

Emotion

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Anxiety Attenuates Awareness of Emotional Faces During Rapid Serial Visual Presentation

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Anxiety limits normative perception and impacts the interaction between key neurophysiological systems, possibly by decreasing recruitment of goal-oriented processes and increasing recruitment of stimulus-driven processes. Previous studies examining the impact of anxiety on emotion processing commonly lack a sample with levels of anxiety comparable to a clinical population. Many also fail to control for co-occurring symptoms like depression. The current study used Rapid Serial Visual Presentation (RSVP) with two emotional targets, comparing healthy controls to a group of individuals with symptom levels comparable to anxiety disorder patients. The results showed a modulatory effect of anxiety; the high anxiety (HA) group showed an enhanced impairment in detecting the second of two emotional targets relative to the low anxiety (LA) control group. Though there were no group-specific effects on the Attentional Blink or Repetition Blindness, there was a significant interaction of group with first and second target valence. Notably, HA individuals showed deficits (where LA individuals showed benefits) when the same emotion was presented twice. Further, when the first target was neutral, second target detection was especially impaired in HA individuals. Correlational analyses confirmed perceptual limitations were related to anxiety, but not depression, positive affect, or negative affect. The current results, along with past findings, suggest that clinical anxiety leads to deficits in overall cognitive control, increased difficulty inhibiting attention to distractors, and impairments in rapid, intuitive emotion processing.

Keywords: anxiety, attention, emotion perception, emotional disorders, attentional blink, repetition blindness

Anxiety enhances normative perceptual limits and impacts the interaction between two key neurophysiological systems (Corbetta & Shulman, 2002), decreasing recruitment of goal-directed processes and increasing recruitment of stimulus-driven processes (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Bishop, 2009; Browning, Holmes, & Harmer, 2010; Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Eysenck, Derakshan, Santos, & Calvo, 2007). Anxious individuals are more likely to perceive threat where there is none (Richards et al., 2002), orient quicker to threatening rather than other cues (Bar-Haim et al., 2007), and allocate limited cognitive resources more fully to threatening relative to neutral information (Fox, Russo, & Georgiou, 2005). These limits may be attributable, in

part, to deficits recruiting goal-directed attentional resources, resulting in a shift toward stimulus-driven attention (Bishop, 2009; Browning, Holmes, Murphy et al., 2010). They may also be attributable to enhancements in stimulus-driven attention (Bar-Haim et al., 2007; Eysenck et al., 2007). Recent evidence provides an integrative account of these deficits in anxiety suggesting changes in both stimulus-driven and goal-directed networks via altered functional brain connectivity (Etkin, Prater, Hoefft, Menon, & Schatzberg, 2010).

Altered emotional processing and related neural activity may not be specific to anxiety but rather related to a common mechanism underlying emotional disorders (Mathews & MacLeod, 2005). At least two lines of evidence support this idea. First, there is considerable overlap between anxiety and depression (Mineka, Watson, & Clark, 1998). Second, several studies have shown neurobehavioral alterations in attentional control in depression similar to those in anxiety (e.g., Johnstone, van Reekum, Urry, Kalin, & Davidson, 2007; Rokke, Arnell, Koch, & Andrews, 2002). Despite this potential overlap, few studies have examined which symptoms best relate to emotion perception, thus examining the specific contributions of common and specific symptoms in emotional disorders is crucial to understanding alterations in the visual processing of emotion. Given that anxiety sometimes temporally precedes depression (Brady & Kendall, 1992), and that there is considerable evidence for rapid and early attentional biases in anxiety (e.g., Bar-Haim et al., 2007; Matthews & MacLeod, 2005), it seems plausible that anxiety is the more pertinent contributor to perceptual limitations when processing emotion.

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The Limits of Temporal Attention

Examination in the temporal domain of attention is crucial to better understand how characteristics of emotional disorders contribute to dynamic alterations regarding what information reaches awareness, and thus better understand how to potentially intervene (see Asplund, Todd, Snyder, & Marois, 2010; Browning, Holmes, Murphy et al., 2010). One common approach to examining temporal limitations of attention is Rapid Serial Visual Presentation (RSVP) (see, e.g., Dux & Marois, 2009; Martens & Wyble, 2010), where stimuli appear in quick succession at the same spatial location, at rates typically ranging from 8–16 stimuli per second. Two well-documented, dissociable perceptual deficits arise when participants attempt to identify two images presented within a particular temporal window of one another. The first perceptual deficit is called the Attentional Blink (AB; Raymond, Shapiro, & Arnell, 1992), named for the difficulty people have identifying the second of two target images (T2) within 200–500 ms of the first target image (T1); it's as if attention “blinks,” preventing the second stimulus from entering awareness. As the space between T1 and T2 increases beyond this 200–500 ms window, the accuracy of identifying T2 increases dramatically (Dux & Marois, 2009; Martens & Wyble, 2010).

The second perceptual deficit occurring in RSVP is called Repetition Blindness (RB; Kanwisher, 1987), named for the inability to identify T2 when it is a repetition of T1. Although AB and RB have similar properties, they are distinct phenomena; both can occur with or without the other (Chun, 1997). Further, these phenomena follow different time courses. The AB exhibits a U-shaped return to optimal T2 detection rates as the number of intervening stimuli increases. In contrast, RB exhibits a monotonic return to optimal T2 detection rates, reaching maximum around 300 ms (Chun, 1997). The etiology of the AB is uncertain, but it likely stems from some central processing limit related to the way that individuals allocate limited attentional resources to targets while inhibiting attention to distractors (Martens, Korucuoglu, Smid, & Nieuwenstein, 2010). In contrast, the RB results when T2 is not individuated from T1 (Chun, 1997; Kanwisher, 1987). Evidence suggests that RB results from information processing limitations *prior* to the so-called “central bottleneck” (Dux & Marois, 2007), which is considered to be key to the AB (Dux & Marois, 2009).

Rapid Processing of Emotion

Using emotional targets or distracters alters perception during RSVP. When T1 is emotional, the AB is magnified (Arend & Botella, 2002; de Jong, Koster, van Wees, & Martens, 2010; Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009)—participants are less accurate at identifying T2. When T2 is emotional, the AB is attenuated (Fox et al., 2005; Keil & Ihssen, 2004; Maratos, Mogg, & Bradley, 2008; Milders, Sahraie, Logan, & Donnellon, 2006)—participants are more accurate at identifying T2. Emotion increases the impact of RB effect as well (Silvert, Naveteur, Honoré, Sequeira, & Boucart, 2004).

The emotional alterations to RSVP are not merely an artifact of stimulus properties (e.g., emotional faces). When combined with aversive stimuli (e.g., electrical shocks), previously neutral T1s show enhanced AB effects (Smith, Most, Newsome, & Zald, 2006)

and previously neutral T2s show diminished AB effects (Lim, Padmala, & Pessoa, 2009; Milders et al., 2006). These results suggest an important role for fear learning in associating stimuli with organismal salience (Milders et al., 2006). At least one study has shown that emotion-related effects on RSVP are only evident when participants must identify the emotion rather than another stimulus feature (Stein et al., 2009), suggesting that rapid emotion perception has somewhat unique properties. Contributions of fear association and emotional alterations to temporal attention would seem to further support an important role of anxiety in rapid emotion processing.

Anxiety and Attention to Emotion

A major limitation of studies examining the impact of anxiety on temporal emotion processing is that levels of trait anxiety for the experimental group are often inconsistent with those of clinical populations (e.g., Fox et al., 2005). In subclinical levels, anxiety may serve to merely enhance normative emotional alterations of RSVP. Further, given that positive stimuli lead to attentional effects similar to negative stimuli (Miyazawa & Iwasaki, 2010) and that dysphoric mood (a commonly co-occurring problem in anxiety; see Mineka et al., 1998) is known to alter processing of positive emotion (see Mathews & MacLeod, 2005), inclusion of positive stimuli is essential to understanding altered emotion processing in emotional disorders. Additionally, a number of studies with anxious individuals continue to use emotional words rather than emotional images (e.g., Arend & Botella, 2002). While this is certainly a valid approach, including more organismally salient stimuli (e.g., emotional faces) may better delineate contributions of anxiety to altered emotion perception, as well as providing relevant information to diagnosis and treatment. Finally, the vast majority of studies only use one emotional target (e.g., Arend & Botella, 2002; de Jong et al., 2010; Fox et al., 2005; Milders et al., 2006; Stein et al., 2009), which facilitates interpretation, but decreases ecological relevance and eliminates the possibility of studying RB. Taken together, all these findings suggest a potentially valuable contribution of emotional RSVP paradigms in (1) samples with symptom levels comparable to those of clinical populations, (2) controlling for comorbid symptom presentations in emotional disorders, and (3) using two emotional targets that (i) comprise natural images rather than words or alphanumeric stimuli and (ii) include positive, negative, and neutral valence.

Current Study

To examine whether deficits in rapid emotion perception is anxiety specific or attributable to vulnerability to emotional disorders more generally, we first examined relations of depression, anxiety, and positive and negative affect with T2 detection during RSVP. From a larger sample of university students, we then selected a subset of individuals with anxiety levels comparable to a large clinically anxious sample (for the experimental group) and another subset comparable to prior norm-referenced controls (for the control group). We hypothesized that anxious individuals would show both general and specific performance decrements related to deficits recruiting goal-directed prefrontal areas, a shift toward stimulus-driven modes of processing, and difficulty disengaging threat-related stimuli. As a result, we predicted the follow-

ing: (1) poorer overall performance in high anxious (HA) relative to low anxious (LA) individuals, (2) enhanced AB in HA relative to LA individuals when T1 was fearful, (3) diminished AB in HA relative to LA individuals when T2 was fearful, and (4) enhanced RB effects for emotional repetition in HA relative to LA individuals.

Method

Participants

Participants were 129 undergraduate students from the University at Albany, State University of New York. All participants received course credit for participation. Participants had normal or corrected-to-normal vision. After screening (see Results), data from 86 undergraduate participants were used for correlational analyses. Demographics are presented in Table 1. Subsequently, 56 participants were grouped on the basis of their scores on the State Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Gros, Antony, Simms, & McCabe, 2007; Ree, French, MacLeod, & Locke, 2008). Participants in the first third (STICSA scores ≤ 32) were assigned to a low anxiety (LA) group, and participants in the top third (STICSA scores ≥ 40) were assigned to a high anxiety (HA) group. The minimum score for the HA group is consistent with one recently derived cut score used to identify the possible presence of an anxiety disorder (Van Dam, Gros, Earleywine, & Antony, Under Review).

Questionnaires

Center of Epidemiologic Studies Depression Scale – Revised.

The CESD-R is an updated version of the CES-D (Radloff, 1977). The CESD-R consists of 20 items that closely reflect the *DSM-IV* criteria for depression (see Eaton, Muntaner, Smith, Tien, & Ybarra, 2004). Participants respond to one of five options for each item: “not at all or less than 1 day,” “1–2 days,” “3–4 days,” “5–7 days,” “nearly every day for 2 weeks.” The CESD-R has exhibited excellent psychometric properties, including a unique relationship

to positive affect when controlling for anxiety (Van Dam & Earleywine, 2011) as predicted by the tripartite model (Clark & Watson, 1991). It also was able to approximate epidemiological levels of depression in a very large community sample (Van Dam & Earleywine, 2011). In the present study, internal consistency was very good (Cronbach’s alpha = .94).

Positive and Negative Affect Schedule. The PANAS is a 20-item questionnaire designed to measure positive and negative affect (Watson, Clark, & Tellegen, 1988), important latent variables in emotional disorders (e.g., Mineka et al., 1998). The questionnaire consists of 10 items that address positive affect (PA) and 10 items that address negative affect (NA). Participants endorse the extent to which single word items generally characterize how they feel on a 1 “very slightly or not at all” to 5 “extremely” response scale. The PANAS is widely used and has good psychometric properties (e.g., Mineka et al., 1998; Watson et al., 1988). Internal consistency was good for both positive (Cronbach’s alpha = .89) and negative affect (Cronbach’s alpha = .87).

State-Trait Inventory for Cognitive and Somatic Anxiety. The STICSA is a 21-item questionnaire designed to differentiate the cognitive and somatic components of anxiety. It was developed as an alternative to other popular measures of anxiety (e.g., State-Trait Anxiety Inventory), which have shown higher covariance with measures of depression than anxiety (Gros et al., 2007; Ree et al., 2008). The STICSA has excellent psychometric properties (Gros et al., 2007; Ree et al., 2008) and had good internal consistency in the present study (Cronbach’s alpha = .87).

Attentional Blink Paradigm

Stimuli. Stimuli were photographs of European and/or European American male faces selected from standardized pictures of facial affect (Georghiades, Belhumeur, & Kriegman, 2001; Solina, Peer, Batagelj, Juvan, & Kovac, 2003; Tottenham et al., 2009). Racial and ethnic groups other than European American were not represented in the stimuli in order to minimize differential reactions to stimuli (Cunningham et al., 2004). Female images were

Table 1
Sample and Group Demographics With Statistics

	Overall (<i>n</i> = 86) <i>M</i> (<i>SD</i>)	LA (<i>n</i> = 28) <i>M</i> (<i>SD</i>)	HA (<i>n</i> = 30) <i>M</i> (<i>SD</i>)	LA vs. HA <i>M</i> (<i>SD</i>)
STICSA	36.8 (9.0)	27.4 (3.6)	46.5 (5.6)	15.63 (49.7)***
Range	21–56	21–32	40–56	
Age	18.7 (1.4)	18.5 (0.9)	19.0 (1.9)	1.39 (56)
	% (<i>n</i>)	% (<i>n</i>)	% (<i>n</i>)	χ^2 (<i>df</i>)
Male	48.8 (42)	50.0 (14)	46.7 (14)	0.26 (1)
Race				
Caucasian	65.1 (56)	75.0 (21)	70.0 (21)	1.00 (3)
African American	11.6 (10)	10.7 (3)	6.7 (2)	
Hispanic/Latino	8.1 (7)	7.1 (2)	10.0 (3)	
Asian	15.1 (13)	7.1 (2)	13.3 (4)	
College Year				
1st	72.1 (62)	71.4 (20)	63.3 (19)	0.58 (3)
2nd	15.1 (13)	17.9 (5)	20.0 (6)	
3rd	8.1 (7)	7.1 (2)	10.0 (3)	
4th	4.7 (4)	3.6 (1)	6.7 (2)	

Note. LA = low anxiety group; HA = high anxiety group; STICSA = State Trait Inventory for Cognitive and Somatic Anxiety.
*** $p < .001$.

excluded for the same reason (see Mignault & Chaudhuri, 2003). All stimuli were converted to black and white and were carefully edited to minimize the presence of irrelevant features (e.g., hair, shoulders) that could influence facial affect detection (e.g., de Jong & Martens, 2007). All stimuli were presented at a resolution of 300×425 pixels (subtending an approximate angle of $8^\circ \times 11.4^\circ$) at the center of a 19-inch LCD computer monitor (Dell Ultrasharp, 1908FP; response rate of 5 ms) with a gray background at a viewing distance of about 60 cm. Stimuli were controlled by an Intel Pentium Core 2 Duo 2.2GHz personal computer. All stimuli were presented and responses collected using DMDX (Forster & Forster, 2003). Before experimentation, DMDX was used to synchronize desired presentation times with the monitor properties (see Forster & Forster, 2003).

Target stimuli. While previous studies have argued for the use of angry faces (direct threat) instead of fearful faces (indirect threat) (e.g., de Jong et al., 2010; Maratos et al., 2008), we decided to use fearful faces for two reasons: (1) Fearful faces represent a relatively uncertain source of threat, a condition that provides informative etiological information for anxiety (Simmons, Matthews, Paulus, & Stein, 2008), and (2) Recent neuroimaging results have shown that fearful faces show more robust neural activity than angry faces when the participant is unaware of the stimulus (Ewbank et al., 2009), seemingly making fearful faces more valid in paradigms where awareness of stimuli is limited (Asplund et al., 2010; Martens & Wyble, 2010). Thirty target images (10 neutral, 10 happy, and 10 fearful) consisting of 10 male European American actors (three images per actor) were selected from the NimStim Face Stimulus Set (Tottenham et al., 2009). One image representing each of the three affective expressions per actor was selected based on reported identification rates, selecting images corresponding to the highest reported accuracies (Tottenham et al., 2009). Equivalence of target arousal level was verified in a small sample of volunteer participants from the same population as the general experiment (cf. Stein et al., 2009) ($n = 12$; see Table 2).

Distractor stimuli. Distractor images were 54 affectively neutral stimuli selected from the Yale Extended Face Database B (Georghiades et al., 2001) and the Computer Vision Laboratory Face Database (CVL FD; Solina et al., 2003). All distractor images were presented in an upside down (rotated 180°) format (e.g., de Jong & Martens, 2007) and were subjected to the same preliminary modifications as target images.

RSVP task. Participants completed 450 total trials, 20% (90 trials) containing 15 stimuli and 80% (360 trials) containing 16

stimuli. There were 40 trials for each stimulus combination, 20 with a short lag (321 ms) and 20 with a long lag (642 ms). Twenty percent of trials only contained 15 stimuli because of the absence of a second target (cf. Maratos et al., 2008). Each trial began with a fixation cross presented for 250 ms and terminated with the question “Which emotion(s) did you see?” presented for 500 ms. There was a 1500-ms pause for participant response between trials. Facial stimuli were presented for 107 ms each with no interstimulus interval. Half the trials were configured with a long intertarget interval (six distractors intervening; 642 ms), while the other half were configured with a short intertarget interval (three distractors intervening; 321 ms). T1 stimuli were equally and randomly presented at serial positions 4, 5, or 6 for long trials and serial positions 8, 9, or 10 for short trials. All T2 stimuli were equally and randomly presented at serial positions 12, 13, or 14. In order to maintain consistency, T1 stimuli were equally and randomly presented at the same serial positions in T1-only trials as in T2-present trials (see Figure 1).

All trials contained at least one target stimulus (T1) consisting of a fearful (F), happy (H), or neutral (N) image (selected from the NimStim Face Stimulus Set; Tottenham et al., 2009); 80% of trials contained a second target stimulus (T2), also a fearful, happy, or neutral image. All emotional combinations (i.e., FF, FH, FN, HF, HH, HN, NF, NH, NN) were presented equally often and target stimuli were sampled randomly—the only specification being that T1 and T2 not be the same image or the same actor portraying a different emotion to confine RB effects only to repeating emotion. Participants were informed that their task was to identify the emotion(s) presented on unrotated face(s) via a corresponding keyboard key (i.e., F – Fearful, H – Happy, N – Neutral) at the end of each trial. Participants were additionally instructed to identify targets in order of presentation, omitting a second response if a second target was not perceived. For example, if a participant viewed a fearful T1 and a neutral T2, the correct response would have been “FN.” Appropriate response keys were identified by white labels to facilitate differentiation from the black keyboard. To diminish fatigue, participants were permitted a brief break (e.g., 30s – 3 min) between each of the five blocks of 90 trials. The task took approximately 35 minutes.

Procedure

After consenting to the conditions of the study, the experimenter provided task instructions that also appeared on the computer screen. Participants then completed 10 practice trials in a private room with the experimenter present. After completion of the practice trials, the experimenter left the room and participants completed the experimental task. Participants completed the battery of self-report questionnaires and demographics after completion of the RSVP task. The local institutional review board approved all procedures.

Statistical Analysis

Correlations were computed between overall T2 detection and T2 detection at both short and long lags with anxiety, depression, and positive and negative affect. Differences in T1 detection rates for both T1-only and dual target trials both within and between were then explored. Subsequently, a 2 (lag) by 3 (T1 valence) by

Table 2
Valence and Arousal Ratings for All Target Stimuli in a Small Sample ($n = 12$) From the Experiment Population

Stimulus type	Fearful	Happy	Neutral
Valence			
<i>M</i> (<i>SD</i>)	2 (0.82)	6 (0.90)	4 (0.68)
Arousal			
<i>M</i> (<i>SD</i>)	5 (1.35)	4 (1.31)	3 (3.00)

Note. Participants rated each image for valence (from 1, *negative*, to 7, *positive*) and arousal (from 1, *unstimulating*, to 7, *very stimulating*). All valence ratings were significantly different from each other (p 's < .01). Images were not significantly different in arousal levels.

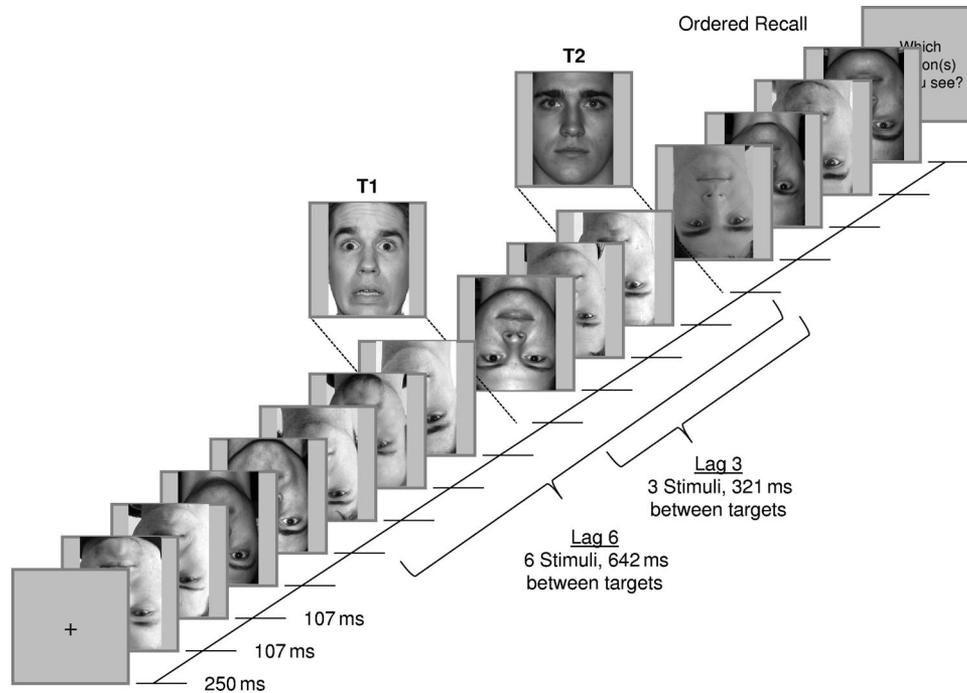


Figure 1. Example of rapid serial visual presentation trial. Each trial consists of 15 (single target trial) or 16 (dual target trial) stimuli with no interstimulus interval. Trials begin with a fixation cross at the center of the screen presented for 250 milliseconds. Each stimulus is presented for 107 milliseconds. For long trials (Lag 6), six stimuli (642 ms) intervene between targets. For short trials (Lag 3), three stimuli (321 ms) intervene between targets. At the end of each trial, participants are prompted to recall the emotion(s) of the targets they saw in the order they were presented. In this example, T1 is a fearful image and T2 is a neutral image. Note: In the above figure, T2 is not one of the actual targets because of copyright limitations.

3 (T2 valence) by 2 (group) factorial ANOVA was computed. Significant main effects and interactions were followed with post hoc comparisons using False Discovery Rate (FDR; Benjamini & Hochberg, 1995) to set $p = .05$ for multiple comparisons. FDR is a sequential Bonferroni correction method that optimizes power while minimizing Type I error rate. All statistics were computed using IBM SPSS Statistics 18.0.

Results

Data Trimming and Outcome Computation

T2 cannot be scored unless T1 is correctly identified. Accordingly, participants who did not respond with at least one key press on 75% (338/450) of the trials were excluded from further analyses ($n = 9$). Any participant with an individual button (F, H, N, or no response) response rate for T1 of $Z > 3.29$ was also excluded from further analyses ($n = 6$). Evidence suggests that even at very high presentation rates, single target trials are accurately identified on approximately 70% of trials (cf. Dux & Marois, 2009). Accordingly, any participant whose T1-only trial accuracy was less than 70% was excluded from further analyses ($n = 28$). Responses with reaction times less than 200 ms or greater than 3 standard deviations from individual participant mean were scored as incorrect answers (Ratcliff, 1993). Keyboard presses inconsistent with available options were scored as incorrect answers because this repre-

sents an uncertain source of error. Similarly, for two-target trials, T2 was only scored correct if T1 was correct (see Chun & Potter, 1995). In order to ensure that errors attributable to data trimming were not different across groups and that task instructions to identify the emotion of both targets did not serve as a confound to T2 detection analyses, we examined response types by group. Meaningful group differences resulted only from correct identification and omitted responses (see Figure 2).

Correlational Analyses

Correlation analyses were computed among the entire screened sample ($n = 84$). Only anxiety exhibited a significant correlation with T2 detection overall, $r = -.256$, $p < .05$. Correlations between T2 detection and depression ($r = -.128$), positive affect ($r = -.109$), and negative affect ($r = -.202$) did not reach significance (all $ps > .05$). A similar pattern held for T2 detection in short trials and long trials. For short lag trials, both anxiety ($r = -.273$, $p < .05$) and negative affect ($r = -.218$, $p < .05$) were significantly negatively correlated with T2 detection (depression, $r = -.192$; positive affect, $r = -.101$). However, follow-up analyses revealed that anxiety had a semipartial correlation with T2 detection for short lag trials ($r = -.182$) that was significant while the correlation of T2 detection and negative affect was not significant ($r = -.064$). Semipartial correlation analyses suggest that anxiety accounts for substantially more unique and common

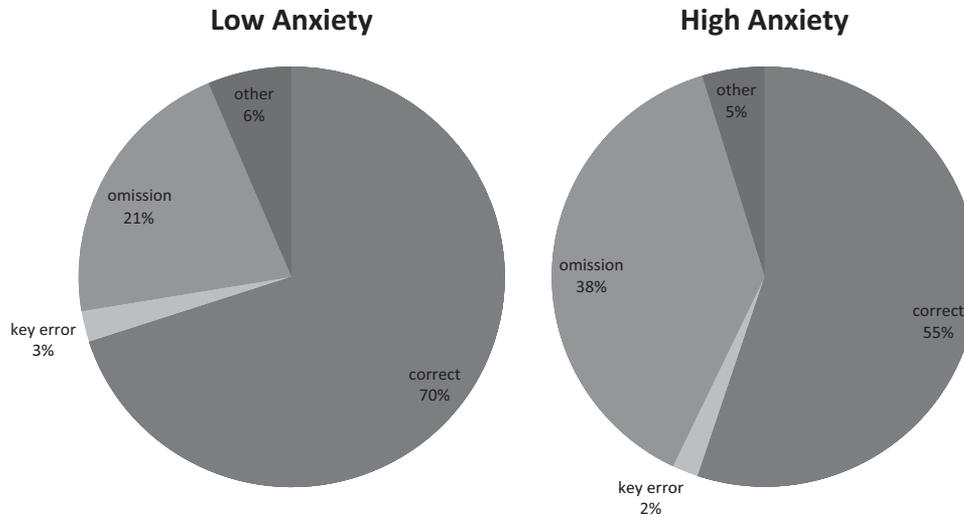


Figure 2. Response type by group. To facilitate ease of interpretation, total response proportions in each category have been divided by total proportion of T2 trials given a correct T1 response. The categories are as follows: correct—accurate identification of T2 emotion, key error—button response not among the designated options (F, H, N) for T2, omission—absence of T2 response, and other—which consists of scoring factors including RT errors and nondesignated button responses. Note the large differences in proportion of correct responses and omissions.

variance than negative affect. For long lag trials, only anxiety was significantly correlated with T2 detection ($r = -.229, p < .05$). Other measures did not exhibit significant correlations (depression, $r = -.063$; positive affect, $r = -.113$; negative affect, $r = -.180$).

Anxiety Groups

As suggested earlier, high anxiety (HA; $n = 30$) and low anxiety groups were established based on scores on the STICSA (see Table 1). A prior study of anxiety disorder patients ($n = 567, M = 51.1, SD = 12.8$) and controls ($n = 311, M = 37.0, SD = 10.4$) (Gros et al., 2007) indicates that the LA and HA groups in the present study are statistically comparable to those with and without anxiety disorders, respectively. In fact, additional analyses comparing the current groups to previous samples (Gros et al., 2007) reveal that the HA group was no different from anxiety disorder patients, $t(595) = 1.96, p > .05, d = .47$, but significantly different from controls, $t(339) = 4.93, p < .001, d = 1.14$. The LA group exhibited lower STICSA scores than both anxiety disorder patients, $t(593) = 9.77, p < .001, d = 2.52$, and controls $t(337) = 4.85, p < .001, d = 1.23$. There were no significant differences in group demographics (see Table 1).

T1 Accuracy

There was no significant difference in overall performance on T1-only trials between anxiety groups (LA: $M = 84.4 \pm 1.5$, HA: $M = 80.7 \pm 1.4$), $p > .5$. However, the LA group ($M = 86.2 \pm 2.2$) was significantly better at detecting fearful targets for T1-only trials than the HA group ($M = 79.2 \pm 1.9$), $t(56) = 2.45, p < .05$. Group differences for happy and neutral targets in T1-only trials did not reach significance ($ps > .10$). There were no within group differences for T1-only trials in either the LA or HA group.

Examination of group differences in T1 accuracy for two-target trials revealed a significant difference for happy targets, $t(56) = 2.42, p < .05$, and a trend toward significance for fearful targets, $t(56) = 1.77, p = .083$. In the case of happy T1s, the LA group ($M = 82.6 \pm 2.0$) was significantly more accurate than the HA group ($M = 73.8 \pm 3.0$). A similar pattern held for fearful T1s, the LA group ($M = 83.8 \pm 2.0$) was more accurate than the HA group ($M = 78.8 \pm 2.1$). In the LA group, fearful ($M = 83.8 \pm 2.0$) and happy ($M = 82.6 \pm 2.0$) T1 identification was statistically equivalent ($p > .5$). This was not the case for the HA group, though; there was a trend to more accurate identification of fearful ($M = 78.8 \pm 2.1$) relative to happy T1s ($M = 73.8 \pm 3.0$) T1s, $t(29) = 2.03, p = .052$. In both groups, fearful and happy T1s were more accurately identified than neutral T1s (LA: $M = 69.7 \pm 3.9$; HA: $M = 65.0 \pm 3.1$), $ps < .005$.

ANOVA Results

Task-related effects. As expected, participants were significantly better at detecting T2 at the long lag ($M = 58.0 \pm 3.3$) relative to the short lag ($M = 54.2 \pm 2.9$), $F(1, 55) = 9.45, p < .01, \eta_p^2 = .147$. There was a main effect of T1 valence, $F(2, 54) = 20.69, p < .001, \eta_p^2 = .434$. There was no difference of fearful ($M = 61.0 \pm 3.0$) and happy ($M = 61.0 \pm 3.0$) T1s on T2 detection, but both led to significantly greater T2 detection than a neutral T1 ($M = 46.5 \pm 3.7$). There was also a main effect of T2 valence on T2 detection, $F(2, 54) = 6.85, p < .01, \eta_p^2 = .202$. While there was no difference between fearful ($M = 58.1 \pm 3.4$) and happy ($M = 57.0 \pm 3.1$) T2 valence on T2 detection, both led to significantly better detection than neutral T2s ($M = 53.1 \pm 2.9$). There was also a significant interaction between lag and T1, $F(2, 54) = 7.97, p < .01, \eta_p^2 = .228$, as well as a significant interaction between lag and T2, $F(2, 54) = 18.49, p < .001, \eta_p^2 = .406$ (see

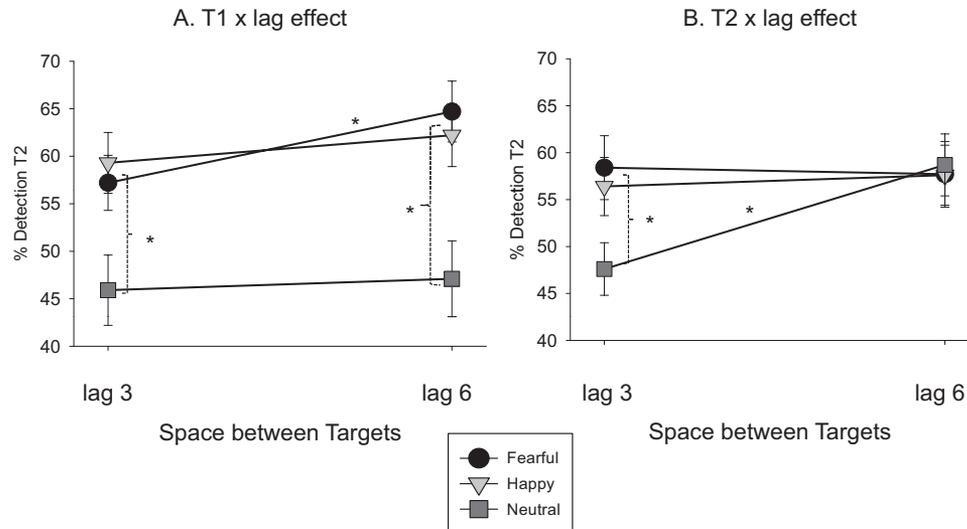


Figure 3. Interactions of lag with first (A) and second (B) target valence. T2 detection rates are shown for each target valence (Fearful, Happy, Neutral) at the short lag (321 ms) and the long lag (642 ms) in panel A for the interaction with T1 valence and panel B for the interaction with T2 valence. All asterisks indicate significant differences at $p < .05$, corrected for multiple comparisons. (A) Note that there is no difference between fearful and happy T1s on T2 detection at either lag 3 or lag 6, but both fearful and happy T1s lead to significantly greater T2 detection than neutral T1s at both lags. Also note a significant improvement in T2 detection from lag 3 to lag 6 for fearful T1s. (B) Note that there is no difference between fearful and happy T2s on T2 detection at either lag 3 or lag 6, but that both fearful and happy T2s differ from neutral T2s at lag 3. Also note that there is a significant improvement in T2 detection for neutral T2s from lag 3 to lag 6.

Figure 3). No other task-related interactions were significant ($ps > .05$).

Anxiety-related effects. There was a main effect of anxiety group, $F(1, 55) = 7.17$, $p < .05$, $\eta_p^2 = .115$. The LA group ($M = 64.2 \pm 4.3$) was significantly better at detecting T2 than the HA group ($M = 47.9 \pm 4.3$) (see Figure 2). Although anxiety did not significantly interact with T1 or with T2, effect sizes were computed to explore potential group differences related to the predictions; there were no group differences (see Table 3). There was a significant three-way interaction between anxiety group, T1 valence, and T2 valence, $F(4, 52) = 2.59$, $p < .05$, $\eta_p^2 = .166$. No other anxiety-related interactions were significant ($ps > .05$). To examine the Anxiety \times T1 \times T2 interaction, additional computations were conducted to explore deviations from what would be expected given a combination of the main effects of Anxiety, T1, and T2. Expected scores were computed for each T1 \times T2 combination for each group by (1) averaging the effect of T1 valence for a given emotion on T2 detection with the effect of T2 valence for the same emotion on T2 detection and (2) averaging the mean from step 1 with each anxiety group mean, respectively. For example, to compute the expected value for an FH trial for LA, the mean of the overall average of T1 = Fear (61.0) and overall average of T2 = Happy (57.0) was first computed. The mean of these two scores (59.0) was then averaged with the overall mean for LA (64.2), resulting in a predicted score for an FH trial in the LA group of 61.6. The actual results were then divided by the predicted results to yield a ratio score (e.g., $68.3/61.6 = 1.11$). Significant deviation from 1 was examined by dividing the difference from 1 of each deviation score by the standard error for each group to yield a Z score. FDR correction for each of the 9 trial

types \times 2 groups (18 comparisons) was used to set $p < .05$ for multiple comparisons. Results are shown in Figure 4.

Discussion

Summary of Findings

The present study examined performance on a two-target RSVP task across a relatively large group of individuals ($n = 84$) and

Table 3
Descriptive Statistics for Short and Long Lag Trials by T1 and T2 Stimulus for Both Anxiety Groups

Trial type	Short lag	Long lag	Cohen's d
	$M \pm SEM$	$M \pm SEM$	
Low anxiety ($n = 28$)			
T1F	65.8 \pm 3.6	72.6 \pm 3.9	.34
T1H	68.5 \pm 4.0	70.8 \pm 3.9	.11
T1N	53.3 \pm 5.5	54.2 \pm 5.6	.03
T2F	67.1 \pm 4.2	66.0 \pm 4.3	.05
T2H	64.2 \pm 4.1	65.7 \pm 3.9	.07
T2N	56.3 \pm 4.0	66.1 \pm 4.1	.45
High anxiety ($n = 30$)			
T1F	48.6 \pm 4.4	56.8 \pm 5.1	.32
T1H	50.1 \pm 4.8	53.6 \pm 5.2	.13
T1N	38.6 \pm 4.8	39.9 \pm 5.5	.05
T2F	49.8 \pm 5.2	49.4 \pm 5.4	.01
T2H	48.6 \pm 4.6	49.6 \pm 4.9	.03
T2N	39.0 \pm 3.9	51.3 \pm 4.9	.50

Note. T1 = 1st Target; T2 = 2nd Target; F = fearful; H = happy; N = neutral.

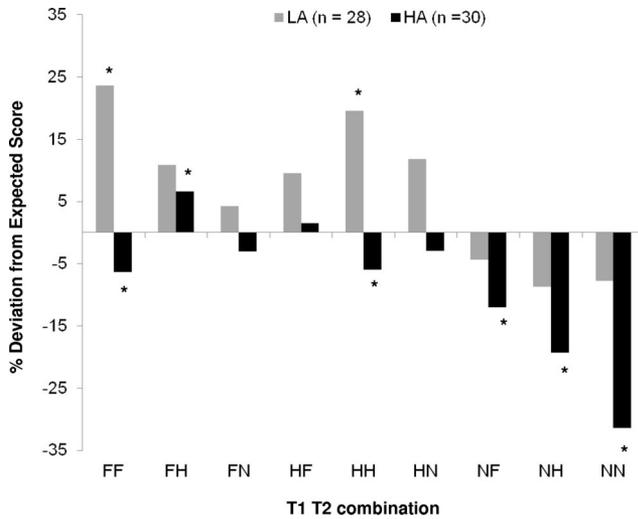


Figure 4. Percent deviations from expected score for each trial type by anxiety group. Expected scores were computed by combining the main effects T1 and T2 valence on T2 detection with the main effect of group for each trial type. Bars represent percent deviation from the expected score, computed as previously mentioned. Asterisks indicate significant deviations at $p < .05$, corrected for multiple comparisons. The light gray bars represent the low anxiety group and the black bars represent the high anxiety group. The letters across the x axis represent T1 T2 combination (F = Fearful, H = Happy, N = Neutral).

subsequently across two subsets with low anxiety (LA) and clinically comparable high anxiety (HA), using emotional (positive and negative) and neutral faces as targets and rotated neutral faces as distractors. Correlational analyses revealed that overall T2 detection was only correlated with anxiety, not depression, positive affect, or negative affect. When T2 detection at the short and long lags was examined individually, negative affect was also significantly correlated to T2 detection, but the effect was no longer present when semipartial correlations were computed. This finding is particularly important as it may suggest that rapid emotion processing alterations in anxiety and depression may be more related to anxiety than depression.

It is worth noting that the LA group tended to be more accurate than the HA group at identifying emotional (i.e., fearful and happy) T1s for both single and dual-target trials. For both groups, fearful and happy T1s were better identified than neutral T1s. Across both groups, happy and neutral T1s were more accurately identified than neutral T1s for both single and dual-target trials. Both T1 and T2 valence significantly influenced T2 detection, but only for emotional targets (i.e., not neutral images). There were also significant interactions between T1 and lag, as well as T2 and lag (see Figure 3).

Anxiety exhibited a main effect; the LA group performed significantly better overall than the HA group (see Figure 2). This confirmed our first prediction. The lack of significant three-way interactions between lag, T1, and anxiety, as well as lag, T2, and anxiety suggest a lack of support for predictions 2 and 3 (enhanced AB for HA vs. LA for fearful T1 and enhanced AB for HA vs. LA for fearful T2, respectively). The results instead reflect a general performance decrement in T2 detection of HA relative to LA

individuals. The lack of a significant four-way interaction between anxiety, lag, T1, and T2 suggests a lack of support for prediction 4 (enhanced RB in HA vs. LA). The only significant interaction with anxiety was with T1 and T2. Closer examination of these results showed that emotion repetition significantly improved target detection for LA individuals but significantly decreased target detection for HA individuals (see Figure 4). The results also showed a significant improvement in T2 detection for FH trials and significant decreases in all trials where T1 was neutral (NF, NH, NN) for the HA group.

Diminished Rapid Processing of Emotional Information in Anxiety

In one-target trials, the HA group was worse than the LA group at identifying fearful T1s. This effect may have resulted in part from the implicit emotion regulation required to both process and label a fearful stimulus; anxious individuals exhibit known deficits in implicit emotion regulation (Etkin et al., 2010). Similarly, the HA group was worse at identifying happy and fearful T1s in two-target trials. These findings, along with all the others, suggest a general performance decrement in HA relative to LA individuals rather than a specific decrement in processes of temporal attention per se. This general performance decrement is consistent with recent behavioral and neuroimaging findings in anxious individuals (Bishop, 2009; Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010). Anxiety only exhibited a significant interaction with T1 and T2 together; an interaction that was not specific to lag. Our long lag period (642 ms) was outside of the commonly acknowledged AB window of ~ 500 ms, thus any target misses at lag 6 cannot be considered “attentional blinks” as traditionally defined (Raymond et al., 1992). Similarly, the enhanced deficits associated with emotion repetition cannot be defined as RB, as originally defined (Kanwisher, 1987). However, there are important individual differences in the AB effect that seems to relate to processing of distractors (Martens & Valchev, 2009). Figure 2 shows that the group difference is clearly attributable to a lack of T2 awareness. Thus while not a traditional ‘attentional blink,’ the effect does appear to be some sort of perceptual ‘blink.’

Difficulty Distinguishing Neutral Distractors From Neutral Targets

Within groups, both groups were worse at identifying neutral T1s relative to happy or fearful T1s. In part, these findings may suggest that it was difficult for participants to differentiate neutral targets from distractors. Table 3 shows that T2 detection rates for the LA group were near what is considered “normal” (Dux & Marois, 2009), for trials where T1 was not neutral. Difficulty detecting neutral targets may be the result of the inherent difficulty of discriminating neutral targets from neutral, rotated distractors. Table 3 and Figure 4 show that both groups exhibited poorer than average T2 detection rates for trials where T1 was neutral. However, this effect was especially pronounced in the HA group. Biases interpreting neutral/ambiguous stimuli among individuals with heightened anxiety (Richards et al., 2002) may have interfered with participants’ ability to inhibit attention to distractors, a

hypothesized contributor to the AB effect (Martens, Korucuoglu et al., 2010) and perceptual processing more generally. Ineffective allocation of attention to neutral distractors may, in part, explain the lack of differences between fearful and happy targets, which are at least theorized to be processed differently in anxiety (Bar-Haim et al., 2007; Matthews & MacLeod, 2005).

Adaptive Attentional Allocation Becomes Maladaptive in Anxiety

Another explanation, not mutually exclusive from those above, is that neutral targets may not gain access to limited attentional resources as readily as emotionally valenced targets. This idea is supported by previous studies where distractors were not rotated neutral faces and targets were emotional and/or neutral (e.g., Maratos et al., 2008). Our results suggest that repeating emotional cues may hold less organismal value than conflicting emotional cues. In gauging rapidly changing facial expressions, a rapid shift in cues signaling approach and then avoid (or vice versa) could signal the need for rapid changes in behavior (Calvo & Lang, 2004). The same signal twice (e.g., a friend smiling upon sight and then again upon nearing) may confer relevant information to an attentional system that is not already taxed (i.e., low anxiety and/or low cognitive load). However, the taxed attentional system does its best to provide information about the most salient environmental cues, minimizing “unnecessary” allocation of limited resources. Clinical levels of anxiety lead to pronounced deficits for processing repeating emotion in direct contrast with normal levels of anxiety, where repeating emotion was beneficial during RSVP (see Figure 4). Our results seem to suggest that HA individuals are not as accurate as LA individuals in identifying rapid, subtle emotions that occur in succession—a potentially important implication for processing changing facial affect in the real world.

Dynamic Neural Systems in Anxiety

A recent neuroimaging study has shown that stimulus-driven and goal-directed attentional activity converge in a lateral prefrontal cortical area (Asplund et al., 2010), also associated with cognitive control (Derrfuss, Brass, Neumann, & von Cramon, 2005). This is particularly relevant given recently identified general cognitive control deficits in anxiety (Pacheco-Unguetti et al., 2010). The current findings, along with previous results, suggest general cognitive control deficits in clinical levels of anxiety. The study of general information processing may lack the additional necessary components to explain emotional processing, which likely entail additional neural underpinnings. Along this line, a study examining detection of fearful stimuli in an RSVP paradigm showed that the rostral anterior cingulate cortex (rACC) was related to increased T2 detection resulting from fearful stimuli (De Martino, Kalisch, Rees, & Dolan, 2009). The ACC, along with the fronto-insular (FI) region, has recently been shown to be important to rapid and intuitive emotion processing (Fan et al., 2011). Consistent with the current findings and the idea that anxious individuals show impairment in rapid and intuitive emotional processing, deficits of ACC activation during implicit emotion regulation have been shown to occur in individuals with generalized anxiety disorder (Etkin et al., 2010). Given the important role of the ACC and FI in emotion processing (Fan et al., 2011), and the role of both the

ACC (Etkin et al., 2010) and FI (Simmons et al., 2008) in anxiety, this network would seem to be a rich area of exploration for further study of rapid, intuitive emotional processing deficits in anxiety. Thus, the present findings, along with previous results, suggest that anxiety alters the relationship between stimulus-driven and goal-directed processing (see Bishop, 2009; Eysenck et al., 2007; Fan et al., 2011).

Limitations

Myriad factors determine the interpretation of facial expressions (Mignault & Chaudhuri, 2003), and anxious individuals are known to process ambiguous and/or neutral images differently than controls (Richards et al., 2002). Thus, further exploration of the factors that contribute to the interpretation of facial affect, especially ambiguous or graded emotion, is warranted. A second potential limitation relates to ecological validity of the task used. Although the use of faces as targets and distractors improved ecological validity of the task, it only mildly mimics everyday facial affect processing. Despite these limitations, the current paradigm does somewhat approximate the type of information that people deal with in any given interpersonal encounter. Accordingly, the present findings provide important information about anxiety-related differences in rapid processing of facial emotion.

Conclusions

When presented with two targets in a rapid stream of facial stimuli, there is a modulatory effect of anxiety; high anxiety is related to overall impairments in detection of the second target relative to low anxiety. Impaired processing of emotional stimuli could be related to difficulty inhibiting attention to neutral distractor faces, especially given known biases processing neutral/ambiguous stimuli in anxiety (Richards et al., 2002). Anxiety-related performance decrements may also relate to an emotional repetition blindness (not to be confused with traditional repetition blindness; see Kanwisher, 1987). In the present study, HA individuals showed particular difficulty detecting T2 when it was a repetition of T1, regardless of lag (see Figure 4). HA individuals also showed more pronounced deficits when T1 was neutral. Increased limitations in emotional processing may be attributable to the maladaptive exaggeration of a normally adaptive strategy, dedicating the largest amount of cognitive resources to the most important environmental cues under conditions of rapid visual processing (Calvo & Lang, 2004). These emotional processing deficits in anxiety are likely attributable to both general impairments in cognitive control (e.g., Pacheco-Unguetti et al., 2010) and to deficits in rapid, intuitive emotion processing and implicit emotion regulation (e.g., Etkin et al., 2010). Further studies using similar paradigms should permit better understanding of these emotional perceptual deficits in anxiety. Examination of new ways of modifying these deficits (e.g., attentional modification training, meditation) in conjunction with more traditional treatment approaches for anxiety may also prove important to overcoming treatment-resistant anxiety.

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