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Relation	

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Processing of Task-Irrelevant Natural Scenes in Social Anxiety

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Abstract

In this study, by manipulating perceptual load, we investigated whether socially anxious people process task-irrelevant, non-emotional, natural scenes. When attention was directed to letters and perceptual load was low, task-irrelevant natural scenes were processed, as evidenced by repetition priming effects, in both high and low socially anxious people. In the high perceptual load condition, repetition-priming effects decreased in participants with low social anxiety, but not in those with high social anxiety. The results were the same when attention was directed to pictures of animals: even in the high perceptual load condition, high socially anxious participants processed task-irrelevant natural scenes, as evidenced by flanker effects. However, when attention was directed to pictures of people, task-irrelevant natural scenes were not processed by participants in either anxiety group, regardless of perceptual load. These results suggest that high socially anxious individuals could not inhibit task-irrelevant natural scenes under conditions of high perceptual load, except when attention was focused on people.

Keywords: social anxiety, perceptual load, natural scene, attentional control, repetition priming, flanker task

Processing of Task-Irrelevant Natural Scenes in Social Anxiety

1. Introduction

People focus on goal-relevant information by top-down processing, which controls where, how, and to what people pay attention. However, task-irrelevant stimuli are not always effectively ignored. In some cases, task-irrelevant distractors interfere with goal-directed attention, and are unintentionally processed (Eriksen & Eriksen, 1974; Gatti & Egeth, 1978). Interference from task-irrelevant distractors is influenced by attentional control (Forster & Lavie, 2007). Individuals with poor attentional control experience greater distractor interference than those with good attentional control. Considering individual differences in attentional control is an important step in revealing the nature of interference effects from task-irrelevant distractors.

Anxiety is clearly related to poor attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007; Moriya & Tanno, 2008). According to the attentional control theory proposed by Eysenck et al. (2007), anxiety increases the influence of bottom-up processing and decreases that of top-down processing on automatic detection and processing of task-irrelevant stimuli (see Derakshan & Eysenck, 2009 for a recent review). Highly anxious people cannot suppress salient task-irrelevant stimuli. Eysenck et al. proposed that attentional control in people with high anxiety is impaired when task demands on processing resources are high. While many previous studies revealed impaired attentional control in anxious individuals, few studies have investigated the processing of task-irrelevant stimulus or manipulated task demands on processing resources.

The perceptual load theory proposed by Lavie (1995, 2005, 2010) is useful for investigating the processing of task-irrelevant stimuli and the effects of task demands. When task-relevant stimuli are presented with other task-irrelevant distractors, people remain focused on the perception of the task-relevant stimuli. However, people are distracted by task-irrelevant stimuli in certain cases, for example when there are few task-relevant stimuli or the task-irrelevant distractors are salient. In contrast, when there are many task-relevant stimuli or the task-irrelevant distractors are not so salient, people are not distracted by the task-irrelevant stimuli. According to the perceptual load theory, people have limited resources and all stimuli are automatically processed until attentional resources are depleted. When task demands are low, such as a condition with a few task-relevant stimuli, there are spare attentional resources and people use them to process task-irrelevant stimuli. However, when task demands are high (e.g. many task-relevant stimuli must be processed), there is no spare capacity for processing task-irrelevant stimuli. In this case, perceptual load is defined as the number of task-relevant stimuli or different-identity items (Lavie, 1995, 2005; Lavie & De Fockert, 2003). Extra attentional resources are allocated to task-irrelevant distractors when just one or very few relevant stimuli are presented (low perceptual load). On the other hand, attentional resources are exhausted as the number of task-relevant stimuli or different-identity items increases (high perceptual load). Therefore, processing task-irrelevant distractors weakens under conditions of high perceptual load.

The perceptual load theory proposes that a high perceptual load diminishes perception of task-irrelevant stimuli. However, according to the attentional control theory (Eysenck et al., 2007), interference from task-irrelevant distractors in anxious individuals might be observed when there is increased demand on processing resources because attentional control is impaired. In other words, impaired attentional control and enhanced sensitivity due to anxiety might increase interference from task-irrelevant distractors under conditions of high perceptual load. Considering the limited attentional resources, interference from task-irrelevant stimuli in anxious people might occur at the cost of target perception. When task demands are high, such people might have difficulty controlling their attention and may not be able to allocate sufficient attentional resources to the target. Instead, they might deploy the remaining resources to the task-irrelevant stimuli.

A few previous studies have investigated the effect of anxiety on processing of task-irrelevant stimuli by manipulating perceptual load (Bishop, 2009; Bishop, Jenkins, & Lawrence, 2007; Moriya & Tanno, 2010; Sadeh & Bredemeier, 2011). Moriya and Tanno (2010) investigated the processing of non-emotional task-irrelevant letters by manipulating perceptual load using an adapted flanker task (Lavie & Cox, 1997). Participants provided speeded choice responses to a target letter presented at the center of the screen while attempting to ignore a distractor letter presented in the periphery. Perceptual load was manipulated by varying the number of different-identity letters presented in the center. The identity of the peripheral task-irrelevant distractors could be either compatible with the target (i.e., the same as the target) or incompatible (i.e., an alternative target). When participants processed task-irrelevant distractors, the reaction times (RTs) in the incompatible condition were longer than those in the compatible condition (Eriksen & Eriksen, 1974). Moriya and Tanno (2010) showed that, in the low perceptual load condition, all participants processed the task-irrelevant stimuli, and RTs in the incompatible condition were longer than in the compatible condition. Moreover, even in a high perceptual load condition, participants with high social anxiety processed the task-irrelevant stimuli. These results suggest that attentional resources are allocated to task-irrelevant distractors in people with high anxiety even when perceptual load is high.

Bishop et al. (2007) designed an fMRI task in which a letter was superimposed on task-irrelevant fearful or neutral facial expressions. They manipulated perceptual load by varying the number of task-relevant letters. The behavioral results revealed that task-irrelevant faces interfered with the performance of high-anxiety participants under high perceptual load; in other words, the highly anxious participants had longer RTs and made more errors than the low socially anxious participants in the high perceptual load condition (for different results in neurological data, see the General Discussion section). This suggests that anxious participants allocate attentional resources to task-irrelevant facial expressions even under conditions of high perceptual load.

Previous studies have investigated the effect of task-irrelevant stimuli in anxious people by using letters or faces as distractors. Considering that highly anxious people routinely process task-irrelevant stimuli, one can reasonably assume that they will also process task-irrelevant natural scenes, which are ecologically valid stimuli. Moreover, the feature integration theory (Treisman & Gelade, 1980; Wolfe, Cave, & Franzel, 1989) posits that stimulus features such as lines, colors, and orientation are processed early, automatically, and in parallel. Processing complex natural scenes, which include many features, might require more attention than processing letters. It is unclear whether anxious people process complicated, task-irrelevant, non-emotional natural scenes in both low and high perceptual load conditions.

This study investigates whether socially anxious people process task-irrelevant natural scenes under conditions of high perceptual load. We focus on social anxiety because previous research has shown that social anxiety is more strongly related to impaired attentional control than other types of anxiety or depression (Moriya & Tanno, 2008). Therefore, in this study, we seek to examine whether people with poor attentional control suppress task-irrelevant distractors.

Eysenck et al. propose that processing task-irrelevant stimuli in individuals with high social anxiety might be observed when task demands on processing resources are high. Therefore, we hypothesize that interference from task-irrelevant stimuli would be observed when high socially anxious people categorized stimuli in a high perceptual load condition. We also hypothesize that both high and low socially anxious people would categorize task-irrelevant natural scenes in the low perceptual load condition.

2. Experiment 1

In Experiment 1, we investigated whether socially anxious individuals processed task-irrelevant natural scenes when their attention was directed to non-natural scenes (i.e., letters). To this end, we used a repetition priming task and manipulated perceptual load according to Lavie, Lin, Zokaei, and Thoma (2009). In this task, stimuli are presented in an initial display (i.e., prime display), and stimuli in a subsequent display (i.e., probe display) are either repeated or non-repeated stimuli (intermixed). The repeated stimuli in the probe display are processed more rapidly than the non-repeated stimuli, a phenomenon known as repetition priming (Forster & Davis, 1984). Processing the stimulus in the prime display enhances target categorization in the probe display, even if the stimulus in the prime display is a task-irrelevant distractor. In other words, whether task-irrelevant natural scenes in the prime display are categorized is measured by facilitation priming in categorizing the natural scene in the probe display.

As described in the perceptual load theory (Lavie, 2005), the extra attentional resources in the low perceptual load condition should lead to repetition priming for the task-irrelevant natural scenes in both high and low socially anxious participants; that is, we hypothesized that RTs to repeated stimuli (i.e., primed condition) would be shorter than those to non-repeated stimuli (i.e., unprimed condition). In addition, the attentional control theory (Eysenck et al., 2007) predicts that high socially anxious people will still be unable to inhibit processing of task-irrelevant distractors in the high perceptual load condition due to their impaired attentional control. Therefore, we hypothesized that in the high perceptual load condition, repetition priming will be observed in highly socially anxious people, whereas repetition priming will be reduced or not observed in low socially anxious people.

2.1. Method

2.1.1. Participants

The participants were 43 undergraduate students aged 18 to 21 (22 males and 21 females) who provided informed consent. All had normal or corrected-to-normal vision. Participants completed the Japanese version of the Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983; Sasagawa et al., 2004), which assesses apprehension related to others' negative evaluations and reflects the degree of social anxiety. The scale consists of 12 items rated on 5-point Likert scales. A previous study indicated that the average scale score in university students is 43.8 (Moriya & Tanno, 2008). Participants were divided into high and low social anxiety groups based on a median split of BFNE scores. The 20 participants who scored 42 and above were placed in the high social anxiety group; the 20 participants who scored 40 and below were placed in the low social anxiety group; the remaining 3 participants who scored the median value of 41 were excluded. All participants also completed the Japanese versions of the State-Trait Anxiety Inventory (STAI; Shimizu & Imae, 1981; Spielberger, Gorsuch, & Lushene,

1970) and the Self-Rating Depression Scale (SDS; Fukuda & Kobayashi, 1973; Zung, 1965) used to measure the degree of state, trait anxiety, and depression.

2.1.2. Materials and apparatus

All stimuli were presented in white on a black background. In the prime display, target and non-target letters were presented on an imaginary circle (with a radius of 2.52°) at fixation. A target letter (X or N) appeared randomly, but with equal probability, in one of six positions. The other five positions were occupied by five O's in the low perceptual load condition and by five different letters (G, H, J, S, and Y) in the high perceptual load condition. The five non-target letters could appear randomly in any of the six positions with equal probability. The target and non-target letters were 0.57° in width and 0.86° in height.

In addition, a task-irrelevant natural scene, which participants were instructed to ignore, was presented on the left or right of the letters in the prime display. The natural scenes comprised 24 pictures of animals, 24 pictures of objects, and 24 pictures of landscapes selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005)[1]. The pictures were relatively neutral. The distance between fixation and the task-irrelevant distractor (animal, object, or landscape picture) was 9.45° from center to center, and the distractor was located to the left or right of fixation with equal probability. The task-irrelevant distractor was 6.45° in width and 4.84° in height.

In the probe display, a single picture was presented at the center of the screen. The picture showed either an animal or an object; the landscape pictures were not used. The picture in the probe display was identical in size to the task-irrelevant distractor in the prime display.

In the primed condition (one-third of trials), the picture in the probe display was identical to the distractor picture presented in the prime display. In the unprimed-related condition (one-third of trials), the picture in the probe display differed from the distractor picture presented in the prime display and was selected from the alternative target category (e.g., if the distractor in the prime display was an animal, the target in the probe display would be an object). In the unprimed-neutral condition (one-third of trials), irrespective of the picture in the probe display, the picture in the prime display was a landscape which was unrelated to the two response options in the probe display. We randomly paired the prime and probe display stimuli so that pairs were presented with equal frequency in the unprimed-related and -neutral conditions.

All stimuli were presented on an EPSON Endeavor MT7500 computer with a 17-inch SONY CPD-E230 screen. Experiments were programmed in Matlab using Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Participants were seated approximately 60 cm from the monitor. RTs and accuracy were obtained from keyboard responses.

2.1.3. Procedure

Figure 1 presents an example of an experimental trial. The participants were seated in front of the monitor in a dark room. A fixation cross appeared at the center of the screen for 800 to 1200 ms and participants were required to fixate on the cross. Following fixation, the prime display was presented for 200 ms. Participants were instructed to ignore the distractor picture and indicate by pressing the appropriate key whether the display contained an “X” or an “N”. A blank screen was presented until the participants responded. After their response, a fixation cross appeared at the center of the screen for 300 to 600 ms and the participants were required to fixate on the cross.

Then the probe display was presented for 200 ms. The participants were instructed to identify whether the picture was of an animal or an object by pressing the appropriate key. A blank screen was presented until the participants responded. The prime and probe displays were presented sequentially, and the intertrial interval lasted for 500 ms.

(Figure 1 about here)

After 24 practice trials for each load condition, the participants completed 288 experimental trials per load condition. The blocks in the load conditions were arranged in random order for each participant. The primed, unprimed-related, and unprimed-neutral conditions were randomized within each load block. The participants were instructed to focus on the centrally located fixation cross throughout the task and to respond as quickly and as accurately as possible. At the end of the task, the participants were required to complete the scales.

2.2. Results

We analyzed data for each participant and excluded incorrect responses and trials where RTs were more than three standard deviations from the mean for each perceptual load and priming condition. The average percentage of outliers in the high social anxiety group was 1.4% (SD = 0.78) in the prime display and 2.7% (SD = 1.8) in the probe display, and the average percentage of outliers in the low social anxiety group was 1.8% (SD = 0.75) in the former and 1.9% (SD = 1.2) in the latter.

2.2.1. Scores on each scale

The high and low social anxiety groups differed significantly in terms of social anxiety (M = 47.2, SD = 4.6 vs. M = 36.7, SD = 3.4; $t(38) = 8.27$; $p < .001$, d = 2.61), trait anxiety (M = 51.1, SD = 11.1 vs. M = 41.8, SD = 9.0; $t(38) = 2.92$; $p < .01$, d = 0.92), and depression (M = 45.4, SD = 8.0 vs. M = 39.6, SD = 6.9; $t(38) = 2.48$; $p < .05$, *d* = 0.79), but not in state anxiety (*M* = 40.5, *SD* = 8.0 vs. *M* = 38.0, *SD* = 8.1; *t* (38) = 0.98; *ns*).

2.2.2. Letter identification task in the prime display

We confirmed the effects of perceptual load by analyzing RTs in the prime display. Mean RTs for the high and low social anxiety groups are presented in Table 1. A 2 (social anxiety: high and low) × 2 (perceptual load: high and low) ANOVA on RTs revealed significant main effects of social anxiety, $F(1, 38) = 5.64$, $p < .05$, $\eta^2_p = .13$, and perceptual load, $F(1, 38) = 224.02$, $p < .001$, $\eta^2_p = 86$, such that RTs in the high perceptual load condition were longer than those in the low perceptual load condition (high perceptual load: *M* = 725 ms, *SD* = 20; low perceptual load: *M* = 510 ms, *SD* = 10). This confirms the validity of our manipulation of perceptual load. There was also a two-way interaction between social anxiety and perceptual load, $F(1, 38) = 6.65$, $p < .05$, $\eta^2_p = .15$. A Bonferroni-corrected simple effects test (two-tailed) revealed that, in the high perceptual load condition, RTs for the high social anxiety group were longer than those for the low social anxiety group, $t(19) = 2.60$, $p < .05$, $d = 0.82$. However, RTs did not differ between high and low social anxiety groups in the low perceptual load condition. In addition, in both high and low social anxiety groups, RTs in the high perceptual load condition were longer than those in the low perceptual load condition (high social anxiety: $t(19) = 12.41$, $p < .001$, $d = 2.37$; low social anxiety: $t(19) = 8.76$, $p < .001$, $d = 1.82$).

(Table 1 about here)

We also analyzed error rates with a 2 (social anxiety) × 2 (perceptual load) ANOVA (Table 1). There were no significant main effects or interaction.

2.2.3. Picture identification task in the probe display

We confirmed the effect of repetition priming by analyzing RTs in the probe display. Mean RTs in the high and low social anxiety groups are presented in Table 1. A 2 (social anxiety) × 2 (perceptual load) × 3 (priming: primed, unprimed-related, and unprimed-neutral) ANOVA on RTs revealed significant main effects of perceptual load, $F(1, 38) = 14.33$, $p < .01$, $\eta^2_p = .27$, and priming, $F(2, 76) = 70.66$, $p < .001$, $\eta^2_p = .65$. There were also significant two-way interactions between social anxiety and priming, $F(2, 76) = 4.52$, $p < .05$, $\eta^2_p = .11$, and perceptual load and priming, $F(2, 76) = 14.13$, $p < .001$, $\eta^2_p = .27$, and a significant three-way interaction between social anxiety, perceptual load, and priming, $F(2, 76) = 3.43$, $p < .05$, $\eta^2_p = .08$. No other main effects or interactions were significant. Bonferroni-corrected simple effects tests revealed that, in the case of low perceptual load, RTs in the primed condition were shorter than those in the unprimed-related and unprimed-neutral conditions for both the high social anxiety (unprimed-related condition: $t(19) = 6.86$, $p < .001$; unprimed-neutral condition: $t(19) = 6.78$, $p < .001$) and low social anxiety groups (unprimed-related condition: $t(19) = 6.38$, $p < .001$; unprimed-neutral condition: $t(19) = 4.99$, $p < .001$). In the high perceptual load condition, RTs in the primed condition were shorter than those in the unprimed-related and unprimed-neutral conditions for the high social anxiety group (unprimed-related condition: $t(19) = 6.43$, $p < .001$; unprimed-neutral condition: $t(19) = 7.11$, $p < .001$) and only shorter than those in the unprimed-neutral condition for the low social anxiety group, $t(19) = 2.11$, $p < .05$. There were no differences in overall RTs between high and low socially anxious people.

In keeping with previous studies (Lavie et al., 2009), we defined priming effects by subtracting RTs in the primed condition from those in the unprimed-related condition, and then we analyzed the correlations between the priming effect and each scale score for all participants (Table 2). The results revealed that social anxiety was positively correlated with priming effects under conditions of high perceptual load, but not low perceptual load. Trait anxiety, state anxiety, and depression were not correlated with priming effects.

(Table 2 about here)

Because RTs between high and low socially anxious people in the prime display differ, the interval between the prime and probe displays might have also been different between high and low socially anxious people. In order to investigate the effects of different RTs in the prime display on the priming effect, we conducted a 2 (social anxiety) × 2 (perceptual load) × 3 (priming) analysis of covariance (ANCOVA) on RTs in the picture identification task, with the RTs in the letter identification tasks as a covariate. The results were generally consistent with those of the ANOVA. There was a significant three-way interaction between social anxiety, perceptual load, and priming, $F(2, 74) = 4.16$, $p < .05$, $\eta^2_p = .10$. A Bonferroni-corrected simple effects test revealed that, in the case of low perceptual load, RTs in the primed condition were shorter than those in the unprimed-related and unprimed-neutral conditions for both the high social anxiety group (*ps* < .001) and low social anxiety group (*ps* < .001). In the high social anxiety group, RTs in the unprimed-related condition were also shorter than those in the unprimed-neutral condition ($p < .05$). In the high perceptual load condition, RTs in the primed condition were shorter than those in the unprimed-related and unprimed-neutral conditions for the high social anxiety group (*ps* < .001), and only shorter than those in the unprimed-neutral condition for the low social anxiety group ($p < .05$).

We also computed the partial correlation between the priming effect and each scale score controlling for RTs in the prime display. The results were consistent with the previously described correlations. In the case of high perceptual load, a significant positive correlation was observed between social anxiety and priming effects, $r = .34$, $p < .05$, but this correlation was not observed in the case of low perceptual load, $r = -.07$, *n.s*. Trait anxiety, state anxiety, and depression were not correlated with priming effects.

We also analyzed error rates with a 2 (social anxiety) × 2 (perceptual load) × 3 (priming) ANOVA (Table 1). There were no significant main effects or interactions.

2.3. Discussion

The present experiment revealed repetition priming of task-irrelevant natural scenes in the low perceptual load condition, and this priming effect was invariant across degrees of social anxiety. In other words, all participants processed the task-irrelevant natural scenes in the low perceptual load condition. In contrast, repetition priming in the high perceptual load condition was related to social anxiety such that the magnitude of this effect increased with increased social anxiety. Individuals with high social anxiety could not inhibit processing of task-irrelevant distractors and processed distractors even in the high perceptual load condition. The distractor priming effect increased in proportion to the degree of social anxiety, but not in proportion to trait anxiety, state anxiety, or depression. These results support the hypothesis that interference from task-irrelevant distractors would be observed under conditions where increased demand was placed on processing resources, while interference was invariant under conditions of low demand; further, these results are consistent with Eysenck et al. (2007).

Repetition priming effects from the task-irrelevant distractors were observed even in the high perceptual load condition, regardless of the degree of social anxiety, which is inconsistent with the results of previous studies (Lavie, 1995; Lavie & De Fockert, 2003). We assume that there are two causes for the difference between the results of our study and those of previous ones. First, the size of the distractors in this study was larger than in previous studies and might have been processed more easily, thereby requiring less attention. Second, natural scenes require fewer attentional resources for processing than simple letters and colors (Fei-Fei, VanRullen, Koch, & Perona, 2005; Li, VanRullen, Koch, & Perona, 2002; Otsuka & Kawaguchi, 2007). In previous studies, participants were required to determine whether five randomly rotated letters presented at the center of the display were the same while also detecting a peripheral target (i.e., rotated letter, vertically bisected disk, or natural scene). These studies showed that performance detecting and categorizing natural scenes was better than performance discriminating letters or color patterns. In fact, Lavie et al. (2009) found that priming effects in a high perceptual load condition were reduced, but not eliminated, when the task-irrelevant distractors were natural scenes. Therefore, it may be difficult to prevent processing of task-irrelevant natural scenes.

3. Experiment 2

Experiment 1 revealed that participants with high social anxiety could not inhibit processing of task-irrelevant natural scenes and they processed those natural scenes while directing attention to letters, even in the high perceptual load condition. However, it is still unclear whether high socially anxious people would process task-irrelevant natural scenes when they are directing attention to other natural scenes. Because people attend to environmental stimuli more than letters in everyday life, investigating distractor processing when attention is directed to natural scenes is more ecologically valid. In Experiment 2, we used natural scenes as both the target and task-irrelevant stimuli to investigate the effect of social anxiety on processing task-irrelevant natural scenes when attention was directed to other natural scenes. We manipulated perceptual load by varying the number of different-identity non-target pictures.

In this experiment, we replaced the pictures of objects with pictures of people. Socially anxious people are afraid of social situations, such as talking in front of people and being evaluated by others (Clark & Wells, 1995; Miers, Blöte, Bokhorst, & Westenberg, 2009; Rapee & Heimberg, 1997; Voncken & Bögels, 2008; Voncken, Dijk, de Jong, & Roelofs, 2010). Considering these features of social anxiety, investigating how pictures of people are processed is important.

We modified the flanker task used in Experiment 1 by replacing the letter stimuli with pictures in the prime display, and measured flanker compatibility effects (Eriksen & Eriksen, 1974). When participants responded to a central target letter flanked by the same task-irrelevant letters, they identified the target rapidly. However, when the target was flanked by different task-irrelevant letters, these task-irrelevant stimuli interfere with target processing and lead to increase in RTs. This is called the flanker compatibility effect. This effect also occurs with natural stimuli (Wells & Hamm, 2009). In Experiment 2, the identity of the peripheral task-irrelevant pictures could be compatible with the target (i.e., same category as the target), incompatible with the target (i.e., the alternative category), or neutral (i.e., neither of the possible target categories). In the incompatible condition, task-irrelevant stimuli should produce interference, thereby resulting in longer RTs compared to the compatible condition.

Based on the results of Experiment 1, we hypothesized that even when directing attention to natural scenes, participants with high social anxiety process the task-irrelevant natural scenes in the high perceptual load condition, and interference effects are observed as flanker compatibility effects. However, participants with low social anxiety might not process the task-irrelevant natural scenes in the high perceptual load condition. On the other hand, in the case of the low perceptual load, we hypothesized that the task-irrelevant natural scenes are processed by both high and low socially anxious people because of the additional, unused attentional resources.

3.1. Method

3.1.1. Participants

The participants were 53 undergraduate students aged 18 to 21 (25 males and 28 females) who provided written informed consent. All participants had normal or corrected-to-normal vision. Participants completed the BFNE and were divided into high and low social anxiety groups based on a median split of BFNE scores. The 26 participants who scored 42 and above were placed in the high social anxiety group, and the other 25 participants who scored 40 and below were placed in the low social anxiety group. The two participants who scored the median value of 41 were excluded. All participants also completed the STAI and SDS.

3.1.2. Materials

A target and three non-target pictures were presented around a fixation cross. A target picture (animal or person) appeared randomly but with equal probability in one of four positions. The other three non-target positions were occupied by three pictures of the same vehicle in the low perceptual load condition, or by three pictures of different vehicles in the high perceptual load condition. The distance between fixation and the task-relevant stimuli was 4.00° from center to center. The task-irrelevant distractor (picture of an animal, person, or landscape) was located to the left or right of the fixation with equal probability. The distance between fixation and the task-irrelevant distractor was 9.45° from center to center. The target, non-target, and task-irrelevant pictures were 6.45° in width × 4.84° in height. The target natural scenes were 12 pictures of animals and 12 pictures of people, and the non-target natural scenes were 3 pictures of vehicles. The task-irrelevant natural scenes were 12 pictures of animals, 12 pictures of people (these were the same as the target pictures), and 12 pictures of landscapes. All pictures were selected from the IAPS[2].

In the compatible condition (one-third of trials), the distractor picture was from the same category as the target; however, it was not the same picture. In the neutral condition (one-third of trials), the distractor had no response association (i.e., the distractor was a landscape picture). In the incompatible condition (one-third of trials), the distractor was from the alternative target category.

3.1.3. Procedure

Figure 2 presents an example of an experimental trial. A fixation cross appeared at the center of the screen for 800 to 1200 ms and the participants were required to fixate on the cross. Following fixation, the target, non-target, and task-irrelevant pictures were presented for 200 ms. The participants were instructed to ignore the task-irrelevant picture and indicate by pressing the appropriate key whether the target picture showed a person or an animal. A blank screen was presented until a response was made. The inter-trial interval was 500 ms.

After 24 practice trials for each load condition, the participants completed 144 experimental trials per load condition. The blocks in the load conditions were arranged in random order for each participant. The participants were instructed to focus on the centrally located fixation cross throughout the task and to respond as quickly and accurately as possible. At the end of the task, the participants were required to complete the scales.

3.2. Results

We analyzed data for each participant and removed incorrect responses and trials where RTs were more than three standard deviations from the mean. The average percentage of outliers was 1.71% (SD = 0.79) in the high social anxiety group and 2.04% (SD = 0.96) in the low social anxiety group.

3.2.1. Scores on each scale

The high and low social anxiety groups differed significantly in terms of social anxiety (M = 49.3, SD = 4.7, vs. M = 33.2, SD = 5.8, $t(49) = 10.88$, $p < .001$, $d = 3.05$), trait anxiety (M = 52.3, SD = 10.2, vs. M = 41.8, SD = 8.3, $t(49) = 3.98$, $p < .001$, d = 1.13), state anxiety (M = 44.5, SD = 10.7, vs. M = 37.6, SD = 6.1, $t(49) = 2.82$, $p < .01$, $d = 0.79$), and depression (M = 45.5, SD = 7.1, vs. M = 39.8, SD = 5.8, $t(49) = 3.09$, $p < .01$, $d = 0.94$).

3.2.2. Animal target condition

We analyzed RTs separately for each target category (i.e., animal and person) because RTs varied between categories (Table 3). In the animal target condition, a 2 (social anxiety) × 2 (perceptual load) × 3 (compatibility: compatible, neutral, and incompatible) ANOVA revealed significant main effects of perceptual load, $F(1, 49) = 33.56$, $p < .001$, $\eta^2_p = .41$, and compatibility, $F(2, 98) = 16.04$, $p < .001$, $\eta^2_p = .25$. There was a significant two-way interaction between perceptual load and compatibility, $F(2, 98) = 4.04$, $p < .05$, $\eta^2_p = .08$. There was also a significant three-way interaction between social anxiety, perceptual load, and compatibility, $F(2, 98) = 3.37$, $p < .05$, $\eta^2_p = .06$. No other main effects or interactions were significant. A Bonferroni-corrected simple effects test revealed that, in the case of low perceptual load, RTs in the incompatible condition were longer than those in the compatible and neutral conditions for both the high social anxiety (compatible condition: $t(25) = 2.75$, $p < .05$; neutral condition: $t(25) = 2.77$, $p < .05$) and low social anxiety groups (compatible condition: $t(24) = 4.15$, $p < .001$; neutral condition: $t(24) = 5.12$, $p < .001$). However, in the case of high perceptual load, RTs in the incompatible condition were longer than those in the compatible condition for the high social anxiety group only, $t(25) = 3.59$, $p < .01$.

Because interference from task-irrelevant natural scenes was observed, we defined flanker compatibility effects by subtracting RTs in the compatible condition from those in the incompatible condition for animal targets, and analyzed the correlations between the compatibility effect and each scale score for all participants (Table 4). The results indicated that social anxiety was positively correlated with flanker compatibility effects under conditions of high perceptual load, but not under conditions of low perceptual load. Trait anxiety was also marginally correlated with compatibility effects in the high perceptual load condition. There were no correlations between the other scale scores and compatibility effects.

(Table 4 about here)

Error rates were also analyzed with a 2 (social anxiety) × 2 (perceptual load) × 3 (compatibility) ANOVA (Table 3). There was a marginally significant main effect of perceptual load, $F(1, 49) = 3.16$, $p = .082$, $\eta^2_p = .06$, and a significant two-way interaction between social anxiety and compatibility, $F(2, 98) = 5.08$, $p < .01$, $\eta^2_p = .09$. Follow-up *t*-tests for simple effects revealed that low socially anxious people made more errors in the neutral condition than the compatible condition, $t(24) = 2.71$, $p < .05$. No other main effects or interactions were significant. Error rates in the high perceptual load condition were higher than those in the low perceptual load condition, thereby demonstrating that perceptual load was successfully manipulated.

3.2.3. Person target condition

In the person target condition, a 2 (social anxiety) × 2 (perceptual load) × 3 (compatibility) ANOVA on RTs revealed a significant main effect of perceptual load, $F(1, 49) = 16.04$, $p < .001$, $\eta^2_p = .25$. RTs in the high perceptual load condition were longer than those in the low perceptual load condition. No other main effects or interactions were significant. Further, no interference effects were observed regardless of perceptual load condition.

(Table 3 about here)

Error rates were also analyzed with a 2 (social anxiety) × 2 (perceptual load) × 3 (compatibility) ANOVA (Table 3). The three-way ANOVA on error rates revealed a significant main effect of perceptual load, $F(1, 49) = 7.25$, $p < .05$, $\eta^2_p = .13$. There was also a significant two-way interaction between social anxiety and compatibility, $F(2, 98) = 3.09$, $p < .05$, $\eta^2_p = .06$. However, the follow-up *t*-tests for simple effects showed no significant effects. No other main effects or interactions were significant. Error rates in the high perceptual load condition were higher than those in the low perceptual load condition, thereby demonstrating that perceptual load was successfully manipulated.

3.3. Discussion

The present experiment revealed that task-irrelevant natural scenes produced interference in high and low socially anxious people when attention was directed to animal pictures and perceptual load was low. However, in the case of high perceptual load interference was not observed in low socially anxious people but was observed in high socially anxious people. Furthermore, the magnitude of interference increased with increases in the degree of social anxiety. High socially anxious people could not inhibit processing of task-irrelevant distractors and processed the distractors even in the high perceptual load condition. These results support the hypothesis that interference from task-irrelevant natural scenes would be observed under conditions where there was a greater demand on processing resources, while these effects were invariant under conditions of low processing demand. In contrast, when directing attention to pictures of people, task-irrelevant natural scenes did not produce interference, regardless of perceptual load and degree of social anxiety; all participants inhibited processing of the task-irrelevant distractors.

When directing attention to animal pictures, interference from the task-irrelevant neutral scenes was observed. Specifically, RTs in the incompatible condition were longer than those in other conditions. Considering that in the incompatible condition the task-irrelevant natural scenes were pictures of people, processing may have been enhanced for these task-irrelevant pictures. Previous studies have shown that task-irrelevant faces are processed efficiently regardless of perceptual load (Lavie, Ro, & Russel, 2003; Neuman & Schweinberger, 2008). Human bodies also attract attention (Ro, Friggel, & Lavie, 2007). Therefore, participants' attention might be attracted to task-irrelevant pictures of people. Because the processing of task-irrelevant stimuli depends on attentional control (Forster & Lavie, 2007) and socially anxious people have impaired attentional control (Eysenck et al., 2007; Moriya & Tanno, 2008), high socially anxious people might process task-irrelevant pictures of people even in the high perceptual load condition.

When directing attention to pictures of people, interference effects from the distractors were not observed. Human faces capture attention automatically through the stimulus-driven attentional system (Langton, Law, Burton, & Schweinberger, 2008), and it is difficult to disengage attention once it has been directed to faces (Bindemann, Burton, Hooge, Jenkins, & de Haan, 2005). Therefore, participants could not process the task-irrelevant natural scenes when the target stimulus was a person. In addition, it is possible that only one face can be processed at a time (Bindemann, Burton, & Jenkins, 2005; Bindemann, Jenkins, & Burton, 2007; Neumann & Schweinberger, 2009). Although the task-irrelevant natural scene in the compatible condition was from the same category as the target, participants may have been unable to process more than one picture of people simultaneously. Therefore, enhanced processing of the target in the compatible condition was not observed.

4. General Discussion

The present study investigated processing of task-irrelevant natural scenes in high and low socially anxious people by manipulating perceptual load when attention was directed to a target letter (Experiment 1) or natural scene (Experiment 2). When attention was directed to letters, increased perceptual load resulted in reduced processing of task-irrelevant distractors in low socially anxious people. However, in high socially anxious people, increased perceptual load did not reduce processing of task-irrelevant natural scenes, and task-irrelevant distractors were processed even in the high perceptual load condition. When attention was directed to a natural scene target, the processing of task-irrelevant natural scenes depended on the target category. When the target was an animal, increased perceptual load prevented low socially anxious people from processing the task-irrelevant natural scenes, whereas increased perceptual load did not diminish the processing of the task-irrelevant distractor in high socially anxious people. However, when the target was a person, task-irrelevant natural scenes were not processed by either high or low socially anxious people regardless of perceptual load. These results suggest that high socially anxious people were unable to inhibit the task-irrelevant distractors when perceptual load was high and that attention is automatically captured by people. While previous studies have demonstrated that high socially anxious people process letter or face distractors under conditions of high perceptual load when target stimuli are letters (Bishop et al., 2007; Moriya & Tanno, 2010; Sadeh & Bredemeier, 2011), in this study, we showed that this pattern of distractor processing also applies to natural scene distractors when directing attention not only to letters but also to animal pictures. This, in turn, supports the hypothesis proposed by Eysenck et al. (2007) that interference from task-irrelevant distractors will be observed in anxious individuals when there is increased demand on processing resources.

The finding that RTs in high socially anxious people were partially longer than those in low socially anxious people (i.e., in the high perceptual load condition in the prime display in Experiment 1) is also consistent with the attentional control theory (Eysenck et al., 2007, Derakshan & Koster, 2010). Socially anxious people with poor attentional control maintain a high performance level (i.e., response accuracy) at the cost of reduced processing efficiency (i.e., response latency). In a difficult task, decision times for target detection were increased in anxious people in order to increase the response accuracy (Derakshan & Koster, 2010). Even if they detected the target once, they might compare the target with other non-target stimuli. In Experiment 1, they detected the target carefully in high rather than low perceptual load conditions in order to maintain the high response accuracy. Therefore, poor attentional control in high socially anxious people might lead to long RTs in high perceptual load conditions.

Attentional control plays an important role in suppressing responses to task-irrelevant stimuli (Foster & Lavie, 2007). Increasing processing demands do not reduce distractor processing in high socially anxious people, and this might be because of inefficient attentional control (Moriya & Tanno, 2008). In order to increase task demands, we only manipulated perceptual load according to Bishop (2009), whereas other previous studies manipulated working memory load in addition to perceptual load (de Fockert, Rees, Frith, & Lavie, 2001; Lavie, Hirst, de Fockert, & Viding, 2004; Lavie & de Fockert, 2005). Although prefrontal attentional control is necessary for coping with both perceptual and working memory loads (Bishop, 2009; de Fockert et al., 2001), high perceptual and working memory loads do not necessarily have the same effects on distractor processing (Lavie, 2005, 2010; Lavie et al., 2004). Future studies should investigate whether high perceptual and working memory loads have different effects on distractor processing in individuals with social anxiety.

The results reported here are not necessarily consistent with those of Bishop (2009). According to Bishop, neither high- nor low-anxiety individuals process task-irrelevant distractors under conditions of high perceptual load, whereas increased interference from distractors is observed in high socially anxious individuals under conditions of low perceptual load. Bishop used letters as target and distractor stimuli, whereas our study used natural scenes as stimuli, which may be more salient than letters. In contrast to Bishop (2009), we may have observed evidence that task-irrelevant natural scenes were processed because anxious individuals are more sensitive to salient stimuli (Eysenck et al., 2007; Moriya & Tanno, 2009).

The present results are consistent with the behavioral results in Bishop et al. (2007) but are not consistent with their neuroimaging results. Bishop et al. (2007) used facial expressions (i.e., fearful faces) for task-irrelevant stimuli and enhanced amygdala activity was revealed for fearful faces in highly anxious participants in low perceptual load conditions, but not in high perceptual load conditions. Similar differences between behavior and imaging results have been indicated in previous studies. For example, MacNamara and Hajcak (2009, 2010) showed that task-irrelevant aversive stimuli increase error rates and RTs; however, these stimuli did not interfere with neural activity measured by ERPs. MacNamara and Hajcak (2009, 2010) suggest that behavioral data does not depend on complete awareness of stimulus meaning, whereas neuroimaging data is related to elaborated processing of stimulus meaning. In the present study, the task-irrelevant stimuli were from very different categories. Therefore, interference may have occurred in high socially anxious individuals because of superordinate-level category processing (e.g., animal), even if they did not process the identity of the task-irrelevant stimuli (e.g., a dog). Therefore, it is possible that interference would not be observed in high socially anxious individuals if the task-irrelevant stimuli were from similar categories.

This study provides the first demonstration that high socially anxious individuals process task-irrelevant non-emotional natural scenes, and this result is important for understanding the mechanisms of attentional control in social anxiety. However, some issues require resolution through further study. Using natural scenes as task-irrelevant distractors, the present results suggest that socially anxious people process task-irrelevant information in social situations, which might lead to poor performance in the situations. Poor performance leads to negative evaluations from others and increases anxiety. However, when directing attention toward people, task-irrelevant information does not interfere with the performance of socially anxious people. Considering that socially anxious people are afraid of interaction with people in social situations, it is important to focus on processing pictures of people in order to elucidate the mechanisms underlying social anxiety in social situations. In addition, although the task demands on processing resources are important in the attentional control theory, few previous studies have investigated the processing of task-irrelevant stimulus in anxiety by manipulating task demands. Further studies should promote the development of this aspect.

In conclusion, two experiments examined the processing of task-irrelevant natural scenes in social anxiety by manipulating perceptual load. The results suggest that high socially anxious people could not inhibit the processing of task-irrelevant natural scenes when the perceptual load was high whereas low socially anxious people were able to inhibit the processing. However, when directing attention to people, all participants inhibited the processing of task-irrelevant distractors regardless of perceptual load.

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Footnotes

[1] The following are the IAPS picture numbers: animals—1333, 1450, 1463, 1500, 1510, 1540, 1560, 1590, 1600, 1602, 1603, 1610, 1620, 1640, 1660, 1670, 1675, 1720, 1721, 1740, 1722, 1810, 1812, 1920; objects—7004, 7006, 7009, 7010, 7025, 7030, 7031, 7034, 7035, 7038, 7040, 7042, 7043, 7050, 7056, 7057, 7080, 7090, 7150, 7175, 7190, 7211, 7233, 7235; and landscapes—5000, 5010, 5020, 5030, 5201, 5220, 5250, 5270, 5593, 5631, 5635, 5660, 5700, 5711, 5720, 5781, 5811, 5814, 5870, 5891, 5900, 5982, 5990, 5991. The mean valence ratings were 6.80 (SD = 0.64) for animals, 4.98 (SD = 0.27) for objects, and 6.85 (SD = 0.48) for landscapes. The valence ratings differed significantly, $F(2, 69) = 116.10$, $p < .001$, $\eta^2_p = .77$, such that ratings for animals and landscapes were higher than those for objects. The mean arousal ratings were 4.22 (SD = 0.72) for animals, 2.84 (SD = 0.66) for objects, and 3.83 (SD = 0.88) for landscapes; these ratings differed significantly, $F(2, 69) = 21.67$, $p < .001$, $\eta^2_p = .39$, such that arousal ratings for animals and landscapes were higher than those for objects.

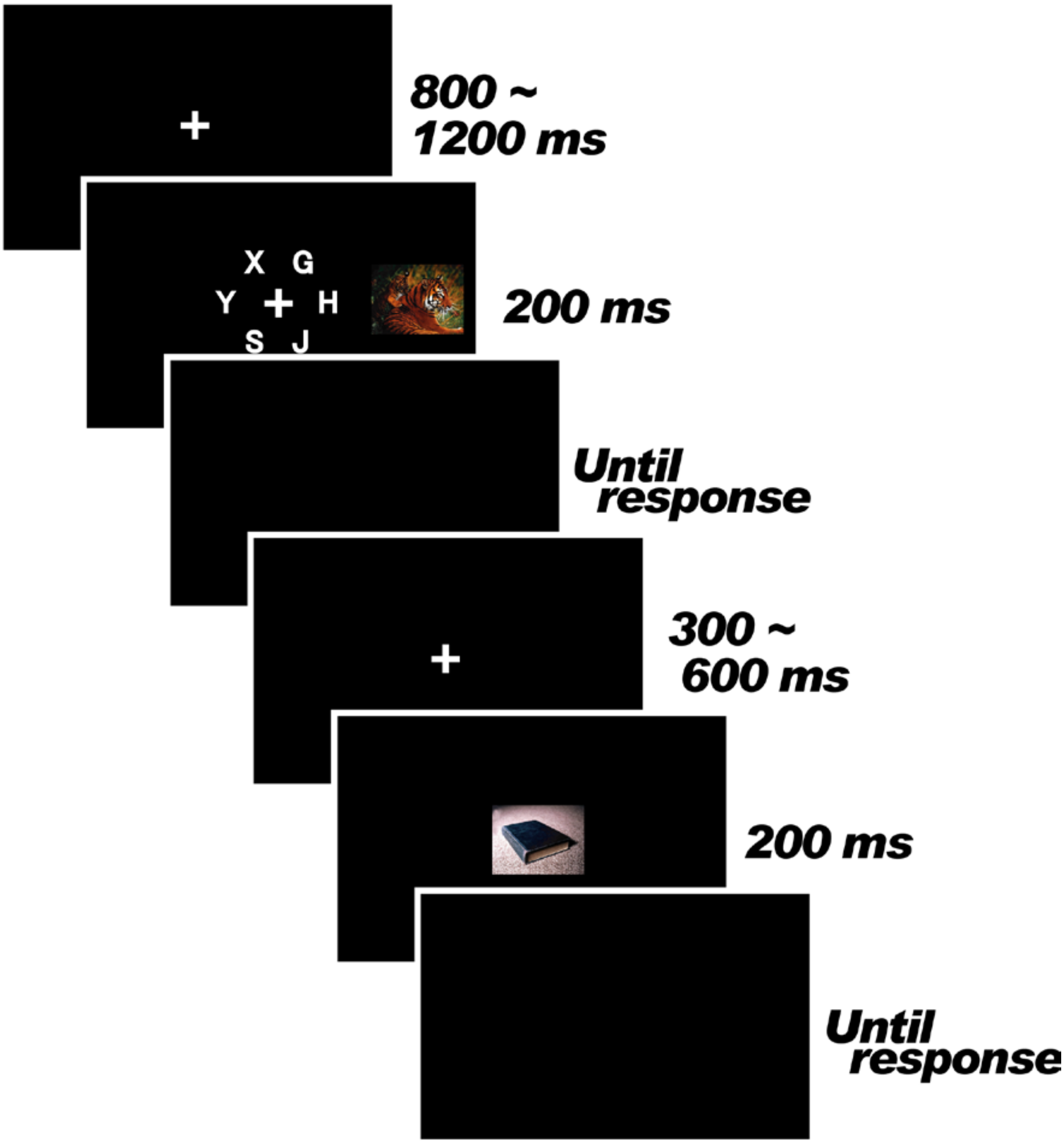
[2] The following are the numbers of the IAPS pictures: animals—1333, 1450, 1510, 1560, 1640, 1660, 1670, 1675, 1720, 1740, 1810, 1812; people—2000, 2025, 2030, 2240, 2250, 2270, 2442, 2500, 2506, 2513, 2620, 2630; landscapes—5020, 5030, 5220, 5250, 5593, 5635, 5711, 5720, 5870, 5900, 5990, 5991; and vehicles—7130, 7595, 8510. The mean valence ratings were 6.35 (SD = 0.52) for animals, 6.21 (SD = 0.35) for people, 6.45 (SD = 0.29) for landscapes, and 5.55 (SD = 1.54) for vehicles. The valence ratings were marginally different, $F(3, 35) = 2.40$, $p = .084$, $\eta^2_p = .17$, such that the ratings for vehicles were slightly lower than those for landscape. However, because the valence ratings did not differ among animals, people, and landscapes, the interference effects might not be related to valence. The mean arousal ratings were 4.24

(*SD* = 0.86) for animals, 3.69 (*SD* = 0.53) for people, 3.55 (*SD* = 0.66) for landscapes, and 4.01 (*SD* = 0.82) for vehicles. Arousal ratings did not differ, $F(3, 35) = 0.11$, *ns*.

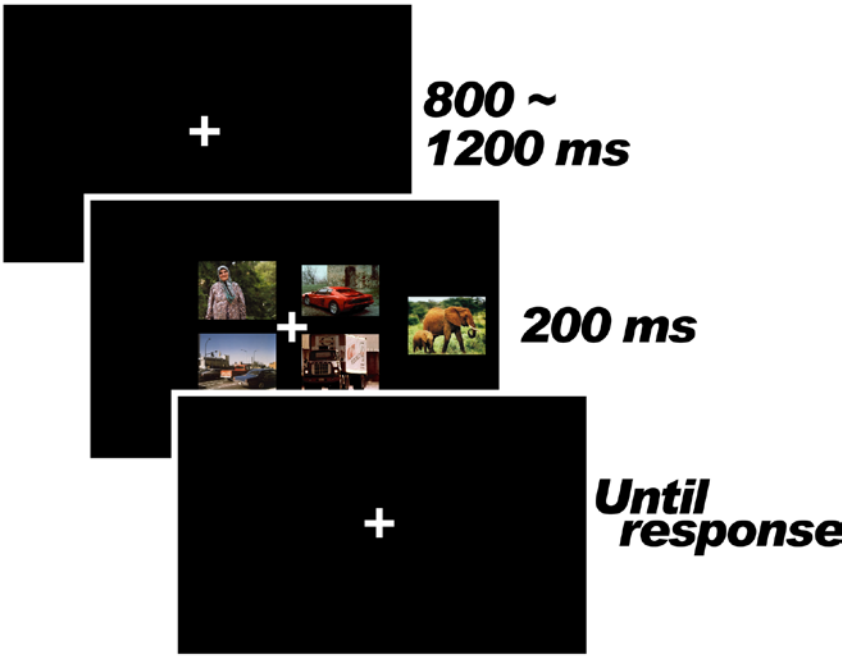
Figure Captions

Figure 1. Sequence of the high perceptual load condition in the unrelated condition in Experiment 1.

Figure 2. Sequence of the high perceptual load condition in the incompatible condition in the person-target condition in Experiment 2.



800 ~
1200 ms
X G
Y + H
S J
200 ms
Until
response
300 ~
600 ms
200 ms
Until
response


800 ~
1200 ms
200 ms
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response

Table 1

Mean RTs (SE in parentheses) and Percentage of Errors in the Prime and Probe Displays in Experiment 1

	Prime Display		Probe Display					
			Low Perceptual Load			High Perceptual Load		
	Low Load	High Load	Primed	Unprimed-related	Unprimed-neutral	Primed	Unprimed-related	Unprimed-neutral
High Social Anxiety								
RT (ms)	526 (14)	778 (31)	502 (16)	538 (13)	546 (13)	531 (14)	560 (14)	563 (14)
% Error	6	8	7	6	7	6	5	5
Low Social Anxiety								
RT (ms)	494 (16)	672 (26)	493 (15)	526 (13)	526 (12)	522 (14)	531 (13)	533 (12)
% Error	5	6	6	4	5	6	6	5

Table 2

Correlations between Priming Effects and Each Score in the High and Low Perceptual Load in Experiment 1.

	BFNE	STAI-T	STAI-S	SDS
High Perceptual Load	.37*	.19	–.15	.02
Low Perceptual Load	.02	.03	–.18	–.13

Note. BFNE: Brief Fear of Negative Evaluation Scale, STAI–T: State Trait Anxiety Inventory–Trait Form, STAI–S: State Trait Anxiety Inventory–State Form, SDS: Self-Rating Depression Scale

*p < .05

Table 3

Mean RTs (SE in parentheses) and Percentage of Errors in Experiment 2

	Low Perceptual Load			High Perceptual Load		
	Compatible	Neutral	Incompatible	Compatible	Neutral	Incompatible
Animal Condition						
High Social Anxiety						
RT (ms)	583(16)	579 (16)	598 (16)	630 (19)	636 (19)	650 (19)
% Error	5	4	3	4	4	7
Low Social Anxiety						
RT (ms)	613 (14)	601 (13)	636 (17)	653 (18)	645 (16)	653 (19)
% Error	2	4	5	5	3	5
Person Condition						
High Social Anxiety						
RT (ms)	573 (16)	566 (16)	565 (15)	604 (18)	619 (22)	599 (16)
% Error	4	6	3	4	4	6
Low Social Anxiety						
RT (ms)	591 (14)	591 (13)	589 (13)	612 (15)	616 (15)	609 (15)
% Error	3	5	5	4	2	5

Table 4

Correlations between Flanker Compatibility Effects and Each Score in the High and Low Perceptual Load in the Animal Target Condition in Experiment 2.

	BFNE	STAI-T	STAI-S	SDS
High Perceptual Load	.31*	.26†	.20	.20
Low Perceptual Load	–.06	–.02	–.05	–.12

†p = .059, *p < .05