The analysis of visual information on the human head from a viewpoint change under the inverted presentation

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Abstract—We investigated visual information on human heads viewed from a viewpoint change under the inverted presentation by using spatial frequency (SF) analysis. Stimuli were inverted images of three familiar peoples’ heads viewed from the frontal view to the back of the head and were created by four band-pass filters (8, 16, 32, and 64 c/fw). Participants were required to identify each person. On the results of Experiment 1, the face inversion effect occurred in all head angles, except the back of the head. The results of Experiment 2 showed that the mean response time (RT) of the inverted frontal view and the profile view significantly decreased when the image was in high SF. In contrast, RT of the back of the head decreased on the middle range of SF. These results suggest that the different view-specific information may exist on each view, even on the inverted presentation.

I. INTRODUCTION

Several studies demonstrated that the configural information, the spatial relations of facial internal features, is useful for recognition of upright faces [1] [2]. One of evidences on the importance of the configural information is the face inversion effect.

It is well known that the inversion of faces is difficult to recognize than the other classes of visual objects. The first study about the face inversion effect is that of Yin (1969) [3]. He demonstrated that faces were more sensitive to inversion than other object stimuli such as houses and airplanes in recognition task. From Yin’s study (1969), it has suggested that the inversion of the face disrupts the processing of the configural information. Therefore, it may be the different processing between the upright and inverted face.

As for the processing on upright and inverted face, Carey & Diamond (1977) proposed that the upright face was processed by the whole perceptual strategy, whereas the inverted face was processed on the analytical perceptual strategy [4]. Sergent (1984) showed that a qualitative difference in the processing of upright and inverted faces [5]. On the upright face, it was useful for both featural and configural information, while on the inverted face, no useful for configural information.

Moreover, Moscovitch, Winocur, & Behrmann (1997) conducted nineteen experiments on a man with normal face recognition but object agnosia and dyslexia [6]. When the face was presented in upright, his performance was worse than the control group. However, in inverted faces, the performances were better as same as the control group. From these results, they proposed that face recognition processing depends on two systems. One is a holistic face-specific system. It depends upon orientation-specific coding of internal features. The other is a part-based object recognition system. Taken together, these studies suggest that inverted faces are processed in a qualitatively different way from upright faces.

The difference between featural and configural information in faces might be explained by using the spatial-frequency (SF) analysis. The SF analysis has been used as one of the methods examining the analysis of information on face recognition. For face recognition, the fine information (high
SF information) carries featural information, whereas the coarse information (low SF information) carries configural information [7].

By using the pixilation, Harmon (1973) demonstrated that low-SF was useful for the face recognition, because it included the configural information for face recognition [8]. Sergent (1986) suggested that the configural information might convey the information of the face pattern [9]. From these results, it suggests that the low SF is effective for the recognition of upright faces.

As for the critical band of SF for face recognition, Costen, Parker, & Craw (1996) estimated that face identification was situated around between 8-16 cycles per face [10]. In addition, by using the band-pass filter, Nagayama, Yoshida, & Toshima (1995) examined that the response time on face familiarization task was faster on 12.4-24.8 cycles per face-width (c/fw) [11]. It suggests that the critical band of information in face recognition occurs in middle range of SF.

In our previous studies, by using the band-pass filter as the same as [11], we demonstrated that the different view-specific information was used for recognizing human heads across variations in viewpoint [12]. The results indicated that frontal view mostly depends on middle range of SF, 16c/fw to 32 c/fw. This range consists with the suggestion of [11]. The back of the head depends on higher range of SF, 32c/fw to 64 c/fw. Information including on higher range is more featural than middle range. However, in the profile view, there was no change in RT every the range of SF. The results proposed that each head of different views depend on the different visual information.

As for studies of the face inversion effect [1] [2], it suggests that the frontal view is processed the different way on the upright and the inverted orientations. The question arises whether identification on inverted profile view and the back of the head rely on different information compared to upright orientation.

In this study, we aimed to investigate whether different view-specific information was useful to identify human heads across a viewpoint change under the inverted presentation.

II. EXPERIMENT 1

In this experiment, we investigated the different processing on the upright and the inverted familiar persons' heads at a variety of viewpoints. We examined if the face inversion effects occur on not only the frontal views but also the profile views and the back of the heads.

A. Method

Participants

Twelve university students and graduate students participated in the experiment. All participants had normal or corrected-to-normal vision.

Materials

We used 30 gray-scale images of three familiar male professors (each of 49, 49, and 50 years old) as stimuli. These photographs were taken in every 45 degrees of head angle from the frontal view to the back of the head. The five different head angles, 0° (the frontal view), 45°, 90° (the profile view), 135°, and 180° (the back of the head) were used. Then, the images were manipulated on inverted orientation by using the graphic software (Adobe Photoshop 7.0). Half of these images were upright, the other half of the images were inversion. The images subtended about 11° by 9° (500 by 400 pixels).

Procedure

The experiment conducted in a dimly lit room. Participants sat in front of the response box with four buttons. Three buttons were the name buttons which was attached each of three stimuli’s name and one button was the start button. The participants were seated with their heads approximately 91 cm from the screen. For every stimulus presentation, the participants were required to press the start button and to watch the screen immediately. Following the fixation point, the image was presented at the center of computer monitor (ACER 5133AT) until the participants responded to press one of the name buttons. If participants didn't response to push the button till 8000 ms, we removed to next trial. 4 sessions of 30 trials were conducted to each
participant in random order. The computer recorded the reaction time (RT) for each presentation. Participants’ task was to identify three familiar people from five different viewpoints on both upright and inverted presentations.

B. Results & Discussion

A 2×5 repeated-measures analysis of variance (ANOVA) with orientation (upright, inversion), head angle (0°, 45°, 90°, 135°, and 180°) was performed on RT of correct responses. The main effects on orientation (F (1,143) = 31.895, p < .001) and head angle (F (4,572) = 3.012, p < .05) were significant (Figure 1). The orientation × head angle interaction was significant (F (4,572) = 2.443, p < .05). Contrast analysis revealed that upright presentation was significantly faster than the inversion on 0°: F(1, 143) = 7.476, p < .01; 45°: F(1, 143) = 27.662, p < .001; 90°: F(1, 143) = 9.743, p < .05; 135°: F(1, 143) = 6.201, p < .05).

The results indicated that the face inversion effect occur on the frontal view and the profile view, while no the face inversion effect on the back of the head.

The previous studies on the face inversion effect proposed that inversion disrupts the configural information [4] [6]. On based in this suggestion, RT of the inversion were significantly longer than that of the upright frontal views and profile views on this experiment due to the disruption of the configural information.

Moreover, the facial internal features such as eyes, nose, and mouth are included in the frontal views and the profile views, whereas there are no those facial internal features in the back of the head. The results suggest that one of the factors for the face inversion effect might be to include the facial internal features.

III. EXPERIMENT 2

From the results of Experiment 1, the face inversion effects occurred in the frontal view and the profile view. Several studies on the face inversion effect, it proposed that the configural information is disrupted in inversion, then inverted faces depends on the featural information [1] [2]. The question is whether the featural information included in high SF is effective for identification of the inverted faces. To assess this question, we used the band-pass filtered to determine which the ranges of SF carried the useful information for identification on different viewpoint.
A. Methods

Participants

Twenty-one university students and graduate students participated in this experiment. Other aspects of participants on Experiment 2 were identical to those of Experiment 1.

Materials

We used 60 images of three familiar male professors. The original inverted images were used as the same as Experiment 1. These images were filtered by band pass-filters, 1.5 octaves wide, located 1 octave apart. The cutoff frequencies of the four filters, 8, 16, 32, 64 cycles per face-width (c/fw) were used on this experiment (Figure 2).

Procedure

Procedure was the same as that of Experiment 1.

B. Results & Discussion

A 4×5 repeated-measures analysis of variance (ANOVA) with SF (8, 16, 32, and 64 c/fw), head angle (0, 45, 90, 135, and 180°) was performed on RT of correct responses. The main effects on SF (F (3, 60) =10.93, p<.01) and head angle (F (3, 60) =2.123, p<.05) were significant. The effective range for the profile view. However, on 180°, there were the significant differences between 8c/fw and 16c/fw, 8c/fw and 64c/fw (t (20) =4.142, p<.01), 8c/fw and 64c/fw (t (20) =3.476, p<.01). It showed that RT was significantly decreased in 64c/fw. It suggests that the range of high SF convey most useful information to identify the inverted frontal views. For 90°, there were the significant difference between 8c/fw and 64c/fw (t (20) =2.898, p<.01). It suggests that the band of SF of 64c/fw is the effective range for the profile view. However, on 180°, there were the significant differences between 8c/fw and 16c/fw (t (20) =4.142, p<.01), 8c/fw and 64c/fw (t (20) =3.476, p<.01). For the back of the head, RT significantly decreased in 32c/fw. It suggests that the middle range of SF from 16c/fw to 32 c/fw is useful for the back of the head. From these results, there were the different bands of spatial

![Figure 3. The result of upright (Nakato & Nagata, 2002) and inverted conditions (Experiment 2). Mean reaction times on the upright condition (Solid triangles) and the inverted condition (Open circles) as a function of the levels of band-pass filter for each head angle: (a) 0°, (b) 45°, (c) 90°, (d) 135°, and (e) 180°. Each graph ((a) to (e)) of head angle is analyzed by t-test of the mean reaction times between 8 cfw and 16, 32, 64 cfw of band-pass filter. Error bars represent SE of the mean reaction time. **: p<.001, *: p<.05, n.s.: no significant](image-url)
frequencies on each head angle.

To assess the different processing between the upright and the inverted faces, we compared the results of the upright data [12] with the results of this experiment of the inverted one.

On the upright frontal views, RT significantly decreased between 16c/fw and 32c/fw. The result indicated that the middle range of SF was most useful information for upright frontal views. In contrast, RT of the inverted frontal views decreased when the images were in 64 c/fw. It showed that the high range of SF conveyed most useful information for inversion. From these results, it suggests that the critical band of SF for the inverted frontal views shifts to higher range than that for the upright faces.

For the profile views, there was no change in RT across the ranges of SF in the upright orientation, while RT significantly decreased as the inverted images were contained in 64 c/fw. It showed that the high range of SF conveyed most useful information for inversion in the profile views.

RT of the back of the head in upright significantly decreased in the range of SF from 32c/fw to 64c/fw. It showed that the high range of SF was effective information for upright. In the inversion, however, RT significantly increased between 16c/fw and 32c/fw in middle range of SF. These results indicated that the critical band of SF for the back of the head in inversion shifts to lower range than upright.

By comparing the upright and the inverted orientation on the frontal view, the profile views, and the back of the head, we assume that there is an effective SF range to identify familiar people on each head angle independently.

IV. GENERAL DISCUSSION

In the present study, we investigated whether there was the different view-specific information for identification of familiar people viewed from the frontal view to the back of the head under the inverted condition.

From the results of Experiment 1, the face inversion effect occurred on the frontal view and the profile view, while there was no face inversion effect on the back of the head.

In Experiment 2, by using the band-pass filters, it showed that identification on the frontal views and the profile views were faster when the image was contained in high SF. In contrast, identification on the back of the head was faster in the middle range of SF. Moreover, there were the different ranges of SF between the upright and the inverted orientation on all heads.

Several studies have suggested that the configural information carried by low SF is critical for the upright face processing [1] [2]. However, inversion disrupts the configural information, and the processing of the featural information is dominant in inverted faces [4] [6].

In Experiment 1, the face inversion effects occurred both on the frontal and the profile views. Also, RT of both views significantly decreased as the images were the ranges of high SF in Experiment 2. High SF conveys the fine information of facial internal features [7]. From these results, we assume that identification of the frontal and the profile views in inversion depend on the local and feature information which is contained in facial internal features such as eyes, nose and mouth. In contrast, there was no face inversion effect on the back of the head. In addition, RT of the back of the head in inversion significantly decreased in the middle range of SF. For identification of the back of the head in upright, the internal features of the head such as hair-quality are useful information [12]. These internal features are independent of the configural information. Therefore, it suggests that the internal features of the head are not affected by inversion.

As compared the results of [12] with Experiment 2, we found that there were the different range of SF on each head angle in upright and inverted conditions. As for the frontal view, the middle range of SF was useful for upright and the high range of SF was useful for inversion. For the profile views, there was no change in RT across the ranges of SF in upright, while RT significantly decreased in the high range of SF at inversion. For the back of the head, the high range of SF was effective in upright. In the inversion, however, the middle range of SF was useful for the back of the head.
Recent neuroimaging studies demonstrated that the brain activation of the upright face was different from that of the inverted face. By using ERPs, it showed that N170, which was sensitive to the face stimuli compared the other object stimuli, was larger response in the upright faces. However, N170 of amplitude and delay indicated in the inverted faces [13]. Additionally, on ERPs data in response to viewing upright and inverted faces, it showed that the right hemisphere responded more rapidly to upright face, while the left hemisphere responded to inverted face [14]. It demonstrated that the right hemisphere dominated the processing of the configural information on faces, while the processing of the feature information on faces was dominated by the left hemisphere. These results suggest that there is the asymmetry of hemisphere between the upright and inverted face processing.

In conclusion, we found that there was the different processing between upright and inverted orientations on each view. The result is consisted with neuroimaging studies [13] [14]. These results suggest that identification in the inverted head views across changing viewpoints is mediated by different mechanisms from that in the upright ones. It implies that each view depends on the different view-specific processing independently even in inversion.

REFERENCES