Tohoku Psychologica Folia
2017, *76*, 46–53

Temporal asymmetry of utilizing attentional resource between preceding presentation of fearful and disgusted faces

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The different functions between fear and disgust have been reported for visual attention. Fear enhances use of attentional resources whereas disgust suppresses use of them. However, these different effects on visual attention have not yet been examined with respect to temporal characteristics. The present study applied an attentional blink paradigm to investigate this research question. In the current experiment, facial expression stimuli (fearful, disgusted, or neutral faces) were presented as the first target (T1), and the discrimination performances of the second target (T2, neutral face) were compared in each lag condition. The lag condition had five levels with 100 (lag 1), 200 (lag 2), 300 (lag 3), 600 (lag 6), and 1000 ms (lag 10) stimulus onset asynchrony (SOA) between first and second targets. The results indicated that the T2 accuracy was higher in fearful T1 than in neutral T1 at 600 and 1000 ms SOA lag conditions. The object encoding process requires a temporal interval of 500 ms. Thus, a sufficient interval for the object encoding process would be necessary to enhance utilizing attentional resources due to fear. On the other hand, T2 accuracy of disgusted T1 was higher than that of neutral T1 at 100 ms SOA lag condition. Moreover, T2 accuracy was higher at lag 1 than at lag 2 in the disgusted T1 condition. Therefore, only disgusted face induced lag 1 sparing in this experiment. In conclusion, the present study found the different temporal characteristics of emotional effects on visual attention between fear and disgust.

Key words: negative emotion, fear, disgust, facial expression, attentional blink

Introduction

Emotional information is one cue to extract important information. In daily life, our surrounding environments are replete with visual information. We extract important information efficiently by orienting our attention to objects. Particularly, environmental information including negative emotional valence rapidly captures attention. LeDoux (1996) has proposed the neural network for rapid processing of negative stimuli (e.g., snakes, spiders, and so on). Simultaneously, emotional stimuli strongly attract our attention. This fact is indicated by emotion-induced blindness (Ciesielski, Armstrong, Zald, & Olatunji, 2010; Most, Chun, Widders, & Zald, 2005; Most, Smith, Cooter, Levy, & Zald, 2007). In emotion-induced blindness, the detection of a single target within the rapid serial visual presentation (RSVP) stream is impaired by preceding presentation of task-irrelevant emotional picture compared to neutral picture (Ciesielski et al., 2010; Most et al., 2005, 2007).

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Many studies have examined the effects of facial expression stimuli on visual attention. Several studies have investigated these effects using the attentional blink paradigm (e.g., Bach, Schmidt-Daffy, & Dolan, 2014; Milders, Sahraie, Logan, & Donnellon, 2006). In the attentional blink paradigm, participants detect two targets from the RSVP stream. Performance during detection of the second target (T2) is generally impaired compared to the first target (T1; Raymond, Shapiro, & Arnell, 1992). Milders et al. (2006) have found that T2 of fearful face, presented after T1 of neutral face, reduced the attentional blink effects (i.e., increasing T2 accuracy) compared with T2 of neutral and happy faces. An attentional blink deficit was explained by a bottleneck model: because a limited-capacity process is still occupied by T1 processing when T2 is presented (Jiang & Chun, 2001). Threat-related T2 faces are allowed preferential access to this limited-capacity process (Milders et al., 2006). Otherwise, threat-related faces are salient stimuli and, thus, result in surviving the attentional blink because they have a lower activation threshold for recognition than less salient stimuli (Milders et al., 2006). On the other hand, Bach et al. (2014) have shown that the recognition performance of a T2 neutral face is impaired after presenting a T1 angry face compared with T1 neutral and happy faces. This effect can be explained by increasing processing upon retrieval and interfering with subsequent retrieval of a neutral T2 according to preceding presentation of arousing T1 facial expression (Bach et al., 2014).

Different influences on visual attention have been reported between fearful and disgusted stimuli (Krusemark & Li, 2011; Vermeulen, Godefroid, & Mermillod, 2009). In evolutionally perspectives, fear is associated with the self-protection system and disgust is related to the disease-avoidance system (e.g., Neuverg, Kenrick, & Schaller, 2011, for a review). Thus, fear is configured to enhance sensory inputs whereas disgust is configured to reduce them (Susskind, Lee, Cusi, Feiman, Grabski, & Anderson, 2008). The effects of these types of negative emotion extend to the attentional system. Krusemark and Lee (2008) have shown the different priming effects between fearful and disgusted pictures on visual search task. In their experiment, any of the neutral, fearful, or disgusted pictures was presented, and then visual search display was presented over this priming picture. The search time was shorter for the fearful picture than for the neutral picture. On the other hand, the search time was longer for the disgusted picture than for the neutral picture. Moreover, according to measuring a visual event-related potential (VERP), the amplitude of the VERP and electrical current density were increased by the fearful picture whereas the disgusted picture reduced the VERP amplitude and diminished current density in associate visual cortices. Vermeulen et al. (2009) has found different priming effects between fearful and disgusted pictures in attentional blink paradigms. In their experiment, either primed fearful or disgusted faces were presented before the RSVP stream. The deficit of T2 detection was increased by primed fearful faces and decreased by primed disgusted face. These results could be explained according to the differences of using attentional resources for T1 processing between fear and disgust. In other words, these two studies have indicated that fear enhanced the use of attentional resources whereas disgust reduced the use of them.

However, this difference between fear and disgust has not yet been investigated in respect of temporal characteristics. These experimental approaches could not elucidate when the different effects on visual attention between fear and disgust occur after presenting facial expression stimuli. Therefore, the facial expression stimuli are presented at a temporal position of T1, and T2 accuracy is compared among the T1 facial expressions and lag (i.e., temporal distance between T1 and T2) conditions in the present study.

Methods

Participants

Sixteen observers, including the author (4 women and 12 men; mean age = 23.06 ± 2.72 years), participated in this experiment. All participants reported orally normal or corrected-to-normal vision. None of the participants had been informed of the purpose of the experiment, except for the author. The present study was approved by the ethics committee of the Faculty of Human Studies, Bunkyo Gakuin University. All participants gave written informed consent before participation.

Apparatus

Stimuli were generated and controlled by means of a custom-made program written with MATLAB (The MathWorks, Inc.), Psychtoolbox (Brainard, 1997; Kleiner, Brainard, & Pelli, 2007; Pelli, 1997), and a laptop PC (MacBook Pro, Apple; OS: macOS Sierra). The visual stimuli were displayed on a 17-inch CRT-display (Trinitron CPD-E230, Sony; resolution: 1024 × 768 pixels; refresh rate: 100 Hz). Participants viewed the monitor binocularly at a distance of 70 cm with their heads stabilized on a chin rest.

Stimuli

The facial stimuli of three facial expression categories were selected from the Karolinska Directed Emotional Faces Database (www.emotionlab.se/resources/kdef; Lundqvist, Flykt, & Öhman, 1998): fearful, disgusted, and neutral faces. Each facial expression category has 70 faces (male and female, 35 each). The images were converted to grayscale. Image size was 168 × 228 pixels (about 4.4° width × 6.0° height of visual angle). Distractors were 70 inverted neutral faces (male and female, 35 each). The facial stimuli were presented in the center of the screen against a black (0.10 cd/m^2) background. A white (195.51 cd/m^2) fixation cross (about 0.5° × 0.5°) was also presented.

Procedure

Participants' task was to discriminate both T1 and T2 faces in each four-alternative forced choice paradigm. A trial sequence is shown in Fig. 1. Each trial was initiated by pressing the "0" key on the keyboard. A fixation cross was presented for 500 ms, immediately followed by the presentation of the RSVP stream. The RSVP stream consisted of 17 facial stimuli. Each stimulus was presented for 100 ms. The RSVP stream started with the presentation of a male or female image randomly chosen from the distractor sets (without replacement). Then, the T1 face was presented as either the third, fourth, or fifth stimulus, immediately followed by a variable number of distractor faces (depending on the lag variable). The number of lags (the number of interleaved faces between T1 and T2) was set to one, two, three, six, and ten. The T1 face was randomly selected from three facial expression category sets; each category had 16 faces (male and female, 8 each). The T2 face was randomly selected from 54 neutral face sets (male and female, 27 each). The T2 face was not the same as the T1 neutral faces. The sex of the targets was always different from that of distractors. In response display, the alternatives were target and three filler faces randomly selected from each of 54 stimulus sets of three facial expression categories (male and female, 27 each). The sex of alternatives was the same. In the T1 response display, the facial expression of alternatives was also same as the presented T1 face. Participants responded to press the corresponding key. The experiment comprised 240 trials: 3 (T1 facial expressions: fearful, disgusted, or neutral) × 5 (lag: lag 1, lag 2, lag 3, lag 6, or lag 10) × 16 repetitions.

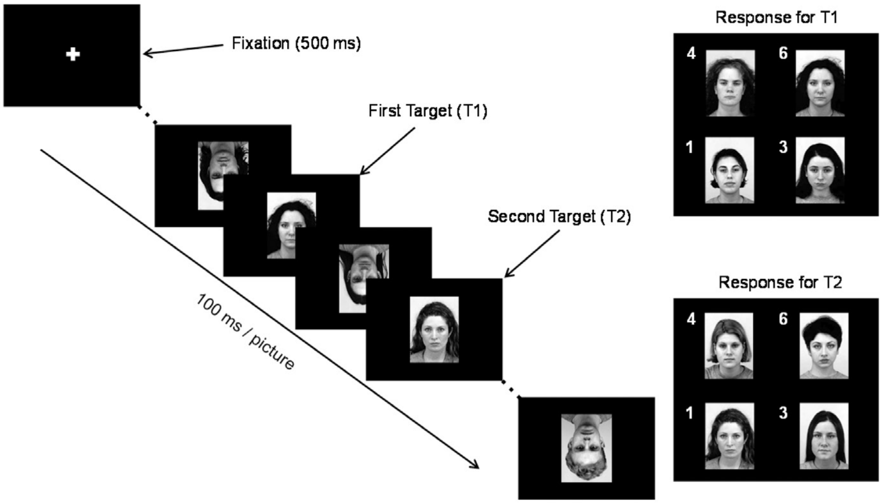

Figure 1. The schematic responses of trial sequence and response display. The response window digits indicate the corresponding numbers on the keypad to respond to the target faces. This example shows the neutral T1 trial, in which the correct response was made if the participants could press the "6" and "1" keys for T1 and T2 responses, respectively.

Results

Accuracy for discriminating T1 and T2 faces, with the latter contingent upon the T1 response being correct, was calculated for each condition. Results are shown in Fig. 2. For T1 discrimination accuracy, a one-way analysis of variance (ANOVA) with T1 facial expression (3) was conducted and the main effect was significant (F (2, 30) = 39.25, p < .001, η^2 = .72).

Multiple comparisons (Ryan's method) indicated that the accuracy was lower for the neutral face than for fearful and disgusted faces (*p*s $< .001$). Moreover, the accuracy was higher for the fearful face than for the disgusted face ($p < .05$).

For T2 discrimination accuracy, a two-way ANOVA with T1 facial expression (3) × lag (5) was conducted. The main effects of T1 facial expression (F (2, 30) = 4.47, $p < .05$, $\eta_p^2 = .23$) and of Lag (F (4, 60) = 11.54, $p < .001$, $\eta_p^2 = .44$) were significant. Moreover, the interaction between T1 facial expression and Lag was also significant (F (8, 120) = 2.47, $p < .05$, $\eta_p^2 = .14$). The simple main effect of T1 facial expressions was significant in the lag 1 condition (F (2, 150) = 4.40, $p < .05$, $\eta_p^2 = .06$). Multiple comparisons indicated that the accuracy was higher for disgusted T1 than for neutral T1 ($p < .01$). The simple main effects of T1 facial expressions were also significant in the lag-6 (F (2, 150) = 4.86, $p < .01$, $\eta_p^2 = .06$) and lag-10 (F (2, 150) = 4.98, $p < .01$, $\eta_p^2 = .06$) conditions. Multiple comparisons indicated that the accuracy was higher for fearful T1 than for disgusted and neutral T1 (*p*s $< .05$). However, the accuracy was not different between disgusted and neutral T1 conditions (*p*s = .27). Furthermore, the significant simple main effects of lag were observed at each T1 facial expression conditions (fearful T1: F (4, 180) = 9.93, $p < .001$, $\eta_p^2 = .18$; disgusted T1: F (4, 180) = 3.84, $p < .01$, $\eta_p^2 = .08$; neutral T1: F (4, 180) = 5.23, $p < .001$, $\eta_p^2 = .10$). Multiple comparisons indicated that the accuracy was higher at lag 10 than at lag 1, 2, and 3 for fearful and neutral T1 conditions (*p*s $< .05$). On the other hand, for the disgusted T1 condition, the accuracy was higher in the lag 1 than in the lag-2 condition ($p < .01$).

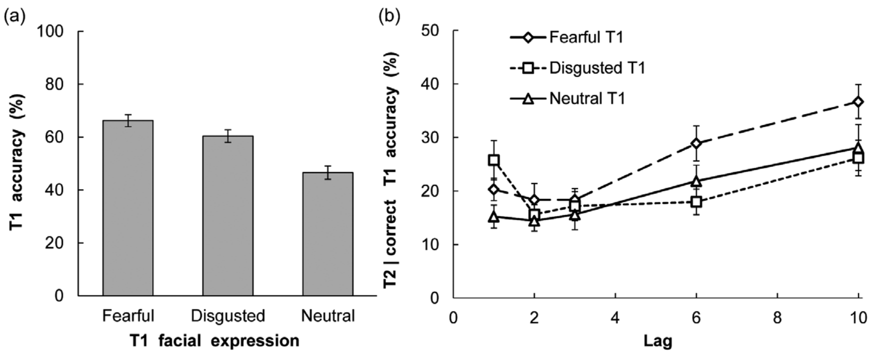

Figure 2. The results of the present experiment. (a) T1 accuracy. (b) T2 accuracy with the contingent upon T1 response being correct. The vertical axes indicate the mean percentages of each accuracy. The horizontal axes indicate the experimental condition (a) and lag (b). Error bars represent the standard error of the mean ($n = 16$).

Discussion

The present study investigated the different effects on visual attention between fear and disgust with respect to temporal characteristics. In the experiment, facial expression stimuli were presented at the T1 temporal position in the attentional blink paradigm. Neutral faces were presented at the T2 temporal position, and the accuracies of T2 were compared among T1 facial expression conditions. The results indicated that T2 accuracy was higher in the fearful T1 than in the neutral T1 and disgusted T1 conditions at lag 6 and 10. On the other hand, in the lag 1 condition, T2 accuracy was higher in the disgusted T1 than in the neutral T1 condition. In the disgusted T1 condition, T2 accuracy was higher at lag 1 than at lag 2.

The enhancement of visual attention by fear was observed. When fearful faces were presented at the T1 temporal position, the following discrimination of T2 faces was enhanced at several lags. Fear enhances utilization of attentional resources for the processing of the following stimulus (Vermeulen et al., 2009). Therefore, fearful faces at T1 facilitated the following attentional processing of T2 in a limited-capacity process. On the other hand, the facilitation of T2 discrimination by T1 fearful faces was observed at lag 6 and 10. In the present experiment, each visual stimulus was presented for 100 ms. Thus, the SOA was over 600 ms between T1 and T2 presentations at lag 6 and lag 10. The object encoding process requires a temporal interval of 500 ms (Alvarez & Cavanagh, 2004). The present study found that the sufficient interval for object encoding is necessary for enhancement of utilizing attentional resource by fear.

Disgust showed different temporal characteristics from fear for the processing of visual attention. When disgusted faces were presented at the T1 temporal position, T2 processing was enhanced at the temporal position immediately after T1 (i.e., lag 1 condition). Moreover, the accuracy of T2 was higher at lag 1 than at lag 2 in disgusted T1 conditions. This phenomenon is called lag 1 sparing (Visser, Bischof, & Di Lollo, 1999). The lag 1 sparing is induced by integration of two stimuli into the same attentional episode (Hommel & Akyürek, 2005; Potter, Staub, & O'Connor, 2002). Therefore, disgust might have attentional characteristics which capture and integrate the immediately following information into the same attentional episode. On the other hand, reduction effects of disgust for visual attention could not be observed in the present study.

The present study includes two main limitations. First, the discrimination performances of T1 differ among facial expression conditions. The accuracy of fearful and disgusted faces was higher than that of neutral faces. However, some previous studies have shown that the difficulty of T1 affects the magnitude of attentional blink (e.g., Chua, Goh, & Hoh, 2001; Visser, 2007). The differences of T1 performance might affect the T2 accuracy in the present study. Second, the discrimination performances of T2 were entirely low. The present task was a four-alternative forced-choice task for presented T1 and T2 faces. Thus, the chance level was 25%. The accuracies of T2 were below chance in some conditions. Therefore, the present results should be interpreted carefully with respect to this low performance.

The difference of temporal characteristics between fear and disgust is the interesting finding. Negative emotions, including fear and disgust, adapt us an outer environment by modifying the attentional system. To understand the role of the emotional system, further studies are necessary to elucidate the different functions of each emotion.

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Authors' note

This experiment was conducted at Bunkyo Gakuin University, which is the author's former affiliation. This works was supported by the Japanese Society for the Promotion of Science KAKENHI (Grant-in-Aid for Research Activity start-up: No. 15H06569 and Grant-in-Aid for young Scientists (B): No. 17K18069).

(Received November 28, 2017)
(Accepted December 22, 2017)