The effects of image blurring on the recognition of facial expressions

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THE EFFECTS OF IMAGE BLURRING ON THE RECOGNITION OF FACIAL EXPRESSIONS

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We investigated the effects of image blurring on the recognition of happy and sad expressions in order to examine the information used for recognizing happy and sad expressions in terms of the spatial-frequency contents in a face. Facial images were blurred using the continuous smearing method (Harmon, 1973). The results of experiments 1 and 2, for which 64 and 32 undergraduate students volunteered respectively, showed that discrimination between happy and neutral expressions did not degrade, even when the facial images were blurred with a 118 × 118-pixel averaging window, the width of which was about 27 percent of the average width of the faces (443 pixels). When the facial images were blurred more severely, the accuracy of discrimination between happy and neutral expressions markedly declined. On the other hand, the discrimination between sad and neutral expressions degraded when the facial images were blurred with a 39 × 39-pixel averaging window, and that it gradually degraded as the degree of blurring increased. The results of experiment 3, for which 20 undergraduate students volunteered, showed that the images of happy faces blurred with a 59 × 59-pixel averaging window were recognized as fast as their original images, whereas the blurred images of sad faces were recognized more slowly than their original images. This indicates that a happy expression can be recognized on the basis of low spatial-frequency contents, whereas the recognition of a sad expression requires a high spatial-frequency content. This supports Kirita and Endo's (1995) suggestion that happy faces are recognized holistically, whereas sad faces are recognized by the analytic mode.

Key words: facial expression, happy face advantage, mode of processing, spatial frequency, blurring.

INTRODUCTION

Happy faces are recognized more quickly and more accurately than any other facial expression (Ekman, Friesen, & Ellsworth, 1982; Kirouac & Dore, 1983). Feyereisen, Malet, and Martin (1986) proposed three hypotheses that could account for this happy face advantage. First, it was assumed that the happy face advantage arises from the properties of the processing of facial expressions. Facial expressions are first classified as positive or

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negative, then they are analyzed in detail. In this case, positive faces would be recognized faster and more accurately, because there are fewer positive emotions than negative ones. Secondly, the happy face advantage could be attributable to the visual properties of happy faces: happy expressions are either simpler, or more salient than other expressions. Thirdly, it could be caused by the conceptual organization of the emotional field. Pleasantness-unpleasantness could be one of the major dimensions of the emotional field. Happiness could be the pole on the axis of this dimension, so that happy expressions are the easiest to process. The first two hypotheses ascribe the happy face advantage to modality-specific factors. The last hypothesis ascribes it to a non-modality-specific factor.

Feyereisen, et al. (1986) examined whether modality-specific and/or non-modality-specific factors influence the happy face advantage. They showed that a happy expression was classified faster than a sad expression not only when faces displaying happy or sad expressions were presented, but also when words referring to happiness or sadness were presented. However, the emotional category effect was greater for faces than for words. This suggests that the happy face advantage depends on both modality-specific and non-modality-specific factors.

Kirita and Endo (1995) investigated modality-specific factors underlying the happy face advantage. In their study, happy and sad schematic faces, which deviated equally from a neutral face, were used as stimuli. It was found that happy faces were recognized faster than sad faces when they were presented upright, but that sad faces were recognized slightly faster than happy faces when they were presented upside down. The results for the upright condition could not be explained only by the difference in visual properties between happy and sad faces, because the spatial deviations of the happy and sad schematic faces were equal. The results for the inverted condition suggest that the happy face advantage can be explained in terms of the mode of processing of happy faces. This is because inversion impairs the processing of the configural information of faces (Valentine, 1988).

Kirita and Endo also showed that there was an emotion × orientation × visual field interaction. When faces were presented in the left visual field, happy faces were categorized faster than sad faces irrespective of their orientations. On the other hand, when they were presented in the right visual field, the happy face advantage was found only for the upright condition. It has been suggested that the left visual field (right hemisphere) is better suited for holistic processing, whereas the right visual field (left hemisphere) is better suited for analytic processing (Sergent & Bindra, 1981). Therefore, their results indicated that when both the factors of orientation and visual field would favor analytic processing, namely when faces were presented upside down to the right visual field, the happy face advantage disappeared. On the basis of these findings, Kirita and Endo argued that while happy faces were likely to be recognized holistically, sad faces were likely to be recognized by the analytic mode.

The aim of the present study was to investigate the effects of image blurring on the recognition of happy and sad expressions, as well as the inversion effects. The configural information in a face is mainly conveyed by low spatial frequencies, and the component information is mainly conveyed by high spatial frequencies (Sergent, 1986). Blurring is a simple method to cut the high spatial-frequency contents from the facial images. If high spatial frequencies are necessary for the recognition of sad faces but not for happy faces, the recognition of a sad face would be impaired by blurring the facial images but not a happy face.

In all of the three experiments reported here, the discrimination between happy and neutral expressions was compared with that between sad and neutral expressions. We did not compare the recognition of happy and sad expressions directly, because then there would be the possibility that the results reflected only the performance of the recognition of happy or sad expressions, especially when the task was difficult for subjects.

The facial images were blurred using the continuous smearing method: a brightness value for each pixel of the image was transformed into an average brightness value of the pixels surrounding it (Harmon, 1973). In this method, the degree of blurring increased according to the size of the average window. In experiment 1, we compared the accuracy of the two discrimination tasks, using the original images of facial expressions and the images blurred with four sizes of the average window. In experiment 2, we examined how the accuracy of the two discrimination tasks decreased to a random level, using the images blurred with larger sizes of the average window than for experiment 1. In experiment 3, we compared the reaction times for the two discrimination tasks, using the original images and the blurred images used for experiment 1.

EXPERIMENT 1

METHOD

Subjects: Sixty-four female undergraduate students volunteered for this experiment.

Stimuli and Apparatus: Seven female students were asked to pose three types of expression (neutral, happy, and sad). Three monochrome pictures of each expression were taken of each student. All of the students wore a dark-blue hair-band so that their hair did not hide their foreheads and eyebrows. When they displayed a happy expression, they were asked to keep their mouth closed. We selected the most appropriate expression out of the three pictures for each expression from each student: 21 facial expressions were chosen.

These facial expressions were digitized using a scanner (SHARP; JX-600) and a microcomputer (NEC: PC-H98 MODEL70) at 256 gray levels, and were displayed on a monitor (BARCO: CALIBRATOR). The average face width was 443 pixels (13.73cm). As mentioned before, the images on the monitor were blurred using the continuous smearing method. Four sizes of the average window were used: 19 × 19, 39 × 39, 59 × 59 and 79 × 79 (pixels). A slide of the original image and slides of the blurred images were made for each facial expression.

The slides were presented on a translucent screen (10 × 10cm). Subjects observed the screen at a distance of 92 cm from a chin rest. The size of the stimuli was approximately 5.7 × 4.2 deg. A microcomputer (NEC; PC9801VX) and JAC Timer Board (NIHON ASSEMBLER Inc.) were used for controlling the stimulus presentation and recording the subjects' response.

Design and Procedure: Type of discrimination task (happy vs. neutral, sad vs. neutral) and orientation (upright or upside-down) were between-subject factors. Blurring (original or four degrees of blurring) was a within-subject factor.

Depending on the condition to which the subjects were assigned, they were instructed that the task was to decide whether the face presented a happy (or sad) expression or a neutral expression, and that the face would be presented upright (or upside down). The experimental trials consisted of 5 blocks of 14 trials. In the first block, the most blurred pictures, i.e., the pictures blurred with a 79 × 79-pixel window, were presented randomly. In the next block, the most blurred pictures of the remaining ones were presented. In the last (fifth) block, the original pictures were presented. The duration of the stimuli was 2,000 msec. After each presentation, the subject reported which expression the face displayed. The subjects were told that half of the faces displayed a happy (or sad) expression.

RESULTS

A correct response for the happy (or sad) expression was considered as a 'hit,' and an error for the neutral expression was considered as a 'false alarm'. For each subject, hit and false alarm rates in each blurring condition were calculated and combined in *A'* scores (Rae, 1976). Mean *A'* scores are given in Figure 1.

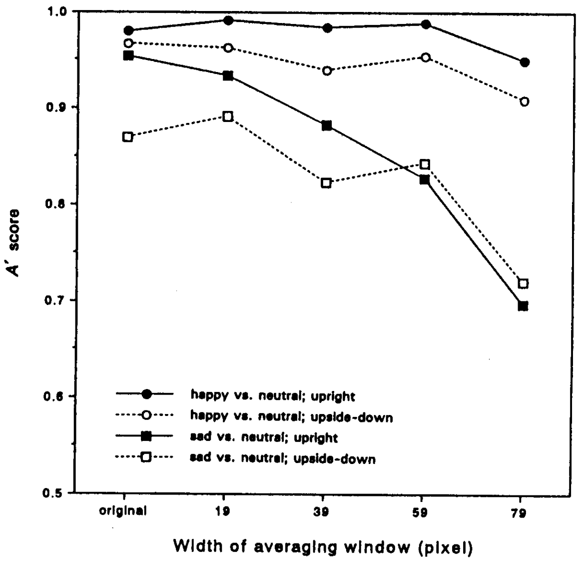

Fig. 1. Mean *A'* scores for each condition as a function of the width of averaging window (experiment 1). Mean face width was approximately 443 pixels.

A 2 (discrimination task) × 2 (orientation) × 5 (blurring) mixed design ANOVA of the A' scores was conducted. All of the main effects were significant (discrimination task: $F(1,60) = 133.76$, $p < .01$; orientation: $F(1,60) = 9.17$, $p < .01$; blurring: $F(4,240) = 26.38$, $p < .01$). And a discrimination task × blurring interaction was significant ($F(4,240) = 10.57$, $p < .01$). No other interactions were significant (all F ratios < 1.85).

An analysis of the discrimination task × blurring interaction revealed that the simple main effect of the discrimination task was significant for all of the blurring conditions (all p's $< .01$). Discrimination between happy and neutral expressions was more accurate than that between sad and neutral expressions. The simple main effect of blurring was significant for the discrimination task between sad and neutral expressions ($F(4,240) = 34.95$, $p < .01$), but was marginally significant for the discrimination task between happy and neutral expressions ($F(4,240) = 2.00$, $.05 < p < .1$). Multiple comparisons with each other blurring condition were conducted by a Ryan test for both the simple main effects of blurring. For the task of discriminating between happy and neutral expressions, any comparisons were not significant ($p > .05$). There was no evidence that discrimination between happy and neutral expressions was impaired by blurring the pictures. For the task of discriminating between sad and neutral expressions, the difference between the A' scores for the original pictures and those for the pictures blurred by a 19 × 19-pixel window was not significant. And the difference between the A' score for the pictures blurred by a 39 × 39-pixel window and those for the pictures blurred by a 59 × 59-pixel window was not significant either. All of the other differences were significant ($p < .05$). It showed that the accuracy of discrimination between sad and neutral expressions declined when the size of the average window changed from 19 × 19 to 39 × 39-pixel, and when it changed from 59 × 59 to 79 × 79-pixel.

Discussion

The main result of experiment 1 was that the discrimination between happy and neutral faces was little impaired by blurring the facial images, whereas the discrimination between sad and neutral faces was degraded in steps as the degree of blurring increased. The subjects seemed to decide whether the presented face displayed a happy (or sad) expression or not, rather than a happy (or sad) or neutral expression. This is because a face seemed to be classified as neutral when it could not be classified as any other expression. Therefore, it can be said that the recognition of sad expressions is found to be impaired by blurring the facial images, but not the recognition of happy expressions. This indicates that happy expressions are recognized with low spatial-frequency contents, but not sad expressions.

Irrespective of the type of task, facial expressions were discriminated more accurately when they were presented upright than when they were presented upside down. This is inconsistent with the results reported by Kirita and Endo (1995) using schematic faces as stimuli (experiments 1 and 2). However, Kirita and Endo obtained the same results as those in this experiment when they used happy and sad expressions on real faces as stimuli (experiment 3): there was no interaction between expression and orientation. Kirita and

Endo suggested that the difference between the results for schematic faces and those for real faces could be explained in terms of stimulus differences, for example, the quality of the expressions.

The blurring and orientation interaction was not obtained; the same patterns of the blurring effects were obtained irrespective of the stimulus orientation. As mentioned before, when faces were presented upside down, the configural information in faces is limited to use, so that facial expressions are recognized on the basis of processing the component information. The high spatial-frequency contents (the component information) are cut from the facial images by blurring. Therefore, a simple prediction was that the discrimination of facial expressions would be more strongly impaired by blurring in the inverted condition than in the upright condition. However, this prediction was not supported in the present experiment.

As mentioned earlier, in the present experiment the recognition of a happy expression was little impaired by blurring the facial images. However, when the facial images are more strongly blurred, the recognition of a happy expression will degrade. If different information in terms of the spatial frequency contents in a face could be used for the recognition of happy and sad expressions, then different patterns of degradation would be obtained for the recognition of the two expressions as the degree of blurring increases. The aim of the next experiment was to examine this hypothesis. In the next experiment, we used facial images blurred with larger size windows than we used those in experiment 1, and compared the accuracy of the two discrimination tasks.

EXPERIMENT 2

METHOD

Subjects: Thirty-two female undergraduate students volunteered for this experiment.

Stimuli and Apparatus: The original pictures were the same as for experiment 1. They consisted of the faces of 7 females displaying three types of expression (neutral, happy, and sad). These pictures were blurred using the same procedure and the same apparatus as in experiment 1. The sizes of the average window in this experiment were 98 × 98, 118 × 118, 138 × 138, and 158 × 158 (pixels). Slides of the blurred pictures were made. The apparatus for the stimulus presentation was the same as in experiment 1.

Procedure: The same procedure as experiment 1 was used, except for the stimuli.

RESULTS

For each subject, hit and false alarm rates under each blurring condition were calculated and combined in A' scores. Mean A' scores are given in Figure 2.

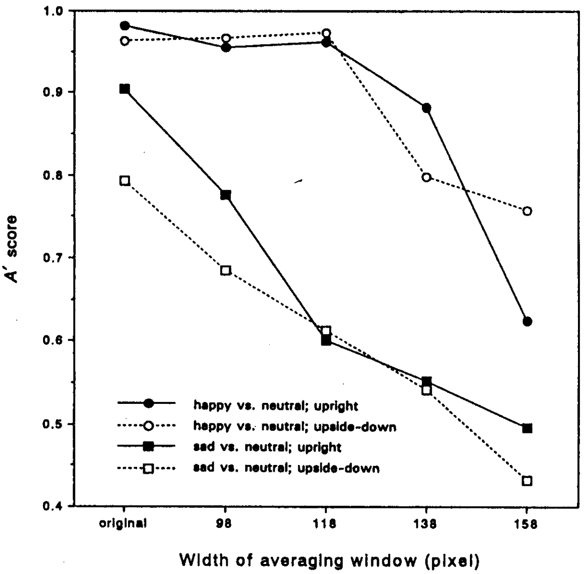

Fig. 2. Mean A' scores for each condition as a function of the width of averaging window (experiment 2). Mean face width was approximately 443 pixels.

A 2 (discrimination task) × 2 (orientation) × 5 (blurring) mixed design ANOVA of the A' score were conducted. This revealed the significant main effects of the discrimination task ($F(1,28) = 89.19$, $p < .01$) and of blurring ($F(4,112) = 24.98$, $p < .01$). The main effect of orientation was not significant ($F < 1$). There was a significant interaction between the discrimination task and blurring ($F(4,112) = 2.80$, $p < .05$). No other interactions were significant (all F ratios < 1.51).

An analysis of the discrimination task × blurring interaction revealed that the simple main effect of the discrimination task was significant for all of the blurring conditions (all p's $< .01$). Discrimination between happy and neutral expressions was more accurate than that between sad and neutral expressions. The simple main effect of blurring was also significant for both of the discrimination tasks (all p's $< .01$). Multiple comparisons with each other blurring condition were conducted by a Ryan test for both the simple main effects of blurring. For the discrimination task between happy and neutral expressions, there was no significant difference in A' scores between the original pictures, the pictures blurred by a 98 × 98-pixel window, and those blurred by a 118 × 118-pixel window. All of the other differences were significant ($p < .05$). For the discrimination task between sad and neutral expressions, the differences between the A' scores for the pictures blurred by a 118 × 118-pixel window and those for the pictures blurred by a 138 × 138-pixel window were not significant. The differences between the A' scores for the pictures blurred by a 138 × 138-pixel window and those for the pictures blurred by a 158 × 158-pixel window were not significant. All of the other differences were significant ($p < .05$).

Discussion

The results of experiment 2 showed that the two discrimination tasks were influenced by blurring facial images differently. Discrimination between happy and neutral expressions was not degraded, even when the facial images were blurred with a 118 × 118-pixel averaging window, the width of which was about 27 percent of the average width of the faces (443 pixels). When the facial images were blurred more severely, the accuracy of discrimination between happy and neutral expressions remarkably declined. On the other hand, discrimination between sad and neutral expressions was degraded for all of the blurring conditions. When the pictures were blurred with a 118 × 118-pixel window, the accuracy of discrimination between sad and neutral expressions was found to be almost at a chance level.

Taken together with the results from experiment 1, it demonstrated that the recognition of a sad expression was degraded when facial images were blurred with a 39 × 39-pixel averaging window, and that it was degraded gradually as the degree of blurring increased. It suggested that a happy expression can be recognized on the basis of low spatial-frequency contents on a face, whereas the recognition of a sad expression requires a broader range of spatial-frequency contents involving the high spatial frequencies.

Inversion effects were not obtained in this experiment, which was inconsistent with the results in experiment 1. It might be attributable to ceiling effects for the discrimination between happy and neutral expressions and to floor effects for the discrimination between sad and neutral expressions.

In experiments 1 and 2, we investigated the effects of image blurring on the accuracy of the two discrimination tasks. In experiment 3, we investigated the effects of blurring on the time taken to discriminate between happy (or sad) and neutral expressions. The information contained in the low spatial frequencies is conveyed faster than that in the high spatial frequencies in an early stage of visual processing (Sergent, 1986). If a happy expression is recognized sufficiently on the basis of low spatial-frequency contents on a face, the time taken to recognize a happy expression will not be influenced by blurring facial images. On the other hand, if a sad expression is recognized on the basis of the high spatial-frequency contents in a face, there will be substantial effects of blurring on the time taken to recognize a sad expression.

Experiment 3

Method

Subjects: Twenty undergraduate students (two males, eighteen females) volunteered for this experiment.

Stimuli and Apparatus: We chose the stimuli for this experiment from the stimuli used for experiment 1: the original pictures and those blurred with a 59 × 59-pixel window for experimental trials, those blurred with a 19 × 19-pixel window for training trials. The apparatus used for controlling the stimulus presentation and recording the subjects' response and response latency were the same as for experiments 1 and 2.

Design and Procedure: Type of discrimination task (happy vs. neutral, or sad vs. neutral) was a between-subject factor. Orientation (upright or upside-down) and blurring (original or blurred) were within-subject factors.

The subjects were instructed that the task was to decide whether the face showed a happy (or sad) expression or a neutral expression as quickly but as accurately as possible. The response was made by pressing one of two keys with the index fingers of the left and right hands. The response-hand assignment was counterbalanced across subjects. The duration of the stimuli was 2,000 msec regardless of subject's reaction time, and the intertrial interval was 2,000 msec. A warning tone preceded each trial by 500 msec.

For the training trials, the 14 pictures blurred by a 19 × 19 window were presented randomly. For the first half of the trials, the pictures were presented upright, and for the latter half, they were presented upside down. The experimental trials were divided into 4 blocks of 14 trials according to the stimulus conditions. Before each block, the subjects were informed of the type of the stimuli: original or blurred, and upright or upside-down. The order of each block and the order of each trial within a block were randomized for each subject.

RESULTS

First, the data on A' scores were analyzed as for experiments 1 and 2. For each subject, A' scores in each blurring condition were calculated. Mean A' scores are given in Figure 3. A 2 (discrimination task) × 2 (orientation) × 2 (blurring) mixed design ANOVA of the A' scores was conducted. All main effects were significant (discrimination task: $F(1{,}38) = 41.76, p < .01$; orientation: $F(1{,}38) = 11.06, p < .01$; blurring: $F(1{,}38) = 10.13, p < .01$). A discrimination task × blurring interaction was marginally significant ($F(1{,}38) = 3.78$, $.05 < p < .1$). Furthermore, a discrimination task × orientation × blurring interaction was significant ($F(1{,}38) = 7.62$, $p < .01$). No other interactions were significant (All F ratios < 2.24). An analysis of the three-way interaction revealed that discrimination between happy and neutral expressions was more accurate than that between sad and neutral expressions (All $ps < .01$), except when the original pictures were presented upright ($F < 1$). The inversion effects were significant for the blurred pictures in the discrimination task between happy and neutral expressions ($F(1{,}76) = 4.16$, $p < .05$), and for the original pictures in the discrimination task between sad and neutral expressions ($F(1{,}76) = 16.41$, $p < .01$), but not for other conditions (All F ratios < 1). The simple simple main effect of blurring was marginally significant for the upside-down condition in the discrimination task between happy and neutral expressions ($F(1{,}76) = 3.11$, $.05 < p < .1$). And it was significant for the upright condition in the discrimination task between sad and neutral expressions ($F(1{,}76) = 17.33$, $p < .01$). No other simple simple main effects of blurring were significant (All F ratios < 1).

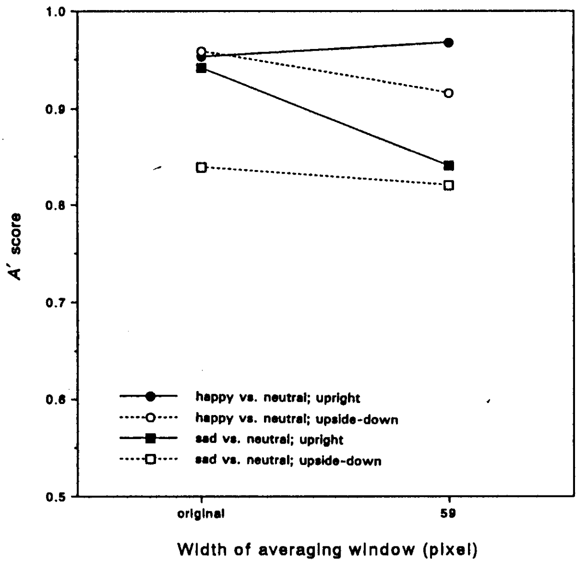

Fig. 3. Mean A' scores for each condition as a function of the width of averaging window (experiment 3). Mean face width was approximately 443 pixels.

For each subject, the mean reaction times for the correct responses and the error rates were calculated for each condition. The overall means for each condition are given in Figure 4. The data on error rates were not analyzed. This is because the data on A' scores reflected those on error rates, and because there was no evidence of speed-error trade-offs.

A 2 (expression) × 2 (orientation) × 2 (blurring) mixed design ANOVA of the correct reaction times for the discrimination task between happy and neutral expressions was conducted. This revealed significant effects of expression ($F(1,19) = 7.39, p < .05$) and of orientation ($F(1,19) = 12.73$, $p < .01$). A main effect of blurring was not significant ($F < 1$). An expression × blurring interaction was significant ($F(1,19) = 4.87$, $p < .05$). An orientation × blurring interaction was marginally significant ($F(1,19) = 3.02$, $.05 < p < .1$). No other interactions were significant (All F ratios < 2.02). An analysis of the expression × blurring interaction revealed that the simple main effect of blurring was significant for happy expression ($F(1,19) = 9.83$ $p < .01$), but not for neutral expression ($F < 1$). The simple main effect of expression was significant for the original pictures ($F(1,19) = 10.32$, $p < .01$), but not for the blurred pictures ($F < 1.12$). An analysis of the orientation × blurring interaction revealed that the simple main effect of orientation was significant for the blurredpictures ($F(1,19) = 17.91$, $p < .01$), but not for the original pictures ($F < 2.04$). The simple main effect of blurring was marginally significant for the

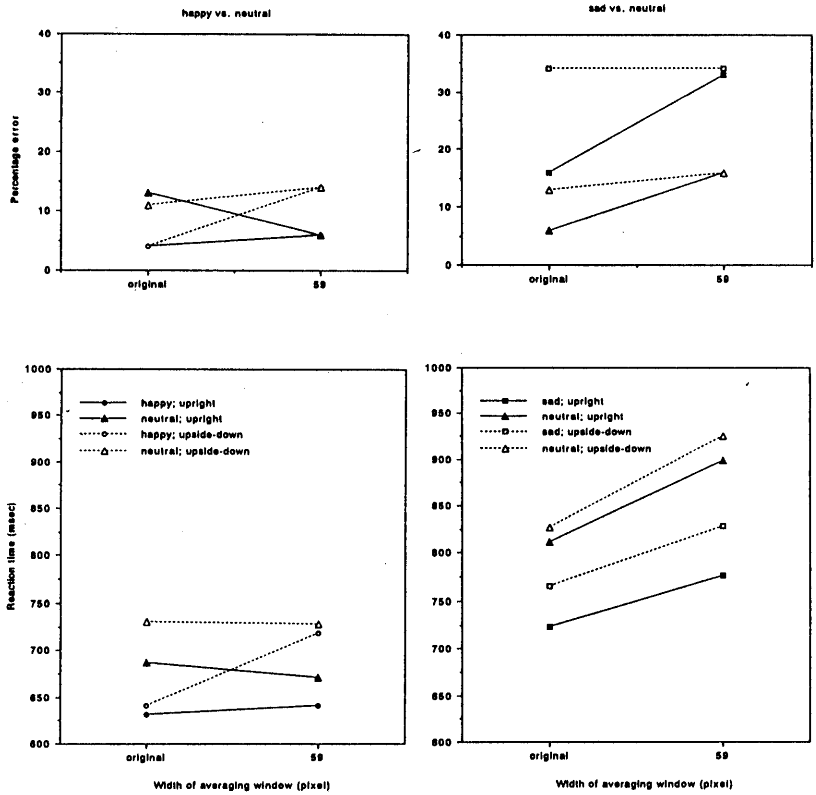

Fig. 4. Percentages of errors (upper panels) and reaction times of correct responses (lower panels) for the two discrimination tasks (experiment 3).

upside-down condition ($F(1,19) = 4.04$, $.05 < p < .1$), but not for the upright condition ($F < 1$).

A 2 (expression) × 2 (orientation) × 2 (blurring) mixed design ANOVA of the correct reaction times for the discrimination task between sad and neutral expressions was conducted. The main effects of expression and of blurring were significant ($F(1,19) = 30.18$, $p < .01$, $F(1,19) = 12.95$, $p < .01$, respectively). And the main effect of orientation was marginally significant ($F(1,19) = 3.79$, $.05 < p < .1$). Any interactions were not significant (All F ratios < 1.99).

Discussion

As for experiments 1 and 2, discrimination between happy and neutral expressions was compared with that between sad and neutral expressions. The reaction times for neutral expressions in the two discrimination tasks showed different patterns: each pattern was similar to that of reaction times for happy or sad expressions in each discrimination task. It supported the hypothesis that a face would be classified as a neutral expression when it can not be classified as any other expression.

The results showed that the time taken to recognize a happy expression was influenced by blurring for the inverted condition, but not for the upright condition; a happy expression can be recognized with low spatial-frequency contents when it is presented upright. On the other hand, irrespective of stimulus orientation, the blurred image of a sad face was recognized slower than the original image; recognizing a sad expression needs the high spatial-frequency contents in a face.

There were some differences in A' data between the present experiment and experiment 1. First, in the present experiment, discrimination between sad and neutral expressions was as accurate as discrimination between happy and neutral expressions when the original images of the facial expressions were presented upright; the happy face advantage was not observed. Second, the blurring effect was not obtained for the inverted condition in the discrimination between sad and neutral expressions. These differences might be caused by the fact that the subjects were asked to respond as fast as possible. In fact, with respect to both the two points, we obtained RT data that were consistent with the results of experiment 1.

We also obtained the results that were different from the previous experiments, not only for A' data but also for RT data. First, in the present experiment, the blurring effect was observed for the inverted condition in the discrimination between happy and neutral expressions. Second, inversion effects were not observed for the original images in the discrimination between happy and neutral expressions, whereas inversion effects were obtained for the original images in the discrimination between sad and neutral expressions. The former could support the simple hypothesis with regard to the interaction between blurring and orientation: when it is presented upside down, a happy expression will be recognized on the basis of processing the component information, so that recognition of a happy expression will be impaired by blurring. The latter also contradicts the results reported by Kirita and Endo (1995) using schematic faces as stimuli. This discrepancy did not deny their suggestion that happy faces are recognized holistically, whereas sad faces are recognized by the analytic mode, because the blurring effects obtained in experiment 3 is consistent with their suggestion. It might be attributable to the fact that the intensities of happy and sad expressions were not matched in the present study. The happy faces used for this study might deviate more from neutral expressions than the sad faces. Therefore, the happy faces would be discriminated from neutral expressions on the basis of component information as easily as on the basis of configural information.

General Discussion

We investigated the effects of image blurring on the recognition of happy and sad expressions in order to examine the information used for recognizing happy and sad expressions in terms of the spatial-frequency contents in a face. The results of experiments 1 and 2 showed that the accuracy of the discrimination between happy and neutral expressions did not decline until the facial images were blurred severely, and that it declined rapidly as the facial images were blurred further. On the other hand, the accuracy of the discrimination between sad and neutral expressions declined when the facial images were blurred slightly, and the accuracy declined gradually as the degree of blurring increased. The results of experiment 3 showed that when facial images were presented upright, the blurred images of happy faces were recognized as fast as their original images, whereas the blurred images of sad faces were recognized more slowly than their original images. This indicates that a happy expression can be recognized on the basis of low spatial-frequency contents in a face, whereas the recognition of a sad expression requires the high spatial-frequency contents. It supports the Kirita and Endo's (1995) suggestion that happy faces are likely to be recognized holistically, whereas sad faces are likely to be recognized by the analytic mode.

We also investigated the inversion effects on the recognition of happy and sad expressions. In this respect we obtained inconsistent results. In experiment 1, inversion effects were obtained for both the recognition of happy and sad expressions, but there was no difference in degree for both expressions. In experiment 2, there was no inversion effect for the recognition of the two expressions. In experiment 3, when the original images of facial expressions were presented, there was no difference in the time taken to recognize a happy expression between for the upright and the inverted conditions, although a sad expression was recognized faster for the upright condition than for the inverted condition. It has been shown that inversion impairs the processing of configural information in a face to some extent, but not completely (Endo, 1986; Endo, Masame, & Maruyama, 1990; Maruyama & Endo, 1983, 1984). Therefore, the inversion effects might be influenced by several factors, such as the stimuli used for the experiments and the subject's tasks.

In respect to the interaction between blurring and inversion, we also obtained inconsistent results. In experiments 1 and 2, it showed that irrespective of the discrimination tasks, inversion effects were obtained when the facial images were blurred slightly (experiment 1), but not when they were blurred severely (experiment 2). In experiment 3, the time taken to recognize a happy expression was influenced by blurring in the inverted condition, but not in the upright condition. On the other hand, irrespective of stimulus orientation, the blurred image of a sad face was recognized slower than its original image. Although the results of experiments 1 and 2 could not be easily explained, the RT data of experiment 3 could be explained by the difference in the processing mode between happy and sad expressions. A happy expression would be recognized holistically in the upright condition, whereas it would be recognized by the analytic mode in the inverted condition. Therefore, the blurring effects would be observed only when a happy face was presented upside down. On the other hand, a sad expression would be recognized by the analytic mode irrespective of its orientation, so that the blurring effects will be observed in both the orientation condition.

Finally, we should discuss the hypotheses for the happy face advantage proposed by Feyereisen et al. (1986), especially the two hypotheses related to modality-specific factors. As mentioned before, the happy face advantage cannot be explained only by the visual characteristics of happy faces, because the happy face advantage could be found, even if the spatial deviations of happy and sad schematic faces were equal (Kirita & Endo, 1995).

The hypothesis that ascribed the happy face advantage to the two-stage processing of facial expressions might accommodate the findings that happy and sad faces are recognized by different modes of processing. The low spatial-frequency contents in a face are sent to the brain first followed by the high spatial-frequency contents (Sergent, 1986). According to the two-stage processing of facial expressions, a face is first classified as positive or negative. This classification could be made on the basis of low spatial frequency contents. Happy faces would be recognized in the first stage, because there are fewer positive emotions. On the other hand, sad faces would be recognized in the second stage, in which high spatial-frequency contents would be used.

However, it should be noted that the two-stage processing model proposed by Feyereisen et al. (1986) involves a problem to be solved. According to this model, surprised expressions would be recognized as fast and accurately as happy expressions, because surprised expressions were also categorized as positive expressions. However, the prediction has not been supported by the investigations reported so far (see for a review, Ekman et al., 1982). One plausible hypothesis is that in the first stage a face would be classified as happy or not, rather than positive or negative, which would be made on the basis of the configural information. If it is not a happy expression, then finer classification to other expressions would be made on the basis of the component information. This hypothesis might be supported by the fact that RT data of experiment 3 can be explained more easily by the difference in the processing mode between happy and sad expressions than A' data of experiments 1 and 2, because RT data seems to reflect the processing modes of facial expression more directly than A' data.

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REFERENCES

Ekman, P., Friesen, W. V., & Ellsworth, P. **1982** Does the face provide accurate information? In P. Ekman (Ed.), *Emotion in the human face* (*2nd ed.*). Cambridge: Cambridge University Press, pp.56–97.

Endo, M. **1986** Perception of upside-down faces: An analysis from the viewpoint of cue saliency. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. W. Young (Eds.), *Aspects of face processing*. Dordrecht: Martinus Nijhoff, pp.53–58.

Endo, M., Masame, K., & Maruyama, K. **1990** A limited use of configural information in the perception of inverted faces. *Tohoku Psychologica Folia*, **49**, 114–125.

Feyereisen, P., Malet, C., & Martin, Y. **1986** Is the faster processing of expressions of happiness modality-specific? In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. W. Young (Eds.), *Aspects of face processing*. Dordrecht: Martinus Nijhoff, pp.349–355.

Harmon, L. D. **1973** The recognition of faces. *Scientific American*, **227**, 71–82.

Kirita, T., & Endo, M. **1995** Happy face advantage in recognizing facial expressions. *Acta Psychologica*, **89**, 149–163.

Kirouac, G., & Dore, F. Y. **1983** Accuracy and latency of judgment of facial expressions of emotions. *Perceptual and Motor Skills*, **57**, 683–686.

Maruyama, K., & Endo, M. **1983** The effect of face orientation upon apparent direction of gaze. *Thohoku Psychologica Folia*, **42**, 126–138.

Maruyama, K., & Endo, M. **1984** Illusory face dislocation effect and configural integration in the inverted face. *Tohoku Psychologica Folia*, **43**, 150–160.

Rae, G. **1976** A non-parametric measure of recognition performance. *Perceptual and Motor Skills*, **42**, 98.

Sergent, J. **1986** Microgenesis of face perception. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. W. Young (Eds.), *Aspects of face processing*. Dordrecht: Martinus Nijhoff, pp.17–33.

Sergent, J., & Bindra, D. **1981** Differential hemispheric processing of faces: Methodological considerations and reinterpretation. *Psychological Bulletin*, **89**, 541–554.

Valentine, T. **1988** Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology*, **79**, 471–491.

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