright Ts from that consisted of upright Ls than from tilted Ts. Texture segregation is much more affected by local features such as line orientation than global similarity of texture elements.

The next two conditions examined the role of terminators of texture elements in texture segregation. Textures differed in second-order statistics are usually indistinguishable. Some iso-second-order textures, however, can be easily discriminated if they contained some local conspicuous features, for example, quasi-colinearity, corner, closure, glanularity, and connectivity. Julesz [26] proposed that the number of terminators (line ends) of texture element was one of the critical features for preattentive texture segregation and called these fundamental texture features as ‘textons’. Fig. 1, Conditions 2a and 3b demonstrate typical examples of the role of terminators [26]. For example, triangle has no line ends, but arrow has three terminators, resulted in effortless texture segregation. On the other hand, both S-like and 10-like shapes have the same number of terminators (= 2), resulted in difficult segregation. Is this always true? Is it possible that the other factors such as relative salience of unique element features affect texture segregation? In Fig. 1, Conditions 2a and 3b, both texture displays differ only in the location of a single line. In the triangle-arrow texture the ratio of the unique and common line lengths are the same, whereas it was 1:4 in the S–10 texture. If this ratio was reversed, difficulty in texture segregation is drastically changed as shown in Fig. 1, Conditions 2b and 3a. S–10 texture with the same line length was easier to segregate than triangle-arrow texture with 1:4 difference in line length. This finding was reported by Enns [15] with human subjects. Humans may segregate textures on the basis of relative salience of unique features but not of the number of terminators as the texton theory predicts. I replicated the study by Enns [15] with a chimpanzee and human subjects with a different procedure in Conditions 2 and 3.

The last series of conditions investigated the asymmetries in the texture segregation by using the stimuli causing visual search asymmetries in humans or chimpanzees. In visual search tasks, search asymmetry was frequently observed both in humans and chimpanzees [39, 43, 47, 48]. For example, humans search a C among Os more quickly and accurately than O among Cs. In other words, C pops out. In general, searching the target containing a ‘feature’ among distractors without feature is easier than searching the target without feature among distractors with feature. Feature integration theory proposed by Treisman [46] successfully explained the search asymmetries. These features are preattentively processed at the early phase of vision (so-called early vision). On the other hand, detection of stimulus without feature requires selective attention. Many researchers found a variety of features which caused pop-out: gap (C versus O), intersection (Q versus O), brightness, size, line orientation, curvature, and so on. Do such asymmetries also occur in texture segregation? In texture segregation task, it is well known that some kinds of textures are easily segregated. Such effortless texture segregation may correspond to pop-out in visual search. Julesz [26] proposed a famous theory of texture segregation, texton theory. This theory suggests that quick and accurate segregation occurs only when two adjacent textures differ significantly in the density of small blob-like objects (called textons) having particular orientations, lengths, widths, color and intensity. Julesz’s textons and Treisman’s features may have the same function in the human early vision. In contrast to the feature integration theory, however, the texton theory did say nothing about asymmetrical processes in texture segregation. Recent studies demonstrated asymmetries in texture segregation in humans [20, 21, 35, 53]. For example, Gurnsey and Browse [20, 21] reported several cases which caused asymmetry in texture segregation: Ls versus + s, triangles and arrows, large versus small circles, regular versus irregular arrangements of circles, and so on. Williams and Julesz [53] also reported asymmetry when using Cs versus Os. Blough and Franklin [6] also found asymmetry in texture segrega-
Fig. 1. Schematic examples of texture displays used in Conditions 1–3. Each display contains a target area at the bottom left. Actual display was presented with white elements on the black background.

In pigeons (e.g. Cs versus Os), I tested asymmetries in texture segregation in the chimpanzee using Cs versus Os, line lengths, and line arrangements. Some of these sets are known to cause asymmetry in texture segregation as well as in visual search.

1. Method

1.1. Subject

One adult male chimpanzee (*Pan troglodytes*), Akira (17 years old), served as subject during the present experiments. He had been experienced a various kind of perceptual-cognitive tasks [2,31,40]. He lived in an outdoor enclosure (624 m²) with the other eight chimpanzees at the Primate Research Institute, Kyoto University. He had no special deprivation throughout the experimental period. Care and use of the chimpanzee adhered to the ‘Guide for the Care and Use of Laboratory Primates’ of the Primate Research Institute, Kyoto University.

1.2. Apparatus

The present experiments were conducted in an experimental compartment (2.7 × 2.1 × 1.5 m) situated adjacent to the outdoor enclosure. A 14-in. color monitor (NEC Model N5923) with an optical touch panel (Carol Touch International Model UL-94V-0) was installed on one wall about 40 cm above the floor. A touch to the screen of the CRT was defined as a response. Two steel pipes (30 × 1.2 cm) protected the CRT monitor and divided the screen into three rows. The chimpanzee sat about 40 cm from the CRT.
universal feeder (Davis Scientific Instruments Model UF-100) delivered a food reward to the food tray installed to the lower left of the CRT. A personal computer (NEC Model PC-98XA) controlled all experimental events and recorded experimental data.

1.3. Stimuli

Examples of texture display used in the present experiments are presented in Figs. 1 and 2. White texture elements were presented on the CRT with the dark background. Texture display was 23 cm (horizontal) by 12 cm (vertical) in size, and contained 16 × 8, 32 × 16, or 48 × 24 elements (varied on the basis of the size of each element). This display was divided into two areas, target and background. Target area mainly consisted of 3 × 3, 6 × 6 or 9 × 9 elements (4.0 × 4.5 cm in size). The other area was defined as background area. Target area randomly appeared one of the eight predefined locations (4 × 2) from trial to trial. Details of stimuli are described in Procedure section.

1.4. Procedure

1.4.1. Texture segregation task

In the most of human research, textures were presented at very brief time [15]. The major difference from the standard procedure is that the texture display is terminated by the subject’s response [6]. Each trial proceeded as follows. After the 3-s intertrial interval (ITI), white cross (warning signal, 0.5 × 0.5 cm) was presented at the center of the bottom row. A single touch to the warning signal resulted in the termination of it, followed by the presentation of the texture display. If the subject touched a target area, texture display disappeared, and 1-s chime and food reward (small piece of apple) was given to the subject. If the subject touched background area, texture display disappeared, but only 0.5-s error buzzer was presented. If the subject made an error, the same trial (correction trial) was repeated until he made correct response. When he made two successive errors, however, only the target area was presented (i.e. background was blank) on the third correction trial.

1.4.2. Preliminary training

Before shifting the first condition, Akira was initially trained on texture segregation task based on colors, using red and green circles as texture elements. Each element was 1.0 cm in diameter, and texture display consisted of 16 × 8 elements and target area of 2 × 2 elements (target area was 2.7 × 3.0 cm). Both colors appeared as target and background areas. Each session consisted of 96 trials. His performance in the first session was 64.1% correct and reached at 92.7% correct in the 4th session. This color discrimination training was continued for six sessions and he showed 93.9% correct in average across the last three sessions. In the next phase, a novel shape, star-like shape was introduced in addition to circles. Akira showed 77.1% correct in the first session and his performance reached at 91.7% correct in the second session. This training was continued for four sessions and he showed 94.3% correct in average across the last two sessions. In the third phase shape discrimination and shape × color disjunctive discrimination were introduced in addition to color discrimination. He showed 95.0% correct for shape discrimination and 93.8% correct for shape × color discrimination in the first session. He was given four sessions of this training. Mean percent correct averaged across four sessions was 99.2 for color, 97.7 for shape, and 96.1 for shape × color discriminations, respectively.

1.4.3. Condition 1: tilted \( T \) versus upright \( T \) and \( L \) versus \( T \)

In the first condition, three types of elements (0.6 × 0.6 cm in size) were used; Ts rotated at 0, 90, 180 and 270°, Ts rotated at 45, 135, 225, 315°, and Ls rotated at 0, 90, 180, 270°. These three types corresponded to upright T, tilted T, and upright L in the study by Beck [3,4], and designated as such in the present experiment. Texture display consisted of 32 × 16 elements, and the target area consisted of 6 × 6 elements. Target was upright L or tilted T and background was fixed to upright T (see Fig. 1). Initially, Akira was given blocked-trial training. In the blocked-trial training, a specific target element (upright L or tilted T) was repeated for eight trials, which was called trial block. Target elements alternated from block to block. This training was continued for four sessions, followed by four-session mixed-target training in which target elements changed from trial to trial. Each session consisted of 64 trials.

1.4.4. Condition 2: triangle versus arrow

In this condition, Akira was trained with triangle-arrow texture. Texture display was composed of 16 × 8 elements. Target area consisted of 3 × 3 elements. Each element size was within 1 × 1 cm. As shown in Fig. 1, Conditions 2a and 2b, all elements were presented at random orientations. For each session, consisting of 64 trials, four target-background pairs were presented. The subject initially received four blocked-trial sessions (block size is eight trials) and then four mixed-target sessions.

1.4.5. Condition 3: \( S \) versus \( 10 \)

As shown in Fig. 1, Conditions 3a and 3b, texture display was composed of 16 × 8 elements. Each element was the same in size as triangles and arrows in Condition 2. Target area consisted of 3 × 3 elements and all elements were also presented at random orientations.
Fig. 2. Schematic examples of texture displays used in Conditions 4–8. Each display contains a target area at the bottom left.
The subject only received six blocked-trial sessions (block size is eight trials).

1.4.6. Condition 4: large C versus O
In Condition 4, large Cs and Os were used. Each element size was 1 x 1 cm. Orientation of C was fixed at 0° (i.e. normal orientation). Texture display contained 16 x 8 elements and target area consisted of 3 x 3 elements (see Fig. 2, Condition 4). Akira was received six-session fixed-target training. In this training, target elements were fixed during a session. Cs and Os appeared as target alternately from session to session (i.e. each target appeared for three sessions). After this training, he was given four-session mixed-target training, followed by six-session fixed-target retraining. Fixed-target sessions consisted of 96 trials and mixed-target sessions consisted of 64 trials.

1.4.7. Condition 5: small C versus O
In this condition, small Cs and Os (0.6 x 0.6 cm) were employed. Texture display contained 32 x 16 elements, and target area consisted of 6 x 6 elements. Cs were presented at random orientations (see Fig. 2, Condition 5). Akira was given six-session fixed-target training and then four-session mixed-target training. Each session consisted of 64 trials.

1.4.8. Condition 6: long versus short lines
In Condition 6, long (0.6 cm) and small lines (0.3 cm) were used as texture elements (see Fig. 2, Conditions 6a and 6b). Although these lines were presented with either regular (Condition 6a) or irregular arrangement (Condition 6b), line length was the critical feature, and arrangement was irrelevant (Fig. 2, Conditions 6a and 6b). Akira initially received five sessions of blocked-trial training (block size = 8), and then four sessions of mixed-target training. During the blocked-trial training all four types of trials (including Conditions 6a and 6b) appeared randomly from block to block.

1.4.9. Condition 7: regular versus irregular arrangements of lines
In this Condition, line arrangement was critical and line length was irrelevant feature. (Fig. 2, Conditions 7a and 7b). Akira received four sessions of blocked-trial training (block size = 16) and then four sessions of mixed-target training. Each session consisted of 64 trials in which all four types of trials (Conditions 7a and 7b) appeared equally.

1.4.10. Condition 8: line length x arrangement
This condition was redundant or disjunctive condition (Fig. 2, Conditions 8a and 8b), in which both length and arrangement were the critical features. In Condition 8a, long irregular-arranged lines and short regular-arranged lines were paired while short regular and long irregular lines were paired in Condition 8b. The subject received two blocked-trial (block size = 8) and four mixed-target sessions. Each session consisted of 64 trials and all four types of trials (Conditions 8a and 8b) appeared equally.

2. Results
Table 1 summarizes the mean percent error and response time on correct trials for the subject for each condition.

2.1. Condition 1: tilted T versus upright T and L versus T
In Condition 1, Akira showed 73.4% correct in the first session. All eight training sessions were used for data analyses. As shown in Table 1, the subject showed more difficulty in segregating upright Ls from upright Ts than tilted Ts than upright Ts. Single-tailed paired t tests applied to the Akira’s data showed significant difference (percent error, t(7) = 3.201, p < 0.01; response time, t(7) = 5.830, p < 0.001).

2.2. Conditions 2 and 3: triangle-arrow and S–10 textures
When the unique feature was the same length as the common feature (1:1 ratio), the subject showed better performance for both textures than when the unique line was shorter than the common line, that is, unique line was less salient (1:4 ratio). These results were consistent with Enns’ [15] study. Especially, Akira was unable to segregate when S–10 texture with 1:4 line length ratio. For triangle-arrow textures, the effect of target-background combination was conditional upon the ratio. Detecting arrow area was easier when the ratio was 1:1, whereas triangle area was easier to detect when the ratio was 1:4. This reversed asymmetry in performance was not observed in S–10 textures. Two-way ANOVAs (target x ratio) were conducted to percent error and response time data for each condition. For Condition 2 (triangle-arrow texture), main effect of Ratio and interaction were significant for both percent error (Ratio, F(1,7) = 10.31, p < 0.05; interaction, F(1,7) = 6.342, p < 0.05) and response time (Ratio, F(1,7) = 12.99, p < 0.01; interaction, F(1,7) = 10.73, p < 0.05). For Condition 3 (S–10 texture), main effect of Ratio was significant for percent error (F(1,5) = 100.85, p < 0.0001) and effect of target was comparably significant for response time (F(1,5) = 5.39, p = 0.068). Nonsignificant difference in response time between the two types of ratios in Condition 3 was due to the failure of discrimination under the 1:4-ratio condition. Mean percent error for each of the two conditions was 13.9%
Table 1
Mean percent error and response times on correct trials and their standard deviations (SD) for the chimpanzee in the present experiment.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Target</th>
<th>Background</th>
<th>% Error (SD)</th>
<th>Response time (s) (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tilted T</td>
<td>Upright T</td>
<td>6.2 (4.7)</td>
<td>1.343 (0.149)</td>
</tr>
<tr>
<td>2a</td>
<td>Triangle (1:1)</td>
<td>Arrow (1:1)</td>
<td>6.3 (5.8)</td>
<td>1.373 (0.150)</td>
</tr>
<tr>
<td>2b</td>
<td>Triangle (1:4)</td>
<td>Arrow (1:4)</td>
<td>22.7 (16.3)</td>
<td>2.834 (1.069)</td>
</tr>
<tr>
<td>3a</td>
<td>S (1:1)</td>
<td>10 (1:1)</td>
<td>15.6 (19.3)</td>
<td>2.168 (0.423)</td>
</tr>
<tr>
<td>3b</td>
<td>S (1:4)</td>
<td>10 (1:4)</td>
<td>84.4 (8.6)</td>
<td>2.339 (0.601)</td>
</tr>
<tr>
<td>4</td>
<td>C (large)</td>
<td>O (large)</td>
<td>7.7 (5.2)</td>
<td>1.334 (0.359)</td>
</tr>
<tr>
<td>5</td>
<td>C (small)</td>
<td>O (small)</td>
<td>10.2 (7.2)</td>
<td>1.681 (0.340)</td>
</tr>
<tr>
<td>6a</td>
<td>Long (irregular)</td>
<td>Short (irregular)</td>
<td>12.5 (7.2)</td>
<td>1.182 (0.120)</td>
</tr>
<tr>
<td>6b</td>
<td>Long (regular)</td>
<td>Short (regular)</td>
<td>10.9 (6.0)</td>
<td>1.189 (0.129)</td>
</tr>
<tr>
<td>7a</td>
<td>Irregular (short)</td>
<td>Regular (short)</td>
<td>9.3 (5.4)</td>
<td>1.008 (0.233)</td>
</tr>
<tr>
<td>7b</td>
<td>Irregular (long)</td>
<td>Regular (long)</td>
<td>1.3 (2.8)</td>
<td>0.850 (0.145)</td>
</tr>
<tr>
<td>8a</td>
<td>Long/irregular</td>
<td>Short/regular</td>
<td>0.0 (0.0)</td>
<td>0.696 (0.040)</td>
</tr>
<tr>
<td>8b</td>
<td>Long/regular</td>
<td>Short/irregular</td>
<td>3.1 (3.6)</td>
<td>0.808 (0.071)</td>
</tr>
</tbody>
</table>

for triangle-arrow and 51.8% for S–10 textures. Enns [15] also reported better performance on triangle-arrow than S–10 textures. The present results were consistent with Enns’ results.

2.3. Conditions 4 and 5: C versus O

All ten sessions for each target (six fixed-target and four mixed-target sessions) in Condition 4 (large Cs and Os), and all seven sessions for each target (three fixed-target and four mixed-target sessions) in Condition 5 (small Cs and Os) were used for data analyses. Akira showed 85.4% correct for Cs and 68.8% correct for Os as target in the first fixed-target session of Condition 4, and 95.8% correct for Cs and 91.7% for Os as target in the first fixed-target session of Condition 5. Asymmetry of performance was observed in the large-element condition (detecting C area was easier than O area; single-tailed paired t-tests; percent error, $t(9) = 1.680, p = 0.064$; response time, $t(9) = 3.215, p < 0.01$) but weakened in the small-element condition (percent error, $t(6) = 1.234$; response time, $t(6) = 0.883$, both $p > 0.1$). Perceptual learning process may affect this reduced asymmetry [36].

2.4. Condition 6: line length

Akira showed 3.1% correct for short-line target trials, while 75.0% correct for long-line target trials in the first blocked-trial session. Accuracy was improved during the course of the blocked-trial training, showing 87.5% correct for short-line target and 78.1% correct for long-line target trials in the last blocked-trial session. Subsequent data analyses were based on mixed-trial sessions. Akira performed better performance when the long-line target area was presented than short-line target. Two-way ANOVAs (target (long, short) × regularity of textures (regular, irregular)) with sessions as repeated measures were conducted to percent error and response time data. For percent error, no main effects and interaction were significant, while for response times, only the main effect of target was significant ($F(1,3) = 164.71, p < 0.01$).

2.5. Condition 7: line arrangement

In this condition, Akira showed 71.9% correct for regular-arranged target trials and 93.8% correct for
irregular-arranged target trials in the first session of the blocked-trial session. He showed 92.5% correct in total during the blocked-trial sessions. In this condition, mixed-trial sessions were also used for data analyses. Akira showed difficulty in detecting regularly arranged target area from irregularly arranged background in comparison with the reversed target-background combination. Interestingly, interaction between the target and line length of texture elements was also observed; Akira showed stronger asymmetry in response time when the textures were consisted of small lines. Two-way ANOVAs (target (regular, irregular) × line length of textures (long, short)) revealed no significant main effects and interaction for percent error, but both main effects and interaction was significant for response time (target, $F(1,4) = 167.51, p < 0.001$; line length, $F(1,4) = 23.72, p < 0.01$; interaction, $F(1,4) = 13.63, p < 0.05$). Length of lines might improve discriminability between target and background areas.

2.6. Condition 8: length and arrangement

In this disjunctive condition, Akira showed better performance than the previous two conditions (98.4% correct in total during the blocked-trial sessions). As in the previous two conditions, data analyses were based on mixed-trial sessions. In contrast to the previous two conditions, the subject showed better performance in this condition, although the asymmetry of texture segregation was also observed (single-tailed paired $t$-tests, long/irregular versus short/regular, $t(3) = 11.497$, $p < 0.001$; long/regular versus short/irregular, $t(3) = 2.803$, $p < 0.05$). Interestingly, these asymmetries were based on line length but not on arrangement, that is, irrespective of line arrangements, he showed better performance in detecting the long-line target area than the short-line target area.

3. Discussion

The present experiments were conducted to reveal the basic characteristics of texture segregation in the chimpanzee and to explore the relationship between the texture segregation and visual search tasks through the investigation of asymmetries in segregation performance.

In Condition 1, the chimpanzee showed better performance in segregating tilted Ts from upright Ts than Ls from Ts. These results well replicated Beck’s [3,4] study. In the previous experiments on perceptual similarity among letters of alphabet, Matsuzawa [29,30] found the chimpanzee perceived T similar to L and less similar to X (similar pattern of tilted T). This suggest that the chimpanzee discriminate between letters of alphabet on the basis of local features such as line orientation, curvature, and closure. The patterns of similarity among letters were also found in humans [30] and pigeons [5]. On the other hand, the chimpanzee showed a quite strong invariance to rotation when given the mental rotation task [18], which suggests that when recognizing objects the chimpanzee might use global shape similarity. In the present experiment, unfortunately, I did not investigate the global similarity among tilted T, upright T, and upright L. However, the present results indicate that the chimpanzee segregate the texture on the basis of local feature difference between elements but not on the global similarity between texture elements themselves. In the feature integration theory [46], features are processed in a parallel manner in the early phase of vision and then these features were integrated into objects serially in the second stage of visual processing. In Condition 1, tilted-T and upright-T textures are only different in their local features (tilted versus vertical or horizontal lines), so that segregation occurs in the early vision, while it is necessary to integrate features into objects when the upright L and T textures are presented. The present results are consistent with feature integration theory and suggest that the same perceptual mechanism be involved in the chimpanzee texture segregation.

In Conditions 2 and 3, the chimpanzee showed the quite similar patterns of performance for each texture. When using the standard texture display (1:4 ratio, see Fig. 1, Conditions 2a and 3b), the subject showed great difficulty in segregating as Julesz [26] noted. When changing the ratio of length of unique features to common features, this difficulty was drastically reduced as Enns [15] demonstrated with human subjects. The present results suggest the possibility that both humans and chimpanzees discriminate the texture difference on the basis of local unique features but no of so-called textons as Julesz noted.

In Condition 2, target × ratio interaction was significant both for percent error and response times, suggesting that asymmetry in segregation was reversed when the ratio was changed (see Table 1). Akira showed better performance when the triangles were the target elements than arrows for 1:1 ratio and vice versa for 1:4 ratio. On the other hand, Gurnsey and Browse [20] reported better performance when the arrows appeared as target than triangles as target in human subjects. At present, it is unclear why such an ‘asymmetry of asymmetry’ was observed in the chimpanzee. It might be possible that the ‘closure’ plays a role of pop-out features in some conditions [15].

From Conditions 4–8, the chimpanzee clearly showed asymmetries in texture segregation when exchanging target and background elements. Some properties tested in these conditions (gap and line length) cause asymmetries in visual search by humans [47,48], and the other (line arrangement) cause asymmetries in
texture segregation by humans [21]. Patterns of asymmetries in these conditions were consistent with those observed in the visual-search and texture-segregation experiments; C was easier to find than O, long than short, and irregular than regular. Texture segregation and visual search may involve the same perceptual processes such as preattentive and attentive processing. Recently some researchers proposed dissociation between the phenomena observed in visual search and texture segregation in humans [54], or independence between Treisman’s feature and Julesz’s texture. We can also contribute to this topic on the standpoint of comparative perception-cognition with the chimpanzees.

In conclusion, I found almost similar patterns of texture segregation in the chimpanzee to those in humans. The present results were derived from only one chimpanzee, but the overall consistency between the present subject and humans tested in the previous literature may be enough to conclude that the chimpanzees have the same perceptual ability in texture segregation as humans have. The present results also indicate functional equivalence between visual search and texture segregation tasks in some aspects in both species. In the future, we can use one of these tasks in nonhuman primate subjects for verifications or systematic replications of some perceptual phenomena observed in the other task [41]. As noted in introduction, behavioral studies using nonhuman primates such as present one will be suggestive in discussing the relationship between neuropsychological studies of nonhuman primates (or other animals) and behavioral or neuropsychological studies with humans. Furthermore, texture segregation and visual search tasks are frequently used in developmental studies on early vision of human infants [1,7,32–34]. Studies with nonhuman primates can also add the comparative perspective to such developmental studies.

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