Attentional capture by threatening stimulus: effect of SOA

Shiho Miyazawa[1], Syoich Iwasaki[2]

([1] Department of Human Psychology, Faculty of Comprehensive Human Sciences Shokei Gakuin College・[2] Graduate School of Information Science, Tohoku University)

Abstract

In the present study, we investigated whether exposure duration of threatening stimuli modulate the effect on automatic capture of visual attention. We used dot probe task to assess the extent to which emotional valence would influence deployment of attention with short and long exposure durations (300ms and 1000ms). The results of this study showed that reaction times (RTs) to a small dot (i.e., probe) that followed threatening stimuli were longer than those to the same probe that followed positive stimuli. Moreover, this difference between positive and negative emotion was significant for 1000ms exposure duration. It is suggested that inhibitory effect by aversive emotion was likely to increase as exposure duration became longer.

（本研究では、情動刺激の提示時間が、その刺激の情動価が視覚的注意へ及ぼす影響を変化させるのかを検討した。本研究では、情動価が注意へ及ぼす影響を評価するためにプローブ課題を使用した。さらに、その影響の大きさと提示時間との関連を検討するために２種類の提示時間を採用した。その結果、ネガティブ刺激が提示された場合には、引き続き出現するターゲットへの反応時間が、ポジティブ刺激と比較して長くなることが示された。また、この傾向はSOAが1000msの条件で顕著であった。以上の結果は、恐怖関連刺激による抑制効果は提示時間と関連することを示唆する。）

Key words: attentional capture, threat, SOA

Introduction

A lot of studies have provided evidence that emotion is important in the control of behavior. These studies suggested that emotional influences on information processing associated with the control of behavior (i.e., decision making; see Kahn & Isen, 1993). Attention is known to be the mental faculty that is important for the acquisition of information that is necessary for the task at hand. Many recent researches have actually shown that information acquisition is under the guidance of emotional valence. Specifically, they have indicated that fear-related emotion can automatically control attention because of its threat to the organism. For example, previous studies suggested that threat-related stimuli like angry face and dangerous animals (e.g. snakes and spiders) were processes automatically, and rapidly relative to positive or neutral stimuli, even if it was not related to task demand, leading to automatic shifting of attention to those threatening stimuli (Bradley, Mogg, Falla & Hamilton, 1998; Öhman, Flykt & Esteves, 2001).

These studies suggested that people allocate their attention to the spatial location of fear-related stimuli more quickly than to that of neutral or positive stimuli. As a result, they were faster to detect these fear-related stimuli relative to neutral or positive stimuli.

There have been several different experimental paradigms for studying automatic attentional control by emotion. One of the most direct methods of assessing selective attentional response to emotional stimuli is the probe task (MacLeod, Mathews & Tata, 1986; Bradley et al., 1998), in which response latencies for detecting or discriminating a probe stimulus is used as an index of attentional deployment.

Based on the well-established evidence for the effect of spatial attention on perceptual processing, it is assumed that (usually automatically captured) attention is responsible for response facilitation to probe stimuli if it is presented at the location of a cue. Unlike conventional spatial attention experiment, however, in the emotional probe task attention is controlled by the meaning of the stimulus or its valence, rather than its physical properties like onset or salience. The attentional bias to negative-valence stimuli have been shown to exist not only among clinically treated anxious individuals but also among non clinical anxious individuals (Bradley et al., 1998; Buckley, Blanchard & Hickling, 2002; Öhman et al., 2001). For example, Bradley et al. (1998) who used the probe detection task demonstrated that high-anxious participants showed the attentional capture effect of anxiety-related stimuli, while low-anxious participants averted their attention away from, rather than directing to, threatening faces. Similar results were reported by other researchers, as well. The findings indicate that anxiety-provoking stimuli can capture attention of highly anxious people, leading to faster responses to threatening stimuli (Fox, Russo, & Dutton, 2002).

In these studies, extraction of emotional valence from stimuli were said to be performed preattentively because they are not task-relevant with no need for participants to selectively attend to them. For example, in the probe task emotional stimulus is not informative of the forthcoming probe location. Consequently people should be able to ignore them without causing any harm to their performance. Actually, however, their performance is affected by the stimuli that bear emotional valence (Mogg & Bradley, 1999; Morris, Öhman, & Dolan, 1999; Niedenthal, 1999; Öhman et al., 2001; Vuilleumier & Schwartz, 2001).

From an evolutionary perspective, this bias toward threatening stimuli is regarded as a result of adaptation to environmental dangers, so that they are detected immediately to make quick coping responses toward them (LeDoux, 1996; Öhman, 1986; Öhman et al., 2001; Öhman, 2000).

With the probe task there is ample evidence that processing of visual stimuli is affected by their emotional valence (especially, of negative one). However, several issues are relatively neglected. One of these issues is the type of stimuli used in the experiment. Majority of previous studies that adopted the probe task used threatening facial expressions. So far only a small portion of them have adopted threatening pictures other than facial expressions. Although threatening faces may constitute biologically important signal for danger, they are also important social stimuli even with neutral expression. Thus, it may be argued that attentional capture reported in those studies that used threatening facial expressions may be partly due to face itself, rather than due to its expression. This is especially the case when only one face is presented to either side of fixation (Fox et al., 2002), rather than a pair of faces with one for each visual field. Furthermore, it is not clear whether the result can be generalized to the threats other than threatening facial expressions. Furthermore, those studies that did use non-face stimuli had their own problem. It was the mixed use of pictures that would provoke different negative affects like disgust and fear. In the present study, we used the threat pictures of snakes and spiders, which could act as evolutionarily acquired signals for danger.

Another relatively unexplored issue is the SOA (stimulus onset asynchrony: the interval from the onset of first stimuli to second stimuli). In many previous researches that showed facilitation by aversive emotion, the time of period from onset of threatening stimuli to target or probe onset was kept to be a constant value of 500ms (MacLeod et al., 1986; Bradley et al., 1998). Only a few studies have employed SOA value other than 500ms, so that it is not clear whether the effect of negative emotion on attentional capture depends on the particular SOA used or not, that is, how its effect would fluctuate over time longer than 500 ms.

Using electro-oculograph (EOG) to record eye movements, which are overt or more natural form of spatial shift of attention, Rohner (2002) assessed the influence of stimuli with negative emotional valence on overt attentional deployment, and found that participants tended to direct their eyes toward the negative stimuli at first but after one second or so they turned their eyes away from them. Thus, the finding of this study suggested that attentional deployment may fluctuate as the exposure duration becomes longer. Thus, it may be possible that with prolonged exposure to threatening stimulus its effect on attention turns from attraction to aversion. In this study, using the probe task as a measure of attention we investigated whether the effect of negative emotion on automatic attentional capture depended on the exposure duration by using two SOA values (300 and 1000ms) in dot probe task.

In this study, we predicted that in the condition in which probe was presented at the location of emotional pictures (called valid condition in this study) participants would respond to the probe faster if the picture was of negative valence than if it was of positive valence, whereas if it was presented at the location of neutral picture (i.e., in invalid condition) they would respond slower to the probe when the other picture had negative valence than when it had positive one.

Method

Participants

Participants were 11 undergraduate and graduate students of Tohoku University (7 male, 4 female), raging in age from 20 to 35 years, with a modal age in the 20s. They had normal or corrected-to-normal eyesight. They received a payment of 1000 yen for their services.

Materials

In this study, following the lead of the previous studies (Öhman et al, 2001; Paquette, Levesque, Mensour, Leroux, Beaudon, Bourgouin, & Beauregard, 2003), one neutral, two threatening and two positive categories of pictures were used as cue stimuli. Pictures of spider or snake were chosen as threatening stimuli and those of infant or cake as positively valenced stimuli. Pictures of landscape were chosen for neutral stimuli like previous studies (Öhman & Mineka 2003; Beauregard et al. 2003).

Following the convention of spatial cuing paradigm, a picture was designated as cue because when valid it indicates the location of probe stimulus. Another category of pictures (i.e., landscapes) that was paired with cue pictures was called distracter. Landscape was used as distracter and four categories of pictures (i.e., spider, snake, infant and cake) were used as cue pictures. Spiders and snakes were the cue of negative valence, while landscapes were those of neutral valence. In all 24 different photographs were used in this study. One third (8) of them were negative (spiders and snakes), and one third (8) were positive (infants and cakes), the remaining one third (8) were neutral (landscape) pictures. Twelve mask stimuli were prepared by cutting up and randomly reassembling pictures used in the study.

The size of the pictures and the mask stimuli were 72 dots by 72 dots ($3.2^\circ \times 3.2^\circ$ in visual angle). A pair of pictures (i.e., a cue and a distracter) was presented at the center of the monitor, with one picture (either cue or distracter picture) at left side of the fixation point and the other at the right side. They were separated by a visual angle of 6.4° between the centers of the stimuli. Each participant was tested individually. S/he was seated facing a 17 inch CRT monitor that stood about 57cm in front. Head movement was restrained with a chin rest. The probe stimulus was a filled red circle of 0.3° in diameter. An IBM PC-compatible computer was used for presenting stimuli and collecting responses.

Procedure

The participant's task was to indicate the location of probe (upper or below) that followed the cue stimuli (negative, positive, or neutral) by pressing one of two keys. The probe was presented at the location that was either just above the upper edge or just below the lower edge of the cue picture.

Participants were brought into a testing room and instructed to indicate the location of the probe that was presented immediately after the termination of cue picture. First, they performed a short practice session, in which they underwent 10 trials. After the practice session, they were asked to participate in the test session of 640 test trials. The order of the conditions was randomized for each participant. The sequence of events within each

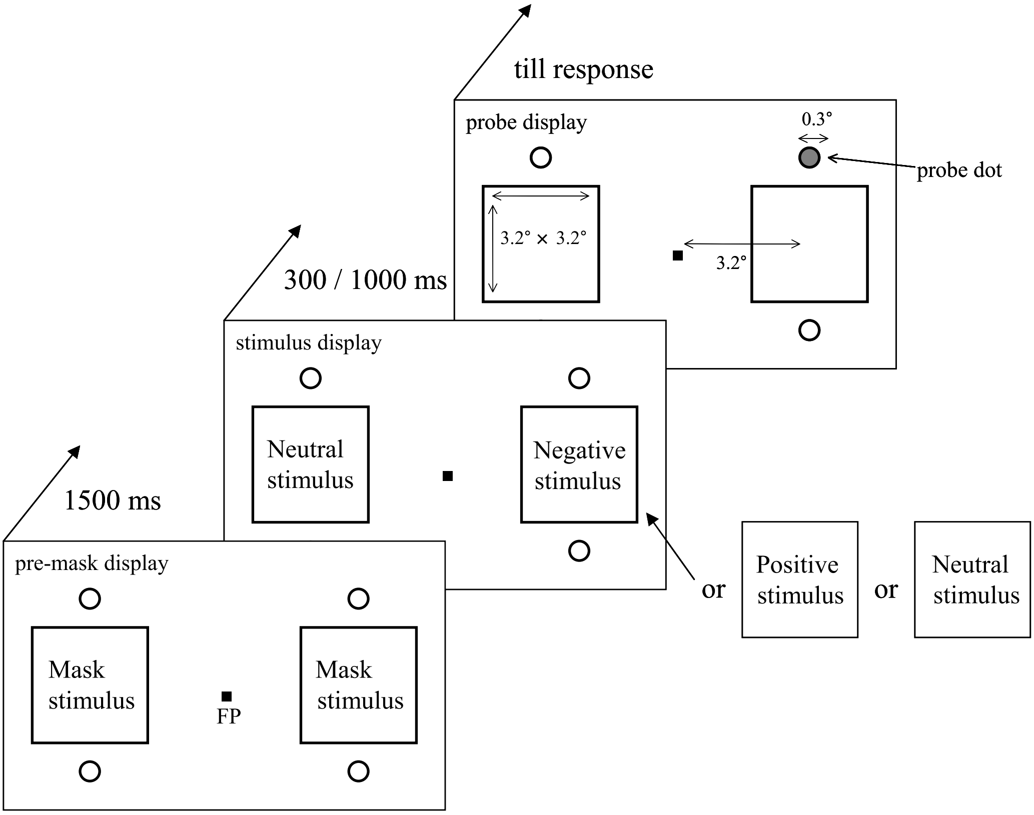

Figure 1. Example of trial in this study.

trials was as follows (see Figure 1): a fixation point (・) was presented at the center of the screen and remained there throughout the trial. The mask stimuli were presented for 1500ms on both sides of the fixation point. The mask stimuli were then replaced by stimulus pair, which were presented for either 300ms or 1000ms. These durations constituted stimulus onset asynchronies (SOAs), since the probe dot was presented immediately after their termination. There were five different combinations of picture pairs, with either a negative or positive picture combined with a neutral picture with neutral one being either on the left or right side of the fixation point. The remaining one combination was consisted of two neutral pictures, one on either side of the fixation point. Immediately after the offset of these cue pictures, a small red dot was presented at either upper or lower side of one of the two pictures, which was displayed until response.

The participants were instructed to respond to the probe dot as quickly and as accurately as possible. The left index finger was assigned to the Z key that corresponded to the upper cue location, while the right index finger was to press the / key for the lower location.

Following the convention of the spatial attention research a probe location was called valid when it was presented at the cue picture which had either positive or negative valence, while it was called invalid when it was presented at the location of a neutral picture (landscape).

There were 640 trials in this study. The 640 trials were a factorial combination of the following conditions: 2 (SOA: 300 ms vs. 1000 ms) × 2 (type of stimulus: negative vs. positive) × 2 (validity: valid vs. invalid) × 2 (visual field: left vs. right) ×32 (the number of times of trials) + 128 (the number of times both pictures were neutral).

Design

In this study, the cue stimulus was presented for either 300 ms or 1000 ms. We explored reaction time (RT) in both 300ms and 1000ms conditions. We considered the RT as measure of influence by emotional valence of stimuli.

A three-way ANOVA with 2 (type of stimuli: negative, positive) × 2 (validity: valid, invalid) × 2 (visual field: left, right) factorial design was applied to the average RTs. The condition was designated valid when location of the probe was the same as that of the emotional pictures (positive or negative). It was invalid when location of target was opposite to the emotional stimuli (i.e., at the location of neutral picture).

Results

RTs greater than 1000 ms or less than 150 ms were excluded from data analysis as outliers. Three-way ANOVA was carried out separately for each exposure duration (300 ms and 1000ms), with type of stimuli (negative, positive), validity (valid, invalid), and visual field (left, right) as main factors.

300ms exposure duration

There was an marginally significant main effect of type of stimuli (F (1, 10) = 4.58, p = .0579). It indicated that the participants tended to respond more slowly to the probe when it followed a negative picture than they did so when positive stimuli preceded the probe (Table 1).

Table 1
Mean and Standard Deviation Reaction Time by Type of Emotion, Stimuli Visual Field, and Validity in 300ms SOA (in msec).

Type of emotion and visual field	Invalid		Valid	
	M	*SD*	*M*	*SD*
Negative				
LVF stimuli	456.65	34.91	465.37	42.22
RVF stimuli	461.29	39.82	452.27	32.95
Positive				
LVF stimuli	452.01	38.20	456.57	35.40
RVF stimuli	452.94	32.41	441.75	35.21

Note. LVF = left visual field; RVF = right visual field

1000ms exposure duration

There was a significantly interaction between type of stimuli and validity (F (1, 10) = 5.76, p < .05). To clarify the interaction, further analyses performed separately for valence (i.e., positive and negative pictures) showed that there was a significant difference in RTs between valid and invalid conditions for negative pictures (F (1, 20) = 10.33, p < .001). This was due to longer RTs for the valid condition relative to the invalid condition (Table 2). In contrast, there was no validity effect for the positive pictures (F (1, 20) = 0.03, p > .1)

Table 2
Mean and Standard Deviation Reaction Time by Type of Emotion, Stimuli Visual Field, and Validity in 1000ms SOA (in msec).

Type of emotion and visual field	Invalid		Valid	
	M	*SD*	*M*	*SD*
Negative				
LVF stimuli	406.40	29.87	432.15	43.50
RVF stimuli	413.90	41.59	414.12	39.47
Positive				
LVF stimuli	412.05	34.35	425.53	31.52
RVF stimuli	424.33	41.17	412.32	41.99

Note. LVF = left visual field; RVF = right visual field

Discussion

In this study, we predicted that RTs to the probe that appeared on the side of emotion-provoking stimuli would be affected by their aversive valence. At the same time we explored the possibility that this modulating effect of emotional valence would depend on their durations.

The result indicated that negative valence was found to be effective in modulating RTs. The results of the present study suggested that RT to the probe that followed negative stimuli was likely to be longer than the RT to the target that followed positive stimuli. These differences between emotional valences were shown when the pictures were shown for 1000ms. In this longer SOA condition, RT to the probe that succeeded negative stimuli was longer than that to the target that succeeded positive stimuli. In contrast, although there was a marginally significant main effect of the type of stimuli, the RT difference between the negative and positive pictures were not significant in the 300ms SOA condition. Thus, in this study the inhibitory effect of aversive emotion was shown. In addition, the SOA or duration of the picture was found to modulate the effect of negative valence with a marked modulation effect in the 1000ms SOA condition. Therefore, the effect of aversive emotion was likely to be dependant on the SOA or duration of the emotional pictures.

Contrary to the current finding, many previous studies using the probe-detection task mostly indicated that negative stimuli results in the facilitation of response to the target, which was interpreted to be due to attentional capture by these stimuli (MacLeod et al., 1986; Bradley et al., 1998). That is, people can allocate their attention to the spatial location of fear-provoking stimuli more quickly than to neutral or positive stimuli as an evolutionary adaptation to environmental threats (e.g. Dangers in environment had to be rapidly detected to be adaptively avoided). On the other hand, however, there were studies that used a task other than the probe paradigm (e.g. emotional Stroop task) have shown that response to aversive stimuli exerted inhibitory influence on performance (Williams, Mathews, & MacLeod, 1996). We interpreted this inconsistency between the results of the previous studies and the current one as being due to differences in the procedures between the studies. One difference in the procedure was the SOA between the onsets of the emotional pictures and the probe. In several previous studies that have found facilitation in probe RTs by aversive emotion, SOA from emotional stimulus onset to probe onset was 500 ms.

However, in the previous research that found avoidance of stimuli of negative valence used much longer SOA in comparison with the above studies in which attraction toward them was the reported result. For example, Rohner (2002) in which EOG was used to monitor overt attention shifts found initial attraction in the stimulus exposure range of 0-1000 ms, but later avoidance in the range of 2000-3000 ms. In order to explore the effects of SOA of stimuli with emotional valence, we used both short and long SOAs in the present probe detection task. We predicted that effect of emotional valence on RT changed with the SOA of emotional stimuli.

In summary, the results of present study indicated that the exposure duration or SOA interacted with aversive valence of pictures in the control of visual attention. It was suggested that inhibitory effect of aversive emotion was likely to increase, as exposure duration of emotional stimuli became longer. This is consistent with the results of EOG study reported by Rohner (2002).

Finally one limitation of the present study was the lack of monitoring individual difference in anxiety. Several previous studies indicated that individual's anxiety level is related to the magnitude of influence of negative emotion (Eysenck, 1988; Mogg & Bradley, 1999; Öhman, 1996). Another limitation was SOAs. Only two SOAs of 300 ms and 1000 ms, which were relatively short in comparison with the range used in the Rohner's study, were used. In a future study, these points must be explored.

References

Bradley, B.P., Mogg, K., Falla, S.J., & Hamilton, L.R. (1998). Attentional bias for threatening facial expressions in anxiety: Manipulation of stimulus duration. *Cognition and Emotion,* 12, 737‐753.

Buckley, T. C., Blanchard, E. B., & Hickling, E. J. (2002). Automatic and strategic processing of threat stimuli: A comparison between PTSD, panic disorder, and nonanxiety controls. *Cognitive Therapy and Research,* 26, 97‐115.

Crawford, L. E., & Cacciopo, J. T. 2002 Learning where to look for danger: Integrating affective and spatial information. *Psychological Science,* 13, 449‐453.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion,* 16, 355‐379.

Kahn, B. E., & Isen, A. M. (1993). The influence of positive affect on variety seeking among safe, enjoyable products. *Journal of Consumer Research,* 20, 257‐270.

LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life.* New York: Simon and Schuster.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology,* 95, 15‐20.

Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition and Emotion,* 13, 713‐740.

Mogg, K., & Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behaviour Research and Therapy,* 40, 1403‐1414.

Morris, J.S., Öhman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdale mediating “unseen” fear. *Neurobiology,* 96, 1680‐1685.

Niedenthal, P. M. (1999). Implicit perception of affective information. *Journal of Experimental Social Psychology,* 26, 505‐527.

Öhman, A. (1986). Face the beast and fear the face: Animal and social fears as prototypes for evolutionary analyses of emotion. *Psychophysiology,* 23, 123‐145.

Öhman, A. (2000). Fear and anxiety: Evolutionary, cognitive, and clinical perspectives. In M.Lewis & J. M. Haviland-Jones (Eds.), *Handbook of emotions.* 2nd ed. New York: The Guilford Press, pp.537‐593.

Öhman, A. (1996). Prefrontal preattentive processing of threat in anxiety: Preparedness and attentional biases. In R.M. Rapee (Ed.), *Current controversies in the anxiety disorders.* First ed. New York: The Guilford Press, pp.253‐290.

Öhman, A., & Mineka, S. (2003). The malicious serpent: Snakes as a Prototypical stimulus for an evolved module of fear. *Psychological Science,* 12, 5‐9.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental psychology: General,* 130, 466‐478.

Paquette, V., Levesque, J., Mensour, B., Leroux, J., Beaudon, G., Bourgouin, P., & Beauregard, M. (2003). “Change the mind and you change the brain” : effects of cognitive behavioral therapy on the neural correlates of spider phobia. *Neuroimage,* 18, 401‐409.

Vuilleumier, P., & Schwartz, S. (2001). Beware and be aware: Capture of spatial attention by fear-related stimuli in neglect. *NeuroReport,* 12, 1119‐1122.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional stroop task and psychopathology. *Psychological Bulletin,* 120, 3‐24.

Rohner, J. (2002). The time-course of visual threat processing: High trait anxious individuals eventually avert their gaze from angry faces. *Cognition and Emotion,* 16, 837‐844.