特集

Categorical perception is not a hallmark of fast initial processing of facial expressions of emotions^{1 2}

Atsunobu Suzuki³

*Department of Cognitive and Behavioral Science, The University of Tokyo, Komaba
Research Fellow of the Japan Society for the Promotion of Science*

Susumu Shibui

*Department of University Evaluation and Research,
National Institution for Academic Degrees and University Evaluation*

Kazuo Shigemasa

Department of Cognitive and Behavioral Science, The University of Tokyo, Komaba

Initial processing of facial expressions of emotions has been shown to occur very fast, even without awareness. In order to determine whether the fast initial processing of facial expressions is categorical, we investigated temporal characteristics of categorical perception (CP) of facial expressions. We examined the effects of shortening stimulus duration on participant performance with respect to identifying (Experiment 1) and discriminating (Experiment 2) morphed facial expressions. Results of the two experiments suggested that CP was attenuated or even disappeared when facial stimuli were presented for as briefly as 50–75 milliseconds. These findings suggest that CP may be irrelevant in the fast initial processing of facial expressions.

Key words: facial expressions of emotions, fast initial processing, categorical perception

Facial expressions of emotions are processed very quickly, even without awareness (Morris, Ohman, & Dolan, 1998; Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998). It has been proposed that the fast initial processing provides a ‘dirty’ image of the external world, enabling organisms to detect salient emotional stimuli immediately (Adolphs, 2002; LeDoux, 1996). It is still not understood, however, how

facial expressions are represented in the fast initial processing.

A hallmark of the processing of facial expressions is its categorical nature, that is, facial expressions are represented as discrete categories of emotions, so-called basic emotions (e. g., Ekman, 1992; Izard, 1992). Reports on categorical perception (CP) of facial expressions are thought to provide strong evidence that people represent facial

1 This article is based on a paper presented at the 26th Annual Meeting of Cognitive Science Society, Chicago, August 2004.

2 Special thanks to Y. Hashimoto and K. Sakaguchi for their help in preparing the facial stimuli.

3 Requests for reprints should be sent to Atsunobu Suzuki, now at the Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, 405 N. Mathews, Urbana, IL 61801, U. S. A., atsuzuki@uiuc.edu.

expressions categorically (Calder, Young, Perrett, Etcoff, & Rowland, 1996; DeGelder, Teunisse, & Benson, 1997; Etcoff & Magee, 1992; Young, Rowland, Calder, Etcoff, Seth, & Perrett, 1997). Previous studies have confirmed that the processing of facial expressions fulfills the following features of CP: (a) in identifying a stimulus within a continuum extending from one category to another, the rate of categorizing the stimulus changes abruptly at a boundary (category boundary); and (b) in discriminating a pair of stimuli that differ by a constant physical amount, discrimination is superior for pairs straddling the category boundary (between-category pairs), as compared to pairs falling within one category (within-category pairs). Based on CP of facial expressions, Etcoff and Magee (1992) propose that the perceptual system obligatorily transforms any given facial expression into categorical information corresponding to the most likely emotion. This view implies that facial expressions are represented categorically already in the fast initial processing.

In previous research, however, facial stimuli were presented for a relatively long period (≥ 750 ms), so it remains to be tested empirically whether the fast initial processing of facial expressions is categorical in nature. The issue is worth empirical examination given conflicting features of categorical perception and fast initial processing: the former involves the fine processing of ambiguous stimuli (attributing a discrete emotion to any ambiguous expression), whereas the latter involves the coarse processing of salient stimuli (Adolphs, 2002; LeDoux, 1996). Furthermore, some authors (Russell, 1997;

Yamada, 1993) propose a different view that continuous information of a few emotional dimensions (e. g., valence, arousal) is extracted from facial expressions in initial stages, and that categorization of facial expressions is done in later stages on the basis of dimensional information.

Therefore, in the current study, we investigated the effects of shortening stimulus duration on CP of facial expressions in order to examine whether the fast initial processing was categorical or not.

Experiment 1

In Experiment 1, participants identified facial expressions from three continua extending from anger to happiness, from happiness to fear, and from fear to anger. We investigated how shortening stimulus exposure duration (750 ms, 150 ms, 50 ms) affected the abrupt change in the rate of identification at the category boundary. The three emotions were selected on the basis of dimensional information of valence and arousal: fear and anger represent unpleasant and aroused states, whereas happiness represents a pleasant and (moderately) aroused state. The three emotions yielded both congruent (fear-anger) and incongruent (anger-happiness, happiness-fear) pairs in dimensional information and enabled us to contrast the categorical account (Etcoff & Magee, 1992) with the dimensional account (Russell, 1997; Yamada, 1993).

Methods

Participants. Twelve undergraduates and postgraduates participated (8 men, 4 women; 20–24 years old).

Stimuli. Three sets of eight gray-scale

images of facial expressions were used (Figure 1). Each set consisted of a continuum extending either from anger to happiness, from happiness to fear, or from fear to anger. The original (endpoint) facial expressions were posed photographs of a Japanese woman. The photographs were prepared by reference to Matsumoto and Ekman (1988), and a pilot study⁴ confirmed high percentage recognition of the corresponding emotion (unpublished data; happiness 99%, fear 57%, anger 86%), comparable to standard picture sets (Biehl, Matsumoto, Ekman, Hearn, Heider, Kudoh, & Ton, 1997; Ekman & Friesen, 1976; Matsumoto & Ekman, 1988).

The interpolated (morphed) expressions between the two continuum endpoints were created with ‘software for facial expression

Figure 1 Facial expression continua used in Experiment 1. From left to right, the continua shown in each row are anger-happiness (top row), happiness-fear (middle row), and fear-anger (bottom row).

processing’ (Information-technology Promotion Agency, Japan, 1998) as was used in our previous studies (Shibui, Yamada, Sato, & Shigemasu, 2001; Shibui, Yamada, & Shigemasu, 2004)⁵. The morph transformation started with the delineation of two endpoint expressions; landmarks were placed manually on critical positions of each image. There were 759 landmarks in total, 88 points of which were placed manually on corresponding positions of each image: for the head, 4 points; for the outline, 28 points; for the eyes, 5×2 points; for the eyebrows, 4×2 points; for the nose, 4 points; for the mouth, 6 points; for the neck, 13 points; and finally for the hairline, 15 points. An intermediate face was then created with linear interpolation between point-to-point pixel intensity values, yielding a weighted blend of both facial configuration and texture of the two endpoint faces. Six intermediate faces were generated for each continuum, so that eight images from one endpoint to the other were spaced with a 14.3% gap.

Procedure and design. Participants performed the identification task (three sessions) by viewing stimuli presented on a 17-inch CRT monitor (resolution 1024×768 pixels; refresh rate 75 Hz). Each trial began with an 800-ms presentation of a fixation point, followed by a blank interval of 300 ms, and then a facial stimulus from one continuum for 750 ms, 150 ms, or 50 ms. After a 300-ms blank interval, participants

4 The seven-alternative (happiness, surprise, fear, anger, disgust, sadness, neutral) forced-choice identification task was carried out ($n = 150$).

5 A sequence of stimuli that vary with a constant physical increment is the requisite of CP experiments. Because people cannot display such a linear sequence of facial expressions voluntarily, morphing techniques have been used in studying CP of facial expressions. The use of morphed facial expressions, at the cost of artificiality, enables us to examine the processing of facial expressions in a well-controlled setting. In addition, morphed facial expressions are assumed to simulate ambiguous facial expressions in real-life communication (Ogawa, 2000).

were asked to decide which endpoint category the face expressed. At a viewing distance of 65 cm, facial stimuli subtended a 6.2×9.0 degree visual angle.

The continuum was manipulated across sessions: from anger to happiness (AH session), from happiness to fear (HF session), and from fear to anger (FA session). The order of the three sessions was counterbalanced across participants. Each session began with 24 training trials, followed by five blocks of 48 experimental trials, corresponding to two repetitions of the 24 combinations of faces (8) and stimulus durations (3). The order of the face-duration sets was fully randomized in each repetition.

Results and discussion

Figure 2 displays the overall percentage with which a given endpoint expression was identified at each stimulus duration, for each continuum. As an estimate of the category boundary, the point at which two endpoints were identified with equal probability was computed by applying a logit model to each identification rate curve (Table 1). In general, the category boundary lay near the 50% morph⁶. More importantly, Table 1 also indicates the slope of the logistic curve at the category boundary as a measure of the identification rate change at the boundary. Multiple comparisons (z tests) with Bonferroni's method ($\alpha = 0.017$)⁷

revealed that the slope at 50 ms was significantly, or marginally significantly, smaller than at 150 ms and at 750 ms for the anger-happiness and happiness-fear continua (AH session, 50 ms vs. 150 ms, $z = 2.37$, $p = 0.018$, 50 ms vs. 750 ms, $z = 3.67$, $p < 0.001$, 150 ms vs. 750 ms, $z = 1.48$, $p = 0.139$; HF session, 50 ms vs. 150 ms, $z = 2.69$, $p = 0.007$, 50 ms vs. 750 ms, $z = 4.07$, $p < 0.001$, 150 ms vs. 750 ms, $z = 1.74$, $p = 0.082$). No slope change was observed for the fear-anger continuum ($p > 0.35$).

The decreased slopes of the identification rate curves for the anger-happiness and happiness-fear continua at 50 ms indicate that the CP of facial expressions is attenuated with the briefest stimulus exposure duration. The lack of slope change for the fear-anger continuum may be due to the originally weak categorical perception between fear and anger, which reflects their remarkable similarity with respect to the dimensional information of valence and arousal (Russell, 1997). Indeed, the slope for the fear-anger continuum was the smallest of the three continua at 750 ms. Likewise, there are previous reports that have failed to detect clear CP for the fear-anger continuum (Calder et al., 1996; DeGelder et al., 1997). Recent neurological (Sato, Kubota, Okada, Murai, Yoshikawa, & Sengoku, 2002) and neuroimaging (Whalen, Shin, McInerney, Fischer, Wright, & Rauch, 2001) studies also indicate overlapping neural substrates for

6 Because physical equality did not accurately correspond to subjective equality, the category boundary was not located exactly at the 50% morph.

7 For each continuum, we obtained maximum likelihood estimates of the slopes at three durations ($\hat{S}_{50\text{ms}}$, $\hat{S}_{150\text{ms}}$, $\hat{S}_{750\text{ms}}$) and their standard errors ($SE(\hat{S}_{50\text{ms}})$, $SE(\hat{S}_{150\text{ms}})$, $SE(\hat{S}_{750\text{ms}})$). By postulating that a maximum likelihood estimator follows an asymptotic normal distribution, we tested a difference between any two slopes with a z test; e. g., under the null hypothesis of $S_{50\text{ms}} = S_{150\text{ms}}$, the test statistic of $z = (\hat{S}_{50\text{ms}} - \hat{S}_{150\text{ms}}) / \{SE(\hat{S}_{50\text{ms}})^2 + SE(\hat{S}_{150\text{ms}})^2\}^{1/2}$ follows the standard normal distribution. Because we performed z tests three times for each continuum, we adopted a Bonferroni-corrected significance level of $0.017 (= 0.05/3)$ to control for type I error. We did not adjust the significance level for all the nine comparisons, because such a strict criterion would result in type II error.

Figure 2 Overall percentage with which a given endpoint expression (top left: happiness, top right: fear, bottom: anger) was identified at each stimulus duration, for each session. *Morph* represents a percentage of happiness (top left), fear (top right), or anger (bottom) for a given face.

Table 1 Estimates of the position of the category boundary and the slope at the boundary

Session	Duration	Boundary (%)	Slope
AH	750 ms	56.9	14.5
	150 ms	52.5	12.5
	50 ms	49.0	10.0
HF	750 ms	43.3	18.1
	150 ms	47.9	14.9
	50 ms	51.2	11.3
FA	750 ms	53.9	13.3
	150 ms	51.8	13.8
	50 ms	49.2	12.6

Note. *Boundary* represents a percentage of happiness (AH Session), fear (HF Session), or anger (FA Session) for a morphed face.

the recognition of fear and anger.

Experiment 2

Experiment 1 revealed that the abrupt change in identification rate at the category boundary was attenuated at the briefest stimulus exposure duration, indicating that CP of facial expressions did not reflect fast initial processing. Thus, we can evaluate relative attenuation of CP by analyzing the level of sigmoidality in the identification curve. However, a certain level of sigmoidality in a response curve is

inevitable in a task where binary responses are required. Because of the limitation, we cannot demonstrate an absolute lack of CP using the identification task alone.

Therefore, Experiment 2 investigated whether superior discrimination for between-category pairs could be observed with the brief stimulus exposure duration when compared to discrimination for within-category pairs. Because a more accurate discrimination performance for between-category pairs is regarded as the key indicator of CP (Harnad, 1987), its disappearance at the brief stimulus duration provides crucial evidence that categorical perception does not occur rapidly. In Experiment 2, participants engaged in both discrimination and identification tasks of facial expressions from the happiness-fear continuum. We selected the happiness-fear continuum from the three continua used in Experiment 1 because it did not incorporate any gross changes in physical features (e. g., from open to closed mouth), which might obscure CP (Calder et al., 1996). In addition, studies using neuroimaging (Morris, Friston, Buchel, Frith, Young, Calder, & Dolan, 1998; Morris, Frith, Perrett, Rowland, Young, Calder, & Dolan, 1996; Whalen et al., 1998; Wright, Fischer, Whalen, McNerney, Shin, & Rauch, 2001) and developmental data (Kotsoni, DeHaan, & Johnson, 2001) have indicated that happiness and fear are the most distinct categories, and thus examination of the happiness-fear continuum is of particular interest.

Methods

Participants. Twenty-three undergraduates participated (12 men, 11

women; 18–24 years old).

Stimuli. One set of 11 gray-scale images of facial expressions was used. The set consisted of a continuum extending from happiness to fear. The endpoint expressions and the morphing procedure to create interpolated faces were the same as in Experiment 1. Nine intermediate faces were generated so that the 11 images from happiness to fear were spaced with a 10% gap.

Procedure and design. Participants performed the XAB discrimination task and the identification task in this order by viewing stimuli presented on a 17-inch CRT monitor (resolution 1024×768 pixels; refresh rate 75 Hz). At a viewing distance of 80 cm, facial stimuli subtended a 3.9×5.7 degree visual angle.

XAB discrimination task. The sequence of the stimuli presented in each trial was as follows: (1) a fixation point for 450 ms; (2) a blank interval for 300 ms; (3) a facial stimulus 'X' for 150 ms or 75 ms (target); (4) a black-and-white checker-pattern for 150 ms (backward mask); (5) a blank interval for 750 ms; (6) and finally, two facial stimuli 'A' and 'B', positioned horizontally to the right and left of center, displayed until the participants responded (reference). Participants were asked to decide which reference was identical to the target.

The backward mask was used to restrict visual access to the target over the controlled stimulus exposure duration (Enns & DiLollo, 2000). Because the backward mask might degrade target perception, we used 75 ms as the brief exposure duration, which is somewhat longer than the 50 ms tested in Experiment 1. We also used 150 ms as the sole longer

exposure duration interval, because we speculated that task difficulty might differ too much between 75 ms and 750 ms. Reference stimuli were spaced with a 20% gap, resulting in nine possible pairs (i. e., from a pair of 0%-fear [100%-happiness] and 20%-fear [80%-happiness] morphs to a pair of 80%-fear and 100%-fear morphs). For each pair, there were four presentation orders; (X, A, B) = (A, A, B), (A, B, A), (B, A, B), (B, B, A). Target duration was manipulated across sessions, and the order of the two durations was counterbalanced across participants. Each session contained 10 training trials and two blocks of 36 experimental trials representing all combinations of pairs (9) and presentations (4). The order of the pair-presentation sets was fully randomized in each block.

Identification task. Stimulus sequence in each trial was the same as in the XAB discrimination task, with the exception that reference stimuli were removed. Participants were asked to decide whether the target stimulus expressed fear or happiness. The order of the two sessions across which the target duration was manipulated was the same as in the XAB discrimination task. Each session contained 10 training trials and two blocks of 44 experimental trials corresponding to four repetitions of the 11 faces. The order of the faces was fully randomized in each repetition.

Results and discussion

Because analyses of the XAB discrimination task were based on those of the identification task, we reported the latter first.

Identification Task. Figure 3 presents the

Figure 3 Overall percentage with which “fear” was identified at each stimulus duration. *Morph* represents a percentage of “fear” for a given face.

overall percentage of trials in which “fear” was identified at each stimulus exposure duration in the identification task. Application of a logit model to each identification rate curve revealed that the category boundary lay at 52.4% (150 ms) and 55.2% (75 ms). Contrary to the results of Experiment 1, logit models also showed that the slope at 150 ms (17.9) was somewhat smaller than at 75 ms (19.4), though this difference did not reach significance ($z = 1.03$, $p = 0.303$). As the slope was attenuated in proportion to the decreased duration in Experiment 1, these data suggest that the duration difference between 150 ms and 75 ms was insufficient to cause a significant slope change.

XAB Discrimination Task. Figure 4 presents the overall correct response rate for each stimulus exposure duration in the XAB discrimination task. The data from the identification task revealed that between-category pairs straddling the category boundary were a 40%-60% pair and a 50%-70% pair at both durations. The peak in discrimination performance at the between-category pairs was found only at the 150-ms stimulus exposure duration.

Figure 4 Overall correct response rate in the XAB discrimination task for each duration (left: 150 ms, right: 75 ms). *Observed* = observed rate. *Theoretical* = theoretical rate predicted from CP. *Morph* represents a percentage of “fear” for the less fearful face of a given pair.

We calculated the mean correct rate for between-category pairs (40%–60%, 50%–70%) and pairs lying well within each category (within-category pairs; 0%–20%, 80%–100%) for each duration (Figure 5), and conducted a 2×2 ANOVA of the mean correct rate with the two factors of pair (between-category or within-category) and stimulus duration (150 ms or 75 ms). A significant main effect of

pair was found ($F(1, 22) = 11.37, p = 0.003$), indicating better discrimination for between-category pairs than for within-category pairs. The main effect of duration was not significant ($F(1, 22) = 1.89, p = 0.183$). There was a significant interaction between the two factors ($F(1, 22) = 5.22, p = 0.032$). Post-hoc paired t tests revealed that superior discrimination for between-category pairs was significant only at the 150-ms exposure duration (150 ms, $t(22) = 3.92, p = 0.001$; 75 ms, $t(22) = 0.84, p = 0.412$).

To indicate CP in the discrimination task, previous studies (Calder et al., 1996; Young et al., 1997) have reported correlations between observed and theoretical performances, predicted from CP. Calder and colleagues (Calder et al., 1996) assumed that discrimination between two facial expression stimuli depends on two cues: first, the physical difference between the stimuli, which is constant for any pair, regardless of their expressions; and second, the expression categories of the

Figure 5 Mean correct response rate for between- and within-category pairs in the XAB discrimination task at each duration. Error bars represent standard errors.

stimuli. To estimate the contribution of the first non-categorical cue, they computed the mean observed discrimination for the two pairs, placed at both ends of the continuum. To estimate the contribution of the second categorical cue, they calculated the difference in identification rates for the two relevant stimuli observed in the identification task, and multiplied the obtained difference by 0.25 (a constant). Calder et al. (1996) argued that summing the two estimates measures theoretical performance in the discrimination task.

Figure 4 also presents theoretical performance, based on the same formula as Calder et al. (1996), along with observed performance. The fit between observed and theoretical performance looks better at 150 ms than at 75 ms; indeed, their correlation was significant only at the 150-ms exposure duration (150 ms, $r = 0.667$, $t(7) = 2.37$, $p = 0.050$; 75 ms, $r = 0.362$, $t(7) = 1.03$, $p = 0.338$).

Analyses revealed that the superior discrimination performance for between-category pairs disappeared at 75 ms but was present at 150 ms, providing good evidence of null CP at the brief stimulus duration. In response to objections claiming that observing only one continuum is insufficient, we argue that happiness and fear have been shown to be the most distinct emotion categories (Kotsoni et al., 2001; Morris et al., 1996, 1998; Whalen et al., 1998; Wright et al., 2001). Thus, we can infer from the lack of CP between happiness and fear (i. e., the most distinct categories) that CP will not occur between other less distinct categories, though the inference may merit empirical examination in the future. Critics might also insist that the disappearance of CP at 75 ms is a floor effect; however,

discrimination for any stimulus pair at 75 ms was above chance ($p < 0.01$), indicating that residual perception of differences in some visual properties was present. Moreover, the 75-ms duration was sufficient for accurate identification of near-endpoint facial expressions (see Figure 3). Ogawa and Suzuki (1999) also reported that prototypical facial expressions of happiness and fear were easily recognized under a brief exposure duration (≤ 64 ms). Thus, categorical perception did not occur, even with such well-preserved visual processing.

General discussion

The current experiments revealed that categorical perception of facial expressions was attenuated and even disappeared with brief stimulus exposure durations. The abrupt change in identifying facial expressions at the category boundary was weakened at the 50-ms stimulus duration (Experiment 1), and the more accurate discrimination observed for between-category pairs than for within-category pairs was eliminated at the 75-ms stimulus duration (Experiment 2). The results indicate that categorical perception is not a hallmark of fast initial processing of facial expressions of emotions.

Our findings are inconsistent with the prediction from Etcoff and Magee (1992) that facial expressions are represented categorically even in the initial processing. It has been argued, however, that the fast initial processing of emotional stimuli such as facial expressions involves subcortical structures, specialized in the coarse detection of salient stimuli (Adolphs, 2002; LeDoux, 1996), and that the fine analysis of ambiguous stimuli involves cortical

structures, implying slower processing. This view predicts that CP is a hallmark of slow processing because it refers to the fine analysis of ambiguous facial expressions. The latter prediction is consistent with our findings.

Moreover, categorical perception has been shown to occur not only for emotional categories but also for non-emotional categories such as identity (Beale & Keil, 1995; Levin & Beale, 2000), race (Levin & Angelone, 2002), and even familiar objects (Newell & Bulthoff, 2002). Categorical perception of facial expressions may thus reflect visual information processing that is common to general object recognition rather than specific to emotional processing. The facts may also predict that CP of facial expressions is unlikely to reflect the fast emotional processing, which is a hallmark of emotional processing.

Etcoff and Magee (1992) further claimed that their observation of CP of facial expressions rejects the possibility that categorization of facial expressions is performed by higher conceptual and linguistic systems. There are data, however, demonstrating that verbal interference eliminated CP of colors and facial expressions, suggesting the essential role of verbal coding over visual coding (Roberson & Davidoff, 2000). Medin and Barsalou (1987) have argued that it is important to distinguish between sensory perception categories (SP categories), categories related to low-level perceptual experiences, and generic knowledge categories (GK categories), categories related to high-level knowledge representation. Shibui and colleagues (Shibui et al., 2001) found that discrimination

accuracy for within-category pairs of facial expressions was proportional to their semantic distance, and they inferred that facial expressions belong to cognitive GK categories. Our findings are consistent with the view that categorization of facial expressions is performed in late stages, which may involve higher cognitive systems.

The above view also seems compatible with a dimensional account of facial expression recognition (Russell, 1997; Yamada, 1993), postulating that assignment of discrete emotion categories is preceded by evaluation of continuous emotion dimensions. The dimensional account is also supported by the results in Experiment 1, suggesting that CP is originally weak between emotions that have similar dimensional information (i. e., fear and anger). Nevertheless, the current study is designed mainly to examine whether the fast initial processing of facial expressions is *categorical or not*, and it provides only indirect evidence for the processing of dimensional information. Thus, in the future research, it is necessary to examine directly whether the fast initial processing of facial expressions is *dimensional or not*.

References

- Adolphs, R. 2002 Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, **12**, 169-177.
- Beale, J. M., & Keil, F. C. 1995 Categorical effects in the perception of faces. *Cognition*, **57**, 217-239.
- Biehl, M., Matsumoto, D., Ekman, P., Hearn, V., Heider, K., Kudoh, T., & Ton, V. 1997 Matsumoto and Ekman's Japanese and Caucasian Facial Expressions of Emotion (JACFEE): reliability data and cross-national

- differences. *Journal of Nonverbal Behavior*, **21**, 3-21.
- Calder, A. J., Young, A. W., Perrett, D. I., Etcoff, N. L., & Rowland, D. 1996 Categorical perception of morphed facial expressions. *Visual Cognition*, **3**, 81-117.
- DeGelder, B., Teunisse, J. P., & Benson, P. J. 1997 Categorical perception of facial expressions: categories and their internal structure. *Cognition and Emotion*, **11**, 1-23.
- Ekman, P. 1992 Are there basic emotions? *Psychological Review*, **99**, 550-553.
- Ekman, P., & Friesen, W. V. 1976 *Pictures of Facial Affect* [CD]. Palo Alto, California: Consulting Psychologists Press.
- Enns, J. T., & DiLollo, V. 2000 What's new in visual masking? *Trends in Cognitive Sciences*, **4**, 345-352.
- Etcoff, N. L., & Magee, J. J. 1992 Categorical perception of facial expressions. *Cognition*, **44**, 227-240.
- Harnad, S. 1987 Psychophysical and cognitive aspects of categorical perception: a critical over view. In S. Harnad (Eds.), *Categorical perception: the groundwork of cognition*. Cambridge: Cambridge University Press. pp. 1-25.
- Information-technology Promotion Agency, Japan. 1998 *Software for Facial Image Processing System for Human-like 'Kansei' Agent* [Computer Software]. Retrieved from <http://www.hc.ic.i.u-tokyo.ac.jp/soft.php>.
- Izard, C. E. 1992 Basic emotions, relations among emotions, and emotion-cognition relations. *Psychological Review*, **99**, 561-565.
- Kotsoni, E., DeHaan, M., & Johnson, M. H. 2001 Categorical perception of facial expressions by 7-month-old infants. *Perception*, **30**, 1115-1125.
- LeDoux, J. 1996 *The emotional brain: the mysterious underpinnings of emotional life*. New York: Simon & Schuster Inc.
- Levin, D. T., & Angelone, B. L. 2002 Categorical perception of race. *Perception*, **31**, 567-578.
- Levin, D. T., & Beale, J. M. 2000 Categorical perception occurs in newly learned faces, other-race faces, and inverted faces. *Perception and Psychophysics*, **62**, 386-401.
- Matsumoto, D., & Ekman, P. 1988 *Japanese and Caucasian Facial Expressions of Emotion (JACFEE) and Neutral Faces (JACNeuF)* [CD]. San Francisco State University, San Francisco.
- Medin, D. L., & Barsalou, L. W. 1987 Categorization processes and categorical perception. In S. Harnad (Eds.), *Categorical perception: the groundwork of cognition*. Cambridge: Cambridge University Press. pp. 1-25.
- Morris, J. S., Friston, K. J., Buchel, C., Frith, C. D., Young, A. W., Calder, A. J., & Dolan, R. J. 1998 A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain*, **121**, 47-57.
- Morris, J. S., Frith, C. D., Perrett, D. I., Rowland, D., Young, A. W., Calder, A. J., & Dolan, R. J. 1996 A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature*, **383**, 812-815.
- Morris, J. S., Ohman, A., & Dolan, R. J. 1998 Conscious and unconscious emotional learning in the human amygdala. *Nature*, **393**, 467-470.
- Newell, F. N., & Bulthoff, H. H. 2002 Categorical perception of familiar objects. *Cognition*, **85**, 113-143.
- Ogawa T. 2000 Studies on the recognition of ambiguous facial expression and their ecological validity. *Japanese Psychological Review*, **43**, 295-306.
- Ogawa, T., & Suzuki, N. 1999 Response differentiation to facial expression of emotion

- as increasing exposure duration. *Perceptual and Motor Skills*, **89**, 557-563.
- Roberson, D., & Davidoff, J. 2000 The categorical perception of colors and facial expressions: the effect of verbal interference. *Memory and Cognition*, **28**, 977-986.
- Russell, J. A. 1997 Reading emotions from and into faces: resurrecting a dimensional-contextual perspective. In J. A. Russell, & J. M. Fernandez-Dols (Eds.), *The psychology of facial expression*. Cambridge: Cambridge University Press. pp. 295-320.
- Sato, W., Kubota, Y., Okada, T., Murai, T., Yoshikawa, S., & Sengoku, A. 2002 Seeing happy emotion in fearful and angry faces: qualitative analysis of facial expression recognition in a bilateral amygdala-damaged patient. *Cortex*, **38**, 727-742.
- Shibui, S., Yamada, H., Sato, T., & Shigemasu, K. 2001 The relationship between the categorical perception of facial expressions and semantic distances. *The Japanese Journal of Psychology*, **72**, 219-226.
- Shibui, S., Yamada, H., & Shigemasu, K. 2004 Evaluation of the processing model of facial expressions by means of adaptation to facial expressions of emotion. *Journal of Japanese Academy of Facial Studies*, **4**, 45-55.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. 1998 Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, **18**, 411-418.
- Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., Wright, C. I., & Rauch, S. L. 2001 A functional MRI study of human amygdala responses to facial expressions of fear versus anger. *Emotion*, **1**, 70-83.
- Wright, C. I., Fischer, H., Whalen, P. J., McInerney, S., Shin, L. M., & Rauch, S. L. 2001 Differential prefrontal cortex and amygdala habituation to repeatedly presented emotional stimuli. *NeuroReport*, **12**, 379-383.
- Yamada, H. 1993 Visual information for categorizing facial expression of emotions. *Applied Cognitive Psychology*, **7**, 257-270.
- Young, A. W., Rowland, D., Calder, A. J., Etcoff, N. L., Seth, A., & Perrett, D. I. 1997 Facial expression megamix: tests of dimensional and category accounts of emotion recognition. *Cognition*, **63**, 271-313.