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Research Report

Neural correlates of top–down processing in emotion perception: An ERP study of emotional faces in white noise versus noise-alone stimuli

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ABSTRACT

In the present study, we investigated the neural correlates underlying the perception of emotion in response to facial stimuli in order to elucidate the extent to which emotional perception is affected by the top–down process. Subjects performed a forced, two-choice emotion discrimination task towards ambiguous visual stimuli consisted of emotional faces embedded in different levels of visual white noise, including white noise-alone stimuli. ERP recordings and behavioral responses were analyzed according to the four response categories: hit, miss, false alarm and correct rejection. We observed enlarged EPN and LPP amplitudes when subjects reported seeing fearful faces and a typical emotional EPN response in the white noise-alone conditions when fearful faces were not presented. The two components of the ERP data which imply the characteristic modulation reflecting emotional processing showed the type of emotion each individual subjectively perceived. The results suggest that top–down modulations might be indispensable for emotional perception, which consists of two distinct stages of stimulus processing in the brain.

1. Introduction

Evidence accumulated during the last decade has suggested that emotional events, particularly when characterized as threatening, can be automatically encoded and processed (Öhman, 2005; Phelps, 2006). Early functional MRI studies showed the process of emotional stimuli to be independent of attention (Vuilleumier et al., 2001, 2004) and of conscious perception (Whalen et al., 1998). Given the significance of emotional information which is closely related to one's safety, this automatic manner of emotional stimulus processing is considered to provide adaptive advantages. Majority of the prior studies on emotional perception were conducted based on the hypothesis that the emotional process is mainly stimulus-driven. However, some recent researches have demonstrated an alternative manner of emotional processing. In one study, it was found that the activation of the amygdala in response to unattended fearful faces at fixation depends on the availability of attentional resources (Pessoa et al., 2005a,b). Another study has shown that the emotional response in the amygdala can be observed only when the subjects were visually aware of the masked fearful stimuli (Pessoa et al., 2006).

In addition to the abovementioned result, Pessoa et al. (2006) have also observed that the amygdala responses were

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closely linked to subjective report, showing stronger activity when the subjects reported seeing fearful faces, even though there were no fearful faces physically presented. Wild and Busey (2004), in another study, presented results showing a distinct evoked potential response reflected by the N170 component, which is a hallmark of facial processing, merely by subjective perceptual choice. In this study, the subjects were required to discriminate between a face and word stimulus embedded in noise with an additional condition consisting of noise-alone stimuli. A larger N170 deflection appeared when the subjects reported seeing a face in the noise display, even when there was no corresponding facial stimulus embedded in the noise-alone display (Wild and Busey, 2004). Together with these findings which showed neural responses closely linked to subjective percepts, a study that covered the contextual effect on emotion also suggested compelling evidence of top–down influence on emotional perceptual processing. In this previous study, amygdala response to surprised facial expressions was modulated by the verbal contextual information. Surprised faces produced greater amygdala activation when preceded by a negative cue compared to a positive cue (Kim et al., 2004). Collectively, these results suggest that a neural response could be evoked correspondingly to the subjective state or by top–down modulation without any bottom–up stimulus. Thus, the specification of neural correlates of top–down processing should be taken into consideration when studying emotional perception.

In the present study, we aimed to investigate the neural correlates of the top–down process in regard to emotional perceptual processing. To address this issue, we used visual stimuli consisting of fearful faces and neutral faces embedded in noise patches so that the emotional perceptual choice toward the facial stimuli would be subject to top–down processing. The amount of noise added (high vs. low) to the stimuli was designed to bring forth differential ambiguities which lead subjects to perceive emotional faces according to their subjective perceptions. By contrasting the choice responses of hit, miss, false alarm and correct rejection elicited in the presence or absence of the corresponding emotional stimuli, we observed a top–down mechanism at work: namely how it asserts influence on the emotional perceptual process.

To this end, we have primarily focused on the modulation of the well-established ERP component early posterior negativity (EPN) and late positive potentials (LPP) related to emotional processing. Steady findings showed that the processing of emotional stimuli is associated with a negative deflection over the temporo-occipital sites within a time window of between 200 and 300 ms. This displays a pronounced difference between the process of emotionally arousing pictures and neutral ones (Schupp et al., 2006). Following the modulation during perceptual encoding, consistent observation showed an elicited increase in late positive potentials apparent around 400–600 ms after stimulus onset over the centro-parietal regions (Batty and Taylor, 2003; Schupp et al., 2004a,b). This positive late potential is known to reflect a process which allows more elaborative processing of the visual stimuli after the stimulus categorization is completed (Ritter and Ruchkin, 1992; Schupp et al., 2006).

As EPN is suggested to reflect a transient stage at which motivationally significant stimuli are 'tagged' for preferential processing and LPP to reflect sustained attention toward such stimuli (Cuthbert et al., 2000; Michalowski et al., 2009; Schupp et al., 2006, 2008), the two ERP components may be viable indices in observing the top–down influence (i.e., viewer-directed emotion) on emotional perceptual processing. We assessed how the specific ERP components which reflect different stages of the perceptual process vary according to different percepts. On the basis of previous findings on preferential processing triggered by fear-relevant cues (Carlsson et al., 2004; Öhman et al., 2001), we hypothesized that people may show differing emotional responses starting from the stage of perceptual encoding. We expected to see modulations in the EPN and LPP components, to reflect the individual's subjective perception with increased amplitude when the subjects reported seeing a fearful face compared to a neutral face.

2. Results

2.1. Behavioral results

Only subjects with visual sensitivity (A') significantly higher than chance performance (i.e., $A'=0.5$) were included in further analysis. Three subjects who were unable to meet the criterion of stimulus detection were discarded. An additional seven subjects were also excluded due to their lack of trial numbers to perform ERP analysis, although they did meet the criterion for successfully detecting the target. Three subjects were also ruled out because of their poor EEG recording condition. A total of twenty-two subjects were included in further analysis.

The mean accuracy was 81.94 ± 7.50% (mean ± SD) for the high contrast condition and 69.67 ± 6.62% for the low contrast condition. The accuracy between these two contrast conditions was significantly different ($t(21)=13.87$, $P<0.001$). The accuracy of 69.67% for the low contrast trials was significantly different from 50% chance level, indicating that the subjects were paying attention to the task instead of randomly responding. The decrease of accuracy rate in this condition could be considered as an effect of task difficulty caused by the additional noise.

The mean RT for fear responses was significantly faster than that of the neutral responses in the presence of fear (624.25 ± 116.48 ms) and neutral (656.18 ± 106.11 ms) faces (i.e., hit and correct rejection trials) only in the high contrast condition ($t(21)=-2.51$, $P<0.05$).

2.2. ERP Results

Trials in the high and low contrast conditions were separated according to the response category. To determine the difference in the ERP amplitude between emotional perception in the presence or absence of the corresponding emotional content, subsets of trials for each response category (hit/miss/false alarm/correct rejection) were submitted to repeated-measures ANOVA separately for the hits vs. correct rejections and the false alarms vs. misses analyses. In the two separate comparisons, ERP analysis was performed using repeated-measures ANOVA with response type ('fear' and 'neutral' responses) × site (O1 and O2) as a within-subject factor for the EPN component. Response type ('fear' and 'neutral' responses) × site (P3, Pz and P4) was used as a within-subject factor for the analysis of the LPP component. We used *Bonferroni* correction for any subsequent post hoc analyses.

2.2.1. *Hit and correct rejection trials*

A significant main effect of response type was observed in the EPN component in both high ($F(1,21)=7.22$, $P<0.05$) and low ($F(1,21)=12.20$, $P<0.001$) contrast conditions. For both high and low contrast conditions, no significant site effect or any significant interaction of response type and site was observed among the two occipital sites O1 and O2. Fear responses were associated with larger negative deflections than the neutral responses in both high (O1; $t(21)=-3.04$, $P<0.05$, O2; $t(21)=-2.23$, $P<0.05$) and low (O1; $t(21)=-3.85$, $P<0.001$, O2; $t(21)=-2.96$, $P<0.05$) conditions.

A significant response type effect appeared in the LPP component over the parietal sites in both contrast conditions (high: $F(1,21)=19.89$, $P<0.001$; low: $F(1,21)=24.39$, $P<0.001$). A significant site effect was also observed in both high ($F(2,42)=6.5$, $P<0.05$) and low($F(2,42)=4.21$, $P<0.05$) contrast conditions. However, the interaction between the site and response type was significant only in the high contrast condition ($F(2,42)=5.12$, $P<0.05$). Further analysis revealed that the activity in the Pz site elicited significantly larger amplitudes than that from the P3 site in both fearful and neutral responses. This result was consistently observed in both high and low contrast condition. An enlarged positive deflection followed a fearful response in both high (Pz; $t(21)=4.70$, $P<0.001$, P3; $t(21)=4.71$, $P<0.001$, P4; $t(21)=3.29$, $P<0.05$) and low (Pz; $t(21)=4.95$, $P<0.001$, P3; $t(21)=4.98$, $P<0.001$, P4; $t(21)=4.31$, $P<0.001$) conditions. Stronger responses were evoked during hit trials than correct rejections, showing a typical emotional response as evidenced in many previous studies on emotional perception.

2.2.2. *False alarms and miss trials*

The modulation of the evoked potential by the subjective report was investigated. This analysis was performed only on the low contrast condition, in which a sufficient number of repetitions of trial types were provided.

The results of the repeated-measure analyses showed a significant response type effect ($F(1,21)=9.36$, $P<0.05$) and a significant interaction between site and response type ($F(1,21)=13.50$, $P<0.001$) confirming the main effect of response type. Enlarged EPN amplitude was elicited when the subjects reported seeing a fearful face even though there was no actual fearful face stimulus presented as opposed to viewing a stimulus that actually contained a fearful face of which the subject perceived as neutral face (O1; $t(21)=-3.63$, $P<0.05$, O2; $t(21)=-2.11$, $P<0.05$).

Results of the LPP component analyses revealed only a significant response type effect ($F(1,21)=5.37$, $P<0.05$). Larger positive deflection was elicited when the subject reported seeing a fearful face than when reported seeing a neutral face even in the absence of a relevant emotional stimulus. However this effect was significant only in the Pz and P4 sites (Pz; $t(21)=2.26$, $P<0.05$, P3; $t(21)=1.91$, n.s., P4; $t(21)=2.21$, $P<0.05$). False alarm trials evoked larger amplitudes relative to miss trials. The results show that the mere exposure of a fearful face was not enough to evoke a typical emotional modulation in the ERP data showing enlarged EPN and LPP component amplitudes.

2.2.3. *Noise-alone trials*

Forced emotional choice responses toward noise-alone patches showed a main effect of response type in both EPN ($F(1,21)=8.78$, $P<0.05$) and LPP components ($F(1,21)=11.80$, $P<0.05$). A significant site effect was observed only in LPP components ($F(1,21)=3.66$, $P<0.05$).

Post hoc analyses showed that a significantly larger EPN amplitude was elicited when subjects reported seeing a fearful face than when they reported seeing a neutral face (O1; $t(21)=3.848$, $P<0.001$, O2; $t(21)=-3.765$, $P<0.001$). However, a larger LPP component was elicited when subjects reported seeing a neutral face than a fearful face (Pz; $t(21)=-3.41$, $P<0.05$, P3; $t(21)=-3.03$, $P<0.05$, P4; $t(21)=-3.46$, $P<0.05$). Although there was a significant difference between the two percepts toward the noise-alone stimulus, the results suggested that the LPP of neutral face perception in the noise-alone condition might be modulated differently from that of the typical response pattern. The resulting ERP modulation pattern was different from the typical modulation in response to emotional perception (Figs. 1 and 2).

3. Discussion

In the present study, we conducted an observation of top–down modulation in the process of emotional perception. The investigation of the neural correlates of the top–down influence on the emotional perceptual process was carried out by comparing the two ERP results according to the subject's response choice in the false alarm and miss trials. Augmented EPN and LPP amplitudes were elicited when the subjects reported seeing a fearful face, even in the absence of the actual fearful stimulus.

EPN and LPP components are known to reflect facilitated and sustained processing of a stimulus with motivational significance (Schupp et al., 2006). One interpretation to reconcile the findings in this study with the aforementioned perspective toward EPN and LPP is that the subject's perception of a stimulus as an arousing emotional one increased the motivational significance of that very stimulus, which led to an enhanced neural response accordingly. Notably, such emotional effect in the EPN amplitude was observed even in the noise-alone condition where there was no actual emotional input. This result, together with the observation of a differential modulation in the ERP responses in accordance to the subject's percept in the false alarm and miss trials, could be seen in light of previous studies suggesting facilitated process of motivationally significant stimuli such as those related to one's survival. Findings of the previous studies have shown faster visual detection and sustained emotional processing toward stimuli of individual significance (i.e., snakes to snake-phobic individuals) not to fear-relevant, but nonfeared stimuli (i.e., snakes to spider-phobic individuals)

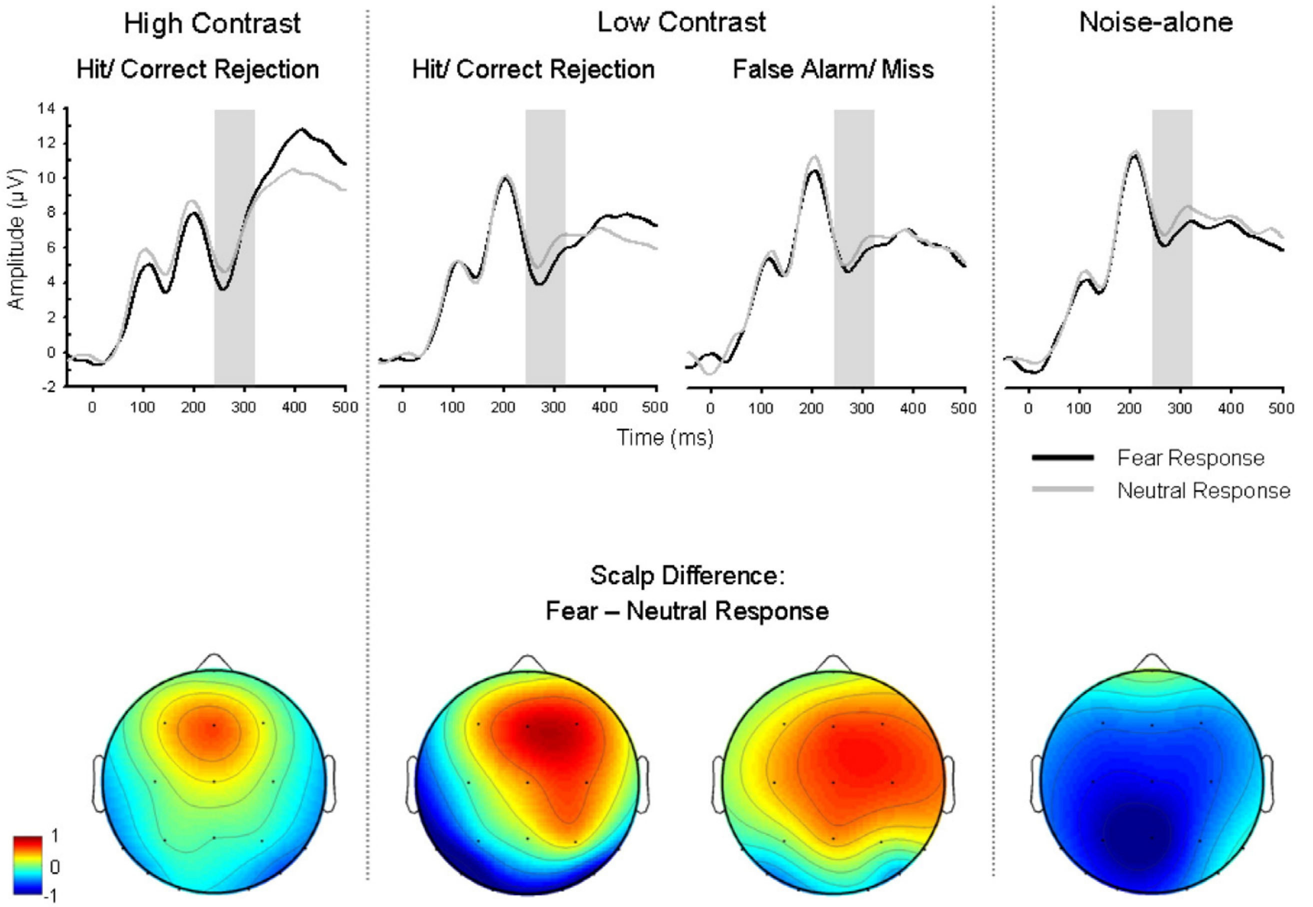

Fig. 1 – The top graphs illustrate the grand-averaged event-related potential waveforms for each response type elicited in different experimental conditions in a representative left occipital site (O1). Shaded areas mark the time interval of 240–320 ms selected for the statistical analysis of the early posterior negativity. The bottom graphs illustrate scalp potential difference maps generated by the mean amplitude of EPN to fearful responses minus that of neutral responses separately for the four different conditions over a time internal of 240–320 ms.

(Michalowski et al., 2009; Miltner et al., 2005; Öhman et al., 2001). Perceiving a stimulus to be emotionally arousing, presumably modulated the motivational significance of the stimulus, and as a result, allows such stimulus to receive a tag for prior processing.

However, as observed in the noise-alone condition where there was no bottom–up emotional information, the modulation in the LPP component showed a larger positive deflection for neutral responses than fearful responses. This result may be related to the nature of the LPP component and the task employed in this study. An increasing number of recent studies have taken on to investigate whether the facilitated processing of emotional stimuli varies according to how emotional stimuli are evaluated and interpreted (Ochsner and Gross, 2005). Such evidence has been accumulated regarding the nature of LPP as sensitive to emotion regulation processes (Moser et al., 2006), the way in which the emotional content of a presented picture is appraised (Hajcak et al., 2006), as well as its being modulated by cognitive strategies such as reappraisal (Hajcak and Nieuwenhuis, 2006). Other studies on concreteness in emotional words have revealed that the late positive component (LPC/LPP), showed differential responses only to concrete emotional words (Kanske and Kotz, 2007). Regarding the findings that concrete words activate more semantic context and involve mental imagery (Levy-Drori and Henik, 2006; West and Holcomb, 2000), the results concerning the relation between LPC and concrete words (West and Holcomb, 2000) suggest that this component is related to mental imagery. Taken together, the dissociation between subjective responses and the LPP components may be based on this attribute of LPP associated with a mental imagery representation. In the noise-alone condition, in which an actual facial stimulus was not presented, the subjects had no image representation to process. As the task used in the present study was a simple detection task, the subjects were not asked to actively draw a mental picture or even had sufficient time to induce such an emotional state. Modulation of the LPP component consistent to the emotional percept in the false alarm and miss trials of the low contrast condition is possible, given the fact that there was a visual representation and that LPP components were modulated according to the subjective appraisal of the emotional stimuli.

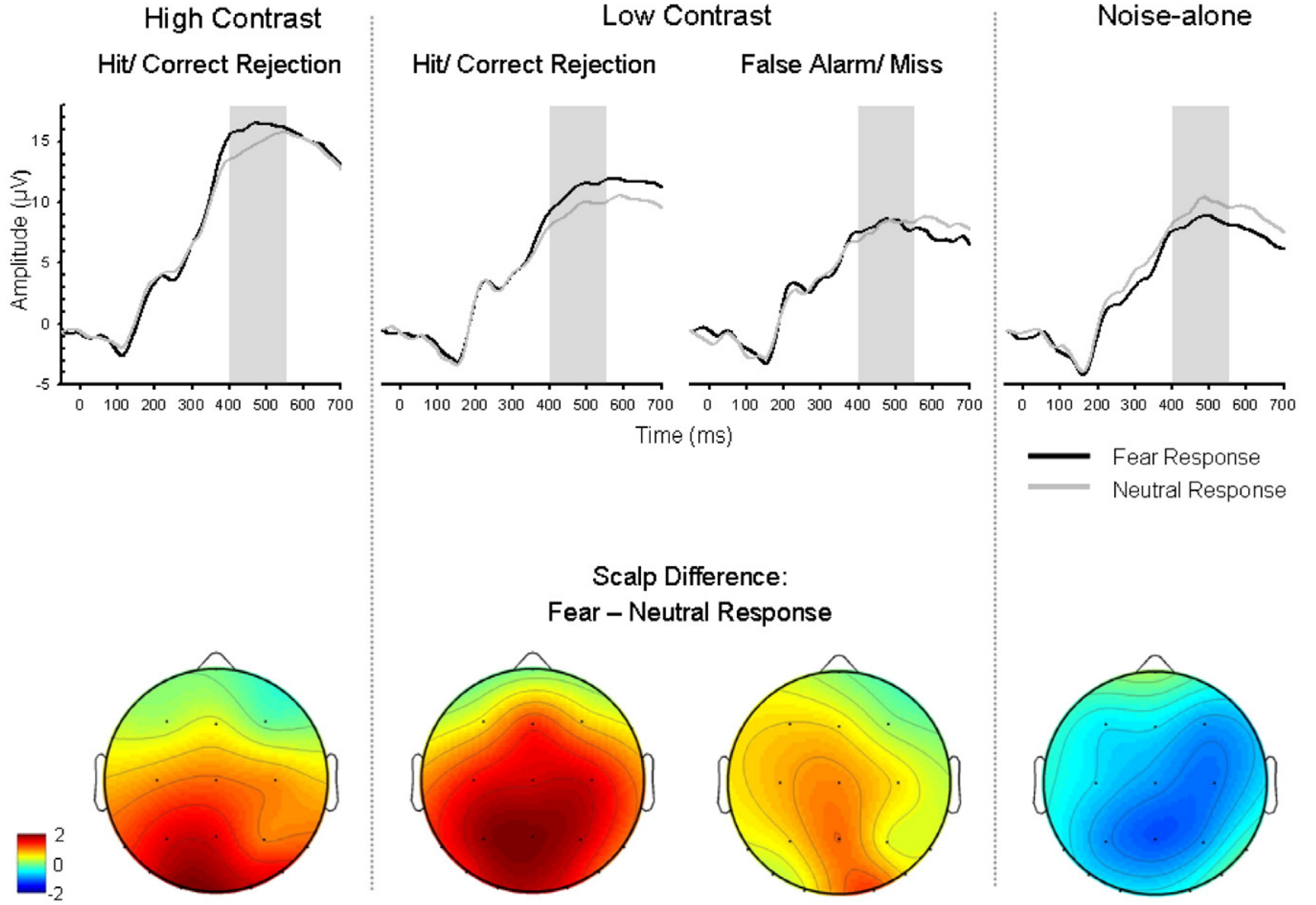

Fig. 2 – The top graphs illustrate the grand-averaged event-related potential waveforms for each response type elicited in different experimental conditions in a representative centro-posterior site (Pz). Shaded areas mark the time interval of 400–550 ms selected for the statistical analysis of the late positive potential. The bottom graphs illustrate scalp potential difference maps generated by the mean amplitude of LPP to fearful responses minus that of neutral responses separately for the four different conditions over a time internal of 400–550 ms.

The results in the present study showed a modulation in the brain potentials which is closely linked to the subjective response, rather than the physical properties of the presented visual stimuli. The present ERP findings are in line with the previous functional MRI data showing amygdala responses linked to the subjective emotional choice response (Pessoa et al., 2006). Even though the subjects were visually aware of the facial stimuli, the emotional cue of the fearful face did not automatically trigger prior and facilitated processing. Should the emotional perceptual process occur automatically as commonly viewed, enlarged EPN and LPP amplitude would follow the presentation of a fearful face regardless of how the subject perceives it. However, the present results show that emotional perception is susceptible to top–down influence. Such display of a top–down modulatory effect was apparent during the perceptual encoding stage and was sustained through the later attentive processing stage as reflected in the characteristic modulation in the EPN and LPP component, respectively.

The current findings suggest that the facilitated processing of emotional stimuli is more closely related to the motivational relevance to the subject, rather than the emotional content of the stimuli as shown in previous studies (Michalowski et al., 2009; Miltner et al., 2005; Öhman et al., 2001; Sabatinelli et al., 2005). Further exploration on the top–down influence on emotional perception in relation to the modulation of the motivational relevance is needed. As the neural responses are closely linked to the subjective percept, individual differences in preattentiveness toward emotional cues or in anxiety level should be taken into consideration when conducting such experiment on emotional perception.

4. Experimental procedures

4.1. *Subjects*

Thirty five healthy volunteers (11 males and 24 females) aged 27.97 ± 34.05 (mean ± SD) years participated. Subjects were given a small amount of monetary incentive for their participation. All subjects were naive as to the purpose of the experiment and gave informed consent. Subjects had normal or corrected-to-normal vision. This study was approved by the ethics Committee of the Korea University (KUCM-IRB-2006007-A-2).

4.2. *Stimuli and apparatus*

Face stimuli consisted of grayscale frontal views of twenty males and twenty females chosen from the Korea University Facial Expression Collection (KUFEC; Lee et al., 2006). Both the fearful expression and neutral expression of each face were employed. An independent sample of 79 students rated these faces on a modified version Self-Assessment Manikin (SAM; Lang et al., 2005). Two sets of seven-point scale for valence (1=unpleasant, 7=pleasant) and arousal (1=calm, 7=arousing) were used to rate the facial stimuli. The fearful expressions (valence: 2.72±0.42, arousal: 4.5±0.42) used in the present study were rated as more unpleasant ($t(39)=-12.34$, $P<0.001$) and more arousing ($t(39)=16.17$, $P<0.001$) than the neutral faces (valence: 3.61±0.26, arousal: 3.15±0.31).

The faces subtended a visual angle of 2.2°×2.6°. All stimuli were embedded in the center of a single, identical (i.e., not resampled) white noise patch subtending a visual angle of 4.7°×4.7°. Using Photoshop 7.0 (Adobe), a uniform white noise filter was added to the facial stimuli on a pixel-by-pixel basis to induce perceptual ambiguity. The high contrast version had a noise level of 60 and a low contrast version of 80. The contrast level in the low contrast condition was adjusted until participants of a preliminary experiment, prior to this study, were able to successfully identify the facial expression of the pictorial stimulus at a rate of 75–80% level.

The noise-alone condition contained the contours of each of the forty pictorial stimuli used in this study. The contours of the faces were made by morphing the initial grayscale fearful and neutral faces of each identity at a 50% level and were then filled in with the brightest color point of the cheek to remove the features of the face. An additional swab of light gray was made in the shape of the upper case letter T where the forehead and nose are situated. The amount of noise added for the noise-alone condition was identical to that in the case of the low contrast version faces. The luminosity was carefully adjusted to a similar level for all stimuli after the noise was added. Since the noise-alone stimuli contained some facial features and were presented three times throughout the whole experimental session, we conducted a rating session prior to this study on these noise-alone stimuli with another test group ($n=31$, 13 males, 16 females, aged 26.86±3.73 years, two refused to reveal their personal information). The noise-alone stimuli were rated in three categories: discriminability (1=not discriminable, 7=discriminable), valence and arousal. The rating results for the noise-alone stimuli proved that the stimuli were difficult to distinguish as faces with any distinct emotional expression, had no clearly distinguishable pleasant or unpleasant valence, and the arousal level was low (discriminability: 2.49±0.55, valence: 3.45±0.16, arousal: 2.35±0.25; Fig. 3).

4.3. *Procedure*

The whole experimental procedure was performed in a dimly lit, sound attenuated shield room. Stimuli were displayed on a 17″ flat CRT monitor (Samsung SyncMaster 713MB) with a 256 mb video card (ATI), placed approximately 60 cm away from the subject. The maximum refresh ratio was adjusted to 60 Hz and the resolution was kept to 800×600. We used SuperLab Pro 2.0.4 (Cedrus Co., San Pedro, CA) and an RB-730 response pad (Cedros Co. San Pedro, CA) for stimuli presentation and for behavioral response data collection.

The subjects completed an emotional forced choice task. Subjects were instructed that there was a face stimulus presented on every trial, despite the fact that one third of the trials were noise-alone displays. The subjects were told about the noise-alone condition that sometimes there would be another condition consisting of lower contrast face stimuli that might be hard to discriminate. Subjects were strongly encouraged not to guess, but to respond on the basis of which emotion they perceived. They were also told that the emotional type (i.e., fearful or neutral expression) of the face stimuli would appear with equal frequency.

Each trial began with a white fixation cross in the center of the screen for 700 ms, followed by a blank screen for 500 ms or 800 ms. The facial stimuli then appeared in the center of the screen for 17 ms. Immediately after the termination of the stimulus, a blank screen appeared for 1500 ms when the subject had to make a response according

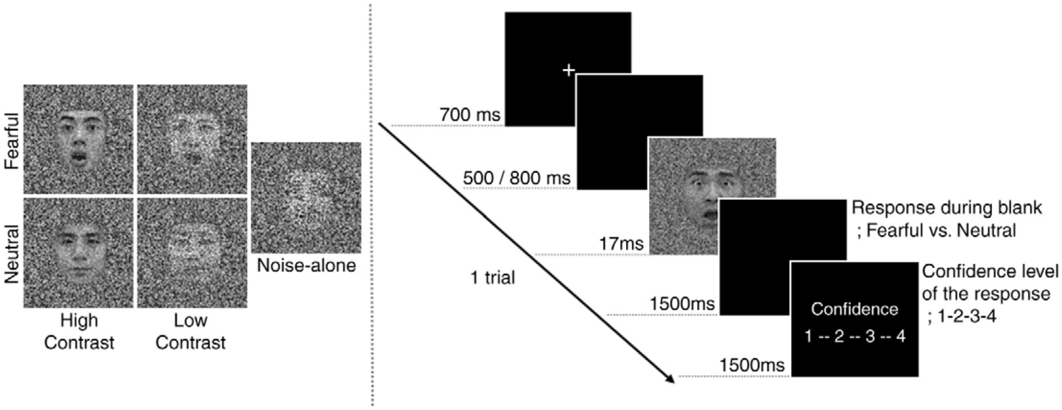

Fig. 3 – The left illustrates examples of the facial stimuli used in the experiment. The right diagram depicts the experimental design and time course of stimulus presentation in the emotional forced choice task.

to their perceived emotion. Subjects indicated ‘fear’ or ‘neutral’ by pressing one of the two buttons, and the response hand (right vs. left) was counterbalanced across the participants. On each trial, subjects also rated the confidence in their response on a scale of four, 1 corresponding to low confidence level and 4 to high confidence level. The duration of the rating was a maximum of 1500 ms or was automatically terminated after a response was made. Each subject performed a total of 720 trials, providing 120 trials for each experimental condition; two contrasts (high vs. low) × two facial emotions (fear vs. neutral) and 240 noise-alone trials. Participants were asked to keep their eyes fixed on the center of the screen and to avoid eye blinks or any kind of movements during the trials (Fig. 3).

4.4. *Behavioral data analysis*

Behavioral response data were analyzed based on the signal detection theory to ensure that the subjects were visually aware of the stimuli. Visual sensitivity to fearful stimuli was determined using A', the area under the ROC curve, and was tested for significance for each individual. Perception was considered aware only when the A' value were significantly greater than chance performance (i.e., $A'=0.5$). The P value adopted for statistical significance was 0.05 (for more details on the analysis method of the ROC curve, please refer to a previous study by Pessoa et al., 2005a). Under the presumption that the subjects were aware of the visual stimuli, it could be assumed that the resulting choices would reflect the subjective perception or the subjective interpretation of the given visual stimuli. In this case, the choice responses would differ from merely erroneous responses when the subjects fail to detect the visual stimuli. The emotional effect was measured by the overall behavioral data including the mean reaction time (RT) for each response type. Since the subjects performed a forced discrimination task between two emotional types (i.e., fearful or neutral), false alarms (‘fear’|neutral) and misses (‘neutral’|fear) were considered as perceived fear and neutral, respectively.

4.5. *Event-related potential recording and analyses*

The electroencephalogram (EEG) was recorded from 16 channels (FZ, CZ, PZ, F3, F4, C3, C4, P3, P4, T5, T6, PO7, PO8, O1, O2) according to the international 10-20 system (Jasper, 1958) using a Grass model 12 system (Grass-Telefactor, MASS) (sampling rate 1000 Hz; impedance <10 kΩ; 20,000 amplification). The common reference site was on the right earlobe (A2); the ground was on the middle of the forehead. In addition, two electrodes were placed on the upper and lower side of the right eye to monitor vertical eye movements. The raw EEG data were analyzed off-line using EEGLAB (Delorme and Makeig, 2004). The raw EEG data were filtered using band-pass of 0.01 and 30 Hz. Data epochs were extracted from a time window between 200 ms before and 800 ms after the stimulus onset. Individual EOG artifact correction was conducted using the independent component analysis (ICA) results and trials with artifacts exceeding ±75 μV in any of the electrodes were additionally rejected.

The time windows and scalp regions of interest for analysis of the ERP components were determined based on previous research and visual inspection. EPN was analyzed in the occipital electrodes (O1, O2) and LPP was analyzed on the parietal sites (Pz, P3, P4). Mean amplitudes of the ERP components (EPN, LPP) were analyzed. EPN component amplitudes were calculated by averaging ERP data samples within the predefined 40 ms time windows centered on the latency of the most negative peak between 200 and 300 ms from stimulus onset for each subject. LPP component amplitudes were calculated by averaging ERP data samples within the predefined 50 ms time windows centered on the maximal point in the time interval of 400–600 ms for each subject. The time windows used for the final statistical analysis of the EPN and LPP components did not exceed 240–320 ms and 400–550 ms for all subjects, respectively. The ERP activity over the two time intervals in each relative scalp regions closely matched the EPN and LPP profile in the grand average waveform. The two components were averaged separately for hits (‘fear’ responses to the presence of fearful faces), misses (‘neutral’ responses to the presence of fearful faces), false alarms (‘fear’ responses to the presence of neutral faces), and correct rejections (‘neutral’ responses to the presence of neutral faces). Greenhouse–Geisser Epsilon Correction was applied, when sphericity was violated.

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