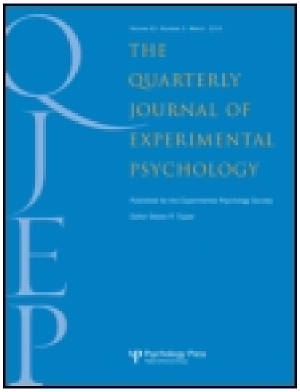

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Response inhibition and attentional control in anxiety

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Traditionally, anxiety has been associated with a selective attentional bias for threat and a decreased capacity in attentional control. In two different experiments, we investigated whether individuals with different levels of self-reported state anxiety (Experiment 1) and induced anxiety (Experiment 2) had impaired response inhibition processes (attentional control deficit) as characterized by a different response style in the presence of negative stimuli under low and high perceptual load conditions. A go/no-go paradigm with emotional distractors (angry, happy, and neutral faces) was used to provide measures of perceptual sensitivity, inhibition, and response style. Our findings showed that perceptual sensitivity, as assessed by the d' parameter of signal detection theory, was reduced in all participants for angry faces under low perceptual load, where enough perceptual resources were available to be attracted by distractors. Importantly, despite similar perceptual sensitivity, the beta parameter indicated that high state anxiety individuals in both experiments were less flexible at adjusting to task demands in the presence of angry face distractors by adopting a stricter criterion. Implications of findings are discussed within current models of attentional control in anxiety.

Keywords: Self-reported anxiety; Anxiety induction; Response inhibition; Go/no-go paradigm; Perceptual load; Emotional distractors; Response style.

A fundamental issue in the study of attention is its function as a filtering mechanism of incoming information. To establish when attention selects the relevant information in the sequence of processing has been a source of debate since the sixties. One perspective suggests that the selection of relevant stimuli and the rejection of distractors occurs early in the mainstream of processing (Broadbent, 1958), while other views propose a later selection controlled by postperceptual processes such as memory (Deutsch & Deutsch, 1963; Norman, 1968).

Lavie (1995) proposed a hybrid model of attention, which considers aspects from both early and

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late selection models of attention. This model has been put to good use within selective attention research (see Lavie, 2010, for a review). Accordingly the effect of distractors on visual attention is determined by the type and level of the load involved in the task, such that if relevant stimuli engage all attentional resources, they will not leave much free capacity to process irrelevant distractors. However, when the task is less demanding, there is spare capacity to automatically process irrelevant stimuli interfering with the main task. In other words, when perceptual load is low, there is a need for cognitive control mechanisms to maintain an adequate level of task performance (Lavie, Hirst, Fockert, & Viding, 2004). Thus, attention, apart from selection processes, also incorporates elements of flexibility required for adjusting the efforts to tackle a task more effectively (Lavie & Cox, 1997). This flexibility seems to depend on emotion and anxiety, an issue that was investigated in the work reported in this paper.

Behavioural and neuroimaging studies have recently provided evidence to support the predictions of load theory and extend its conceptual framework in a number of important domains such as the investigation of stimulus competition under conditions of conscious awareness (Bahrami, Carmel, Walsh, Rees, & Lavie, 2008), the effects of possible internal sources of distraction such as task-unrelated thoughts (Forster & Lavie, 2009), and the differential effects of stimulus saliency and emotionality (Lavie, Ro, & Russell, 2003; Pessoa, Padmala, & Morland, 2005; Wei & Zhou, 2006). In a related manner, research into individual differences in executive function and selective attention has begun to explore the effects of personality dimensions such as trait anxiety on attentional control within the framework of load theory (Bishop, 2009; Forster & Lavie, 2007).

Traditionally, anxiety has been associated with a selective attentional bias for threat (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007, for a review) and to a decreased capacity in attentional control (Derakshan & Eysenck, 2009; Derryberry & Reed, 2002; Eysenck, Derakshan, Santos, & Calvo, 2007). Threat-related information can be evaluated preattentively (Mathews & Mackintosh, 1998; Öhman & Mineka, 2001) and, given its functional relevance in anxious people, competes significantly for attentional resources.

Neuroimaging studies have established that the amygdala–prefrontal circuit supports the relationship between anxiety and attentional bias. Results have collectively demonstrated an increased activity in the amygdala in response to negative stimuli and a deficient recruitment of prefrontal control mechanisms (Bishop, Duncan, & Lawrence, 2004; Bishop, Jenkins, & Lawrence, 2007; Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Hsu & Pessoa, 2007; Pessoa et al., 2005). For example, Bishop et al. (2007) carried out a functional neuroimaging study to specifically address the stage of processing and neural regions associated with the anxiety modulation in processing negative distractors. Participants were asked to search for a letter target embedded amongst non-target letters, which were repetitions of the same or different consonants (i.e., low vs. high perceptual load conditions). Neutral or fearful faces were presented in the background as distractors. Results showed an elevated amygdala response to negative face distractors but only under low perceptual load conditions, where it was argued that attentional control is needed for the efficient inhibition of distractors.

The current study set out to further investigate, by means of two experiments, whether state anxiety is related to an attentional control deficit and a greater difficulty to adjust to task demands under emotional conditions. Specifically, the aim was to know how emotional material affected the attentional control and response style mechanisms required for response inhibition under low and high demand conditions, in participants with state anxiety, both self-reported and induced. In Experiment 1, participants were divided into three groups depending on their level (high–medium–low) of self-reported state anxiety. In the second experiment, all participants were selected according to medium or low trait anxiety levels, but they received a protocol to induce either a high anxiety or a low anxiety (positive) mood before the experimental task. We adapted a go/no-go paradigm (see Nigg, 2000) with varying levels of load. We also used emotional (angry and happy) and neutral facial expressions of emotion as distractors. Previous studies have included emotional stimuli in this procedure (Albert, López-Martín, & Carretié, 2010; Shafritz, Collins, & Blumberg, 2006) and have manipulated the level of perceptual load (Schulz et al., 2009; Schulz et al., 2007) in order to assess the control capacity in depression (Elliot, Rubinsztein, Sahakian, & Dolan, 2002) and obsessive-compulsive (Bannon, Gonsalvez, Croft, & Boyce, 2002) disorders.

According to Lavie's theory of attention (Lavie, 1995, 2010) we predicted slower responses but better performance under high load conditions where all attentional resources are occupied and when perception should be selective to improve the discrimination of target stimuli. We used the detection signal theory parameters (Pastore & Scheirer, 1974) to obtain specific information about the effects of valence on both perceptual processes (as indexed by d') and the response style adopted by participants (as indexed by β).

With regard to the effects of valence, given that angry faces are processed preferentially and compete strongly for attentional resources (Mathews & Mackintosh, 1998; Öhman & Mineka, 2001), we expected significantly slower responses and worse discrimination of the task-relevant stimuli (i.e., reduced d') in the presence of angry than in the presence of happy or neutral faces. These effects should be larger under low load conditions, when more resources are available to be attracted by the threatening distractors.

Since the limitations in cognitive control of anxious people are not usually observed under high load conditions, it is possible that their perceptual resources are appropriate. Therefore, their limitations under low load conditions should be due to the use of inappropriate response strategies. Thus, regarding anxiety, and in line with previous studies (Bishop et al., 2007; Pessoa et al., 2005; Schulz et al., 2007), we predicted that low state anxiety, as compared to high state anxiety participants, would be better at inhibiting the distractors by adopting a stricter response criterion (i.e., larger β) under low load conditions (where we expect larger interference), and this effect would be greater when the distractors are angry facial expressions of emotion. On the other hand, high-state-anxious participants should show greater impairment in inhibiting distractors, especially angry facial expressions under low load conditions, due to their inflexible response strategy that is generally applied in both high and low levels of cognitive demand.

EXPERIMENT 1: SELF-REPORTED STATE ANXIETY

Method

Participants

Fifty-eight participants (mean age = 25.56 years, $SD = 7.53$; 37 females) were recruited to participate in this experiment via electronic and manual advertisements posted through the *"Experiment Management System"* of Birkbeck College, University of London. Participants had normal or corrected-to-normal vision and were naïve to the purpose of the experiment. The experiment was approved by the ethical committee of the Department of Psychological Science at Birkbeck.

Apparatus and stimuli

An Intel Pentium IV computer with a 17-inch DELL screen monitor was used for the presentation of stimuli. The experiment was programmed in the E-Prime v2.0 software (Schneider, Eschman, & Zuccolotto, 2002). Participant responses were collected through the keyboard.

The face stimuli depicted faces from 18 different individuals (9 male and 9 female) selected from the Karolinska Directed Emotional Faces set (KDEF; Lundqvist, Flykt, & Öhman, 1998), Facial Action Coding System (FACS; Ekman & Friesen, 1978), and the NimStim face stimulus set (Tottenham et al., 2009). There were six faces for each of the angry, happy, and neutral emotional expressions, balanced for gender. The faces were trimmed of all nonfacial features, were converted to greyscale, were matched for luminance and brightness, and were presented as an oval on a black background subtending to 10.88 × 13.41° (11.43 × 14.11 cm) of the visual angle at a 60-cm viewing distance. The target display consisted of a string of five red letters (Courier New Bold, 18-point size) superimposed on the middle of the face.

Procedure

Participants were tested individually in a dimly lit cubicle, in one session that lasted approximately 40 minutes. Upon arrival at the laboratory, participants completed the consent form and the trait and state version of the Spielberger State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Before commencing the experimental task, they completed a distractor task (following the protocol for this kind of experiments in the Affective and Cognitive Control Lab), where they were instructed to search for specific letters and numbers in a large matrix of numbers for 2 min.

Participants read the task instructions, which were emphasized by the experimenter, and asked any questions for clarification before the beginning of the experiment. Next, they completed a practice block of 20 trials (with neutral faces only), in which feedback about accuracy and response time was provided. After this block, the experimenter left the room, and the main experiment started. The main task took around 20 min.

Each trial began with a fixation point (grey square of 0.16 × 0.20° and 0.17 × 0.21 cm. in dimension) of variable duration (500–1,500 ms) presented in the centre of the screen on a black background. After this, a face with an angry, happy, or neutral expression appeared for 200 ms, accompanied by a string of five letters. This was followed by a 500-ms blank screen allowing participants time for responding before the fixation cross was presented for the next trial. Figures 1a and 1b show examples of a go and no-go trial, respectively.

Participants were instructed to press the yellow button on the keyboard if the string of letters contained either "X" or "O" as quickly as possible while avoiding mistakes (go trials). If the string of letters did not contain an "X" or an "O", they were told to refrain from responding (no-go trials). The no-go trials included either the letter "P" or the letter "Z" embedded amongst distractors where participants had to refrain from responding. In the high perceptual load condition, the distractor letters were selected to be different from one another (MTRZP), whereas in the low perceptual load condition all distractor letters were repetitions of the same letter (NNNN). The following are examples of each condition: *go* trials with *high* perceptual load: XMTRZ; MTRZO; *go* trials with *low* perceptual load: NXNNN; NNNON; *no-go* trials with *high* perceptual load: TRMZS; TRMPS; *no-go* trials with *low* perceptual load: ZNNNN; NNNPN. Both target and distractor appeared in random order across the letter string.

Task

Participants completed six blocks of 60 trials each with representation of all experimental conditions and separated by a few minutes to rest. In total, 360 trials were presented, two thirds of which were "go" trials and the remaining third "no-go" trials. Half were presented in the low and half in the high load condition, all balanced across gender and emotional expression of face; the different trial types were randomly presented within each block. Upon finishing the main experimental task, participants completed the State Anxiety subscale of the STAI (STAI–SA) again. They were paid £5 for participation and were debriefed at the end.

Design and data analysis

The experiment featured a mixed design with group (high, medium, low state anxiety) as between-participants factor and face (positive, negative, neutral expression), perceptual load (high, low), and target condition (go, no-go trials) as within-participants factors.

Reaction time (RT) of correct responses on go trials and signal detection measures of perceptual sensitivity (d') and response bias (ß) were analysed. The variable d' is a measure of discrimination in response to different stimuli and was calculated as $z(H) - z(FA)$, where H represent hits (correct go trials) and FA false alarms (commission errors) transformed to z scores. The values can range from 0 to infinity, where lower values indicate an

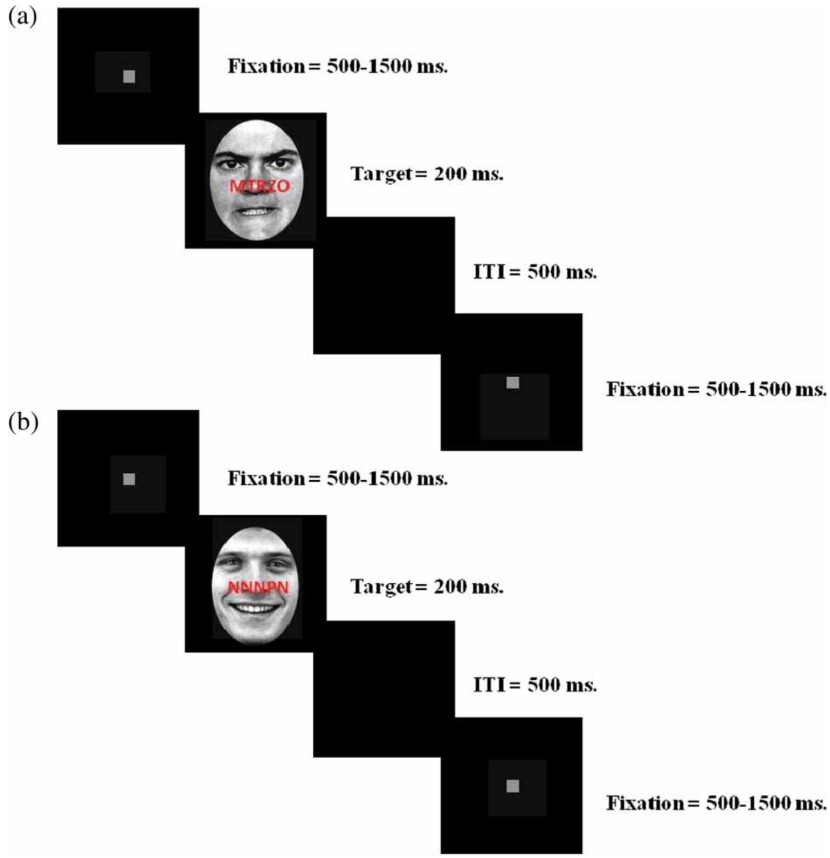

Figure 1. *(A) Example of "go" trial with angry face and high load. (B) Example of "no-go" trial with happy face and low load. To view a colour version of this figure, please see the online issue of the Journal.*

inability to distinguish between stimuli and can indicate a random level of performance. On the other hand, higher values indicate better discrimination and more accurate performance levels. The response bias or ß reflects the level of internal certainty to decide whether the signal stimulus (i.e., the target) was present or just the noise (i.e., only the distractors) was presented. This measure were calculated using the formula $\exp\{d' * [z(\text{H}) + z(\text{FA})]/2\}$, where values greater than 1 mean adopting a strict response criterion—the higher the stricter—to minimize false alarms (i.e., commission errors), and lower values (between 0 and 1) represent a more liberal criterion (the lower the more liberal) to maximize hits (at the expense of committing false alarms). In order to be able to compute d' and ß, 0 and 1 values were substituted, respectively, by .01 and .99. These measures were based on the signal detection theory (SDT; Green & Swets, 1966; see Stanislaw & Todorov, 1999, for a review) and have been previously used to analyse performance in go/no-go tasks that have used emotional stimuli (Kaiser et al., 2003; Putman, van Peer, Maimari, & van der Werff, 2010; Schulz et al., 2009; Schulz et al., 2007), as well as in studies that have used facial expressions of emotion (Bocanegra & Zeelenberg, 2009).

Results and discussion

Mean state anxiety score during the experimental session was 34.57 ($SD = 8.36$). As shown in

Table 1. *Mean scores in the STAI–SA for the different mood groups in Experiment 1*

Mood group	*STAI–SA (range 0–80)*
High anxious	44.38 (5.53)
Medium anxious	34.02 (2.53)
Low anxious	25.89 (3.20)

Note: Means; standard deviations in parentheses. STAI–SA = State Anxiety subscale of the State–Trait Anxiety Inventory. Contrast between groups may be seen: Differences between groups were significant.

Table 1, tercile splits on the state anxiety scores yielded three groups of high anxious ($N = 18$, min = 39, max = 58), medium anxious ($N = 21$, min = 30, max = 38), and low anxious ($N = 19$, min = 20, max = 29), with anxiety levels that were significantly different from each other (all ps < .001).

Reaction time analysis: Go trials

Mean RTs per experimental condition (see Table 2) of correct responses were introduced into a 3 × 3 × 2 mixed analysis of variance (ANOVA) with group (HA: high anxious; MA: medium anxious; LA: low anxious) as between-participants factor and face (angry, happy, neutral expression) and perceptual load (high, low) as within-participants factors. The analysis revealed a significant main effect of face, $F(2, 110) = 8.05$, $p = .0005$, where participants took significantly longer to respond when the face was an angry then when it was a happy face, $F(1, 55) = 7.97$, $p = .0065$, or had neutral expression, $F(1, 55) = 15.04$, $p = .0002$, the latter two not differing from each other ($F < 1$). In line with previous findings (see Lavie, 2010, for a review), the main effect of load was significant, $F(1, 55) = 16.93$, $p = .0001$, where RTs on trials with low load were faster than RTs on trials with high load, confirming an effective manipulation of perceptual load.

The interaction between face and load was not significant ($F < 1$), and neither were their respective interactions with the factor group, Face × Group, $F(4, 110) = 1.44$, $p = .2226$, and Load × Group, $F < 1$. Although the main effect of anxiety group was not significant, $F(2, 55) = 1.71$, $p = .1897$, the HA group was slower than MA and LA groups, respectively. Only the difference between the HA and LA groups was significant, $F(1, 55) = 2.33$, $p = .04$.

Perceptual sensitivity

A 3 × 3 × 2 mixed ANOVA was performed on d' accuracy scores. The analysis revealed a significant main effect of face, $F(2, 110) = 10.71$; $p < .0001$, and load, $F(1, 55) = 23.42$; $p < .0001$. As we expected according to the literature (e.g., Putman et al., 2010), the perceptual sensitivity was worse for angry than for happy, $F(1, 55) = 9.84$, $p = .0027$, and neutral faces, $F(1, 55) = 20.97$; $p < .0001$; the latter two did not differ from each other, $F(1, 55) = 1.82$, $p = .1819$. The high load condition produced a greater perceptual sensitivity than low load, suggesting that the load manipulation was effective, and participants invested more attentional recourses to detect potential targets in the high load condition.

The Face × Load interaction was significant, $F(2, 110) = 25.61$; $p < .0001$, showing comparable perceptual sensitivity levels in high and low load conditions when the face had a neutral, $F(1, 55) = 1.00$, $p = .3209$, or happy expression ($F < 1$), but a significant decrease in perceptual sensitivity under low load condition for an angry expression, $F(1, 55) = 73.14$; $p < .0001$. There were no significant interactions with anxiety group (Fs < 1).

Response bias

A 3 × 3 × 2 mixed ANOVA was performed on ß values (see Table 2 for descriptive statistics). Analyses revealed a significant main effect of face, $F(2, 110) = 4.48$, $p = .01$, showing a more conservative or strict criterion or response bias for angry than for happy, $F(1, 55) = 7.11$, $p = .01$, or neutral faces, $F(1, 55) = 3.61$, $p = .06$, with no difference in criterion between neutral and happy faces, $F(1, 55) = 1.23$, $p = .27$. The load had no significant main effect ($F < 1$), and its interaction with group was not significant, $F(2, 55) = 1.78$, $p = .176$. The Load × Face interaction was marginally significant, $F(2, 110) = 3.02$, $p = .0527$. The criterion was similar for angry, neutral, and

Table 2. *Mean RT on go trials, perceptual sensitivity, and response bias for each experimental condition and anxiety group in Experiment 1*

		RT			*d'*			*ß*		
Mood group	*Load*	*Angry*	*Neutral*	*Happy*	*Angry*	*Neutral*	*Happy*	*Angry*	*Neutral*	*Happy*
High anxiety	High	520	515	507	4.78	4.32	4.27	4.94	2.08	1.98
		(55)	(55)	(59)	(1.03)	(1.06)	(1.04)	(13.76)	(7.13)	(7.16)
	Low	505	499	497	3.04	4.22	4.36	0.44	1.06	1.29
		(47)	(52)	(46)	(0.91)	(0.77)	(1.23)	(0.25)	(4.07)	(4.02)
Medium anxiety	High	500	492	498	4.77	4.69	4.23	1.87	2.87	4.24
		(63)	(71)	(78)	(1.16)	(1.19)	(1.08)	(6.60)	(6.08)	(12.80)
	Low	492	487	486	3.25	4.20	4.00	7.66	3.89	0.16
		(68)	(60)	(61)	(0.95)	(1.04)	(1.09)	(13.15)	(13.64)	(0.31)
Low anxiety	High	482	471	477	4.68	4.66	4.66	2.08	3.47	0.48
		(57)	(54)	(57)	(1.22)	(1.21)	(1.20)	(6.92)	(10.12)	(0.50)
	Low	474	463	468	3.58	4.76	4.50	11.44	1.32	0.36
		(52)	(53)	(52)	(1.03)	(1.31)	(1.26)	(15.75)	(3.90)	(0.42)

Note: RT = reaction time. *d'* = perceptual sensitivity. ß = response bias. Standard deviations in parentheses.

happy faces on high load condition (Fs < 1), but was more conservative for angry than for neutral, $F(1, 55) = 5.02$, $p = .0290$, and happy faces, $F(1, 55) = 13.68$, $p = .0005$, on low load condition. There were no differences between neutral and happy faces, $F(1, 55) = 1.56$, $p = .2159$.

Central to the aims of the current experiment, the three-way interaction of Face × Load × Group was significant,[1] $F(4, 110) = 2.79$, $p = .0295$. As shown in Figure 2, high perceptual load did not elicit any significant response biases as a function of face type in any of the groups. Thus, the LA group did not show any significant differences in bias between angry and neutral (Fs < 1) or happy faces, $F(1, 55) = 1.50$, $p = .2255$, and neither did the HA and MA groups (Fs < 1). However, under low perceptual load, where greater attentional control is required for the inhibition of distractors, the LA group employed a stricter response criterion in responding to angry than in responding to neutral, $F(1, 55) = 8.65$, $p = .0047$, and happy faces, $F(1, 55) = 15.82$, $p = .0002$; no differences were found between happy and neutral faces ($F < 1$). This pattern was not observed in the HA, where the criterion was similar for angry, neutral, and happy faces (Fs < 1). The MA group showed a stricter response to angry than to happy, $F(1, 55) = 8.01$, $p = .0004$, but not neutral faces, $F(1, 55) = 1.32$, $p = .2539$. The difference between neutral and happy faces was marginally significant, $F(1, 55) = 3.57$, $p = .0638$.

To summarize, this first experiment confirmed that different levels of self-reported state anxiety entail different response criteria, at least under low perceptual load conditions, where greater attentional control is needed for response inhibition under negative valence of distractors. HA participants were less flexible at adjusting to task demands in the presence of angry face distractors. In other words, the low-state-anxious individuals showed better response inhibition (i.e., larger β values) on no-go trials with angry distractors by adopting a response style that maximizes the number of correct responses. However, high-state-anxious participants showed greater impairment in inhibiting distractors, especially angry facial expressions under low load conditions, due to their inflexible response strategy that was generally applied in both high and low levels of cognitive demands. Regression analysis

[1] This interaction was also significant when the analysis was performed with STAI State as a continuous predictor, Face × Load × Anxiety–SA, $F(2, 212) = 3.40$, $p = .0366$. While the Face × Anxiety–SA interaction was significant for low load conditions, $F(2, 212) = 3.91$, $p = .0228$, it was far from significance for high load conditions ($F < 1$).

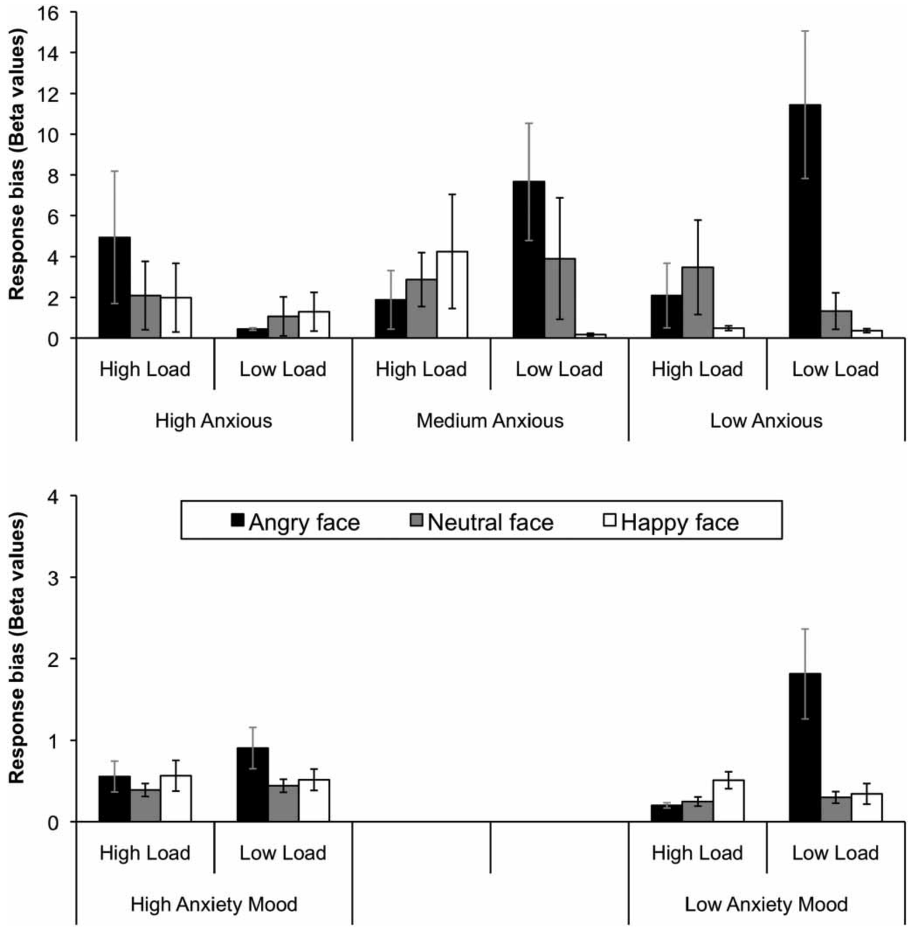

Figure 2. *Response bias (ß values) for each of the angry, neutral, and happy faces, as a function of load for each state anxiety group. Error bars represent standard errors of the mean. Data from Experiment 1 are displayed on the top panel; data from Experiment 2 are displayed on the bottom panel.*

with participants' state anxiety scores predicted significantly the change in beta values between low and high perceptual load conditions, $F(1,\ 56) = 6.226$, $p < .015$, $\beta = -.316$, $t = -2.495$, $p < .015$, for angry faces trials. State anxiety also predicted significantly the changes in beta values between angry and happy distractor faces, $F(1,\ 56) = 4.254$, $p = .043$, $\beta = -.265$, $t = -2.062$, $p > .043$, for low perceptual conditions.

In Experiment 2, where the current mood was manipulated, we expected results in line with Experiment 1 and perhaps with stronger effects. We expected better inhibitory processes in the low-anxiety (positive mood) group than in high-anxiety group, and no differences between groups regarding the valence of distractors, in high or low load conditions, in perceptual sensitivity.

EXPERIMENT 2: ANXIETY INDUCTION

Therefore we decided to carry out another experiment in order to test whether anxiety plays a causal role in the effects obtained in this experiment. To do so, we manipulated the level of state anxiety, instead of by selection, by directly inducing a state of high anxiety. To do so, we used a series of emotionally negative or positive pictures, accompanied by a brief text emphasizing, respectively, the control versus lack of control featured in the pictures. This procedure has been shown to be useful in inducing high state anxiety levels in previous studies (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010).

Method

Participants

Forty-two participants (21 in each group; mean age = 18.15 years, $SD = 0.86$; 31 females) from the University of Granada (Spain) were selected from 244 incoming first-year students based on their trait anxiety scores on the STAI–Trait Anxiety (STAI–TA; Spielberger et al., 1983). Only individuals scoring 35 and below were included (mean trait anxiety was 27.32, $SD =$ 4.8), in order to guarantee that the observed effect were due to the experimentally induced anxiety state and not to any other variable (like trait anxiety) with which it covaries. All participants had normal or corrected-to-normal vision and were naïve as to the purpose of the experiment.

Mood induction materials

The mood induction procedure included two sets of 10 pictures selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) on the basis of the Spanish normative population in valence and arousal[2] (Moltó et al., 1999; Vila et al., 2001). One set of pictures had a positive emotional content (i.e., couples, families, or landscapes), and the other had a negative emotional content (i.e., mutilations, victims of violence, or natural disasters). Each picture was shown for 6 seconds, always preceded by a brief text related to the content, which was also shown for 6 seconds during the image. In the high anxiety mood induction set, the written information emphasized the lack of control over the circumstances represented in the picture (i.e., a picture of a baby in the incubator and the sentence: *"Pain and suffering can affect us or our loved ones at any time"*). In the low anxiety mood induction,[3] the material referred to accomplishment and goal achievement (i.e., picture of a medal ceremony with this text: *"When we achieve our goal we feel reinforced. There are always personal achievements in our life"*). This mood induction procedure has been successfully used in previous studies at both individual and group levels (e.g., Pacheco-Unguetti et al., 2010; Pacheco-Unguetti, Acosta, & Lupiáñez, 2011).

Procedure and design

Participants were tested individually in a dimly lit cubicle, in one session that lasted for approximately 40 minutes. Upon arrival at the laboratory, participants were randomly assigned to one of two groups (high anxiety mood induction or low anxiety mood induction; in order to avoid carry-over effects, mood was manipulated between participants), and informed consent was obtained from all participants.

In order to check the effect of mood induction, participants filled out the State subscale of the STAI questionnaire and the Mood Evaluation Scale[4] (EVEA; Sanz, 2001) immediately before and after mood induction. Before the

[2] The pictures' numbers for negative induction were 3000, 3071, 3080, 3150, 3170, 3350, 3550, 6312, 9040, and 9410 (mean valence = 1.78 and arousal = 7.49), and for positive induction the numbers were 2040, 2091, 2340, 2501, 2540, 4599, 5260, 5830, 8540, and 8600 (mean valence = 7.77 and arousal = 4.41). IAPS values range from 1 to 9. The differences in valence, $F(1, 18) =$ 1,393,128, $p < .0000$, and arousal, $F(1, 18) = 113{,}029$, $p < .0000$, were significant between the two sets of pictures.

[3] The goal of inducing a low anxiety mood by means of positive pictures was to increase the differences in the anxiety levels between groups, more than to produce a positive mood. The negative mood induction gave rise to a greater state anxiety level, some increase in hostility and depression, and a higher reduction in happiness (this group is named high state anxiety throughout the paper). In the group receiving the positive induction (defined as low state anxiety), participants had a reduction in anxiety, hostility, and depression levels and an increase in happiness.

[4] The EVEA is a scale that includes 16 items (adjectives referring to mood states) with four factors evaluated in a Likert scale (ranging from 0 to 10): Fear–Anxiety, Anger–Hostility, Sadness–Depression, and Joy–Happiness. The alpha coefficients for these factors fluctuate from .88 to .93.

mood induction, participants were informed that they would see a series of pleasant or unpleasant pictures (depending on the group they were assigned to), and their task would be to read the sentences, look at the pictures, and try to involve themselves emotionally in the content. After the mood induction, participants once again filled out the questionnaires mentioned above and directly proceeded to run the same experimental task as that described in Experiment 1.

The experiment featured a mixed design with group (high anxiety and low anxiety mood induction) as between-participants factor, and face (angry, happy, neutral expression), perceptual load (high, low), and target condition (go, no-go trials) as within-participants factors.

Results and discussion

Data analysis

The data from one participant in each group were lost due to a technical problem. Analyses similar to those performed in Experiment 1 were performed on the data, with the exception that in this new experiment, anxiety state differences between groups were tested to make sure that the mood induction procedure was successful.

Mood manipulation check

A different unifactorial ANOVA with the variable group was performed for STAI–State scores and each EVEA's subscale scores (anxiety, hostility, depression, and happiness) contrasting the measures taken before and after the mood induction. As shown in Table 3, our induction procedure was effective, and both the high anxiety and the low anxiety (positive) mood induction groups showed similar levels in all questionnaire measures before mood induction but they differed significantly in the expected direction after mood induction.

Reaction time analysis: Go trials

RTs per experimental condition (see Table 4) were analysed using a $2 \times 3 \times 2$ mixed ANOVA with group (high anxiety vs. low anxiety mood induction) as between-participant factor, and face (angry, happy, neutral expression) and perceptual load (high, low) as within-participants factors.

The analysis revealed a significant main effect of group, $F(1, 38) = 25.12$; $p < .0001$, which showed that responses in the group receiving high anxiety mood induction were significantly slower than those in the group receiving low anxiety mood induction. In line with the results of Experiment 1, the main effect of load was significant, $F(1, 38) = 6.36$, $p = .0159$, since RTs on trials with low load were faster than RTs on trials with high

Table 3. Mean scores in the STAI–SA and Mood Evaluation subscales of EVEA for the different mood groups in Experiment 2

			EVEA			
Mood group	*Pre/post mood induction*	*STAI–SA (range 0–80)*	*Anxiety (range 0–10)*	*Hostility (range 0–10)*	*Depression (range 0–10)*	*Happiness (range 0–10)*
High anxiety	Pre	35.90 (6.40)	1.85 (1.44)	0.46 (0.80)	1.80 (1.55)	6.56 (1.66)
	Post	50.6 (7.94)	4.13 (2.56)	3.05 (2.75)	4.50 (2.36)	3.80 (2.26)
Low anxiety	Pre	35.80 (6.68)	2.08 (1.70)	0.93 (1.68)	1.48 (1.79)	6.87 (1.88)
	Post	30.40 (7.58)	0.96 (1.51)	0.43 (1.61)	2.06 (2.22)	7.01 (2.68)

Note: Means; standard deviations in parentheses. STAI–SA = State Anxiety subscale of the State–Trait Anxiety Inventory. EVEA = Mood Evaluation Scale. Contrast between groups may be seen: Groups did not differ in preinduction measures (all ps $>.25$), but differences in postinduction measures were significant (all ps $< .005$). Pre- and postinduction scores for all the questionnaire scales were also significant (all ps $<.0001$, except for EVEA–Hostility, with $p = .0126$).

Table 4. *Mean RT on go trials, perceptual sensitivity, and response bias for each experimental condition and anxiety group in Experiment 2*

		RT			d′			*ß*		
Mood group	*Load*	*Angry*	*Neutral*	*Happy*	*Angry*	*Neutral*	*Happy*	*Angry*	*Neutral*	*Happy*
High anxiety	High	517 (42)	506 (46)	511 (40)	3.46 (0.84)	3.62 (0.65)	3.50 (0.54)	0.56 (0.84)	0.39 (0.35)	0.57 (0.84)
	Low	506 (39)	500 (39)	501 (39)	3.12 (0.55)	3.72 (0.74)	3.78 (0.57)	0.90 (1.13)	0.44 (0.35)	0.52 (0.58)
Low anxiety	High	452 (26)	454 (31)	457 (37)	3.23 (0.51)	3.35 (0.56)	3.54 (0.86)	0.20 (0.14)	0.25 (0.25)	0.51 (0.46)
	Low	446 (29)	453 (32)	458 (31)	3.06 (0.69)	3.40 (0.78)	3.39 (0.59)	1.81 (2.46)	0.30 (0.31)	0.34 (0.56)

Note: RT = reaction time. *d′* = perceptual sensitivity; ß = response bias. Standard deviations in parentheses.

load. However, the main effect of face was not significant, $F(2, 76) = 1.21$, $p = .3037$.

The interaction between face and group was significant, $F(2, 76) = 5.77$, $p = .0046$, indicating that although the high anxiety mood induction group showed significantly slower RT for all faces than the low anxiety mood induction group, the differences were bigger when the face showed an angry expression, $F(1, 38) = 35.92$; $p < .0001$, than when it showed a neutral one, $F(1, 38) = 18.84$, $p = .0001$, or a happy one, $F(1, 38) = 18.95$; $p < .0001$. The interaction between face and load was not significant ($F < 1$), and neither were the interactions between face and group, $F(1, 38) = 2.17$, $p = .1482$, and between the three variables, Face × Group × Load ($F < 1$).

Perceptual sensitivity

A 2 × 3 × 2 mixed ANOVA was performed on *d′* accuracy scores. The analysis yielded a significant main effect of face, $F(2, 76) = 14.31$; $p < .0001$. Perceptual sensitivity was worse for angry than for neutral, $F(1, 38) = 23.74$; $p < .0001$, and happy expressions, $F(1, 38) = 24.35$; $p < .0001$; the latter two did not differ from each other ($F < 1$).

The main effect of load was not significant ($F <$ 1), and neither were the interactions of load or face variables with group (*F*s < 1). However, the Face × Load interaction, which was significant in Experiment 1, just failed to reach significance, $F(2, 76) = 2.83$, $p = .0650$. Planned comparisons were performed and showed similar perceptual sensitivity levels in high and low load conditions, respectively, when the face had a neutral or happy expression (*F*s < 1), but a significant decrease in perceptual sensitivity under low load conditions for an angry facial expression, $F(1, 38) = 6.13$, $p = .0178$.

Response bias

The 2 × 3 × 2 mixed ANOVA performed on ß values showed a significant main effect of face, $F(2, 76) = 7.25$, $p = .0013$, revealing a more conservative or stricter criterion for angry than for happy, $F(1, 38) = 5.18$, $p = .0285$, or neutral faces, $F(1, 38) = 10.75$, $p = .0022$, with no difference in criterion between neutral and happy faces, $F(1, 38) = 2.84$, $p = .0999$. The load factor also had a significant main effect, $F(1, 38) = 6.41$, $p = .0155$, showing a more conservative response bias for low than for high load conditions. The Load × Face interaction was also significant, $F(2, 76) = 9.67$, $p = .0001$. The criterion was similar for high and low load conditions for neutral and happy faces (*F*s < 1). However, for angry faces, the criterion was significantly different under both load conditions, $F(1, 38) = 9.74$, $p = .0034$, being more conservative under low than under high load conditions. The interactions between load or face with group were not significant, $F(1, 38) = 2.44$, $p = .1258$, and $F(2, 76) = 1.35$, $p = .2638$, respectively.

Nevertheless, as in Experiment 1, the three-way interaction between face, load, and group, which is crucial to the aims of our experiment, proved to be significant again, $F(2, 76) = 4.09$, $p = .0204$. As shown in Figure 2, the high anxiety mood induction group did not show any significant differences in bias between angry, neutral, or happy faces (Fs < 1) as a function of the perceptual load. However, the low anxiety mood induction group had a different bias depending on the face. These participants employed a similar response criterion in their response to neutral and happy faces (Fs < 1) independently of high and low load, but they used a stricter response criterion in responding to angry faces, $F(1, 38) = 13.15$, $p = .0008$, under low than under high perceptual load conditions. Note that low load and angry facial expression proved to be the condition in which participants required the greatest level of attentional control in order to inhibit distractors (i.e., larger interference was observed from the face, thus reducing perceptual sensitivity).

GENERAL DISCUSSION

The aim of this study was to investigate whether state-anxious people show impaired response inhibition processes (i.e., an attentional control deficit) or a different response style in facing negative stimuli under conditions in which attentional resources are not fully occupied.

First, and supporting Lavie's theory of attention (Lavie, 1995, 2010), participants in both experiments were slower but had better discrimination in high load conditions, regardless of anxiety level. In the first experiment, the main effect of load was significant and also its interaction with face distractor valence. In the second experiment, the main effect did not reach statistical significance, but the interaction was significant, as in Experiment 1. It seems likely that negative distractors (angry faces) were maximizing the differences between the load levels. In complex situations, more cognitive resources are recruited to perform the task correctly, but at the expense of a decrease in speed. The negative distractors consolidate these differences better than positive or neutral distractors.

Regarding the valence of distractors, our results showed that all the participants were slower and showed worse target sensitivity when the distracting face portrayed an angry than when it portrayed a happy or neutral expression. This impairment (also shown as slower RT in the high-anxiety state group) could be understood as an emotional Stroop effect (Williams, Mathews, & MacLeod, 1996) since faces were negative but completely task irrelevant. This distinctive feature of our pattern of results is interesting because the emotional Stroop effect is usually found in conditions where some dimensions of the negative stimuli are relevant to the task. For example, in the standard task, participants are to name the ink colour in which emotionally relevant versus neutrals words are printed, RT being larger for negative words. However, in our experiments, participants never had to attend to faces, in spite of which they showed reduced perceptual sensitivity under low load conditions, where enough perceptual resources were available to be attracted by angry faces. The fact that perceptual sensitivity was reduced is a clear index that angry faces attracted attention, not just that participants adopted a different criterion in the presence of them.

Threatening faces are evolutionary relevant stimuli (Öhman & Mineka, 2001), which strongly compete for limited attentional resources, thus decreasing perceptual sensitivity of the target letter and increasing reaction time to it. Although this prioritization of threatening stimuli is enhanced in anxious people, as faces are evolutionary relevant stimuli, it is adaptive for everyone to prioritize them. Such stimuli are automatically detected and processed in early stages of processing, which may be the reason for angry faces interfering with performance in the main task in all individuals, independently of state.

Our central prediction concerned nevertheless the differences in processing style as a function of state anxiety. The results confirmed that both high versus low self-reported state anxiety participants, and participants under positive versus negative (anxiety) induced mood showed different response styles (i.e., differences in response criterion) under low perceptual load, where greater attentional control is required for response inhibition. This finding suggests that in the presence of threat-related information, high-anxious individuals find it difficult to adjust to task demands. In contrast, low-anxious individuals employed a more efficient or flexible response style, directed to maximize the number of correct responses while avoiding making mistakes. In other words, they adopted a stricter response criterion in the most difficult condition—that is, when an angry face was presented, and there was low perceptual load (note that this was the condition on which participants showed overall the lowest perceptual sensitivity, as measured with d', and larger RT). High-anxious individuals, however, showed the same response style to angry, neutral, and happy faces, therefore not showing the "additional" effort shown by low-anxious individuals to efficiently avoid responding in the presence of the negative stimuli. It is important to note that such effects were not due to group differences in sensory-discriminative power as the effects were not observed in perceptual sensitivity analyses (d') but only in response criterion (β).

The pattern of results can be easily accommodated within current theoretical accounts. On the one hand, Bishop et al. (2007) showed that state anxiety was associated with increased activity in the amygdala and superior temporal sulcus (STS) in response to fearful faces and conditions of low perceptual load. These areas are involved in rapid detection of threatening stimuli and are associated with evaluation of facial expressions, respectively. It is possible that the difficulties exhibited by our anxious participants in adjusting their response style in a flexible way could be due to a this increased activation in the amygdala together with a reduced activation in cortical areas related to control.

Without involving affective material, Pacheco-Unguetti et al. (2010) found that state-anxious participants showed an overfunctioning of the alerting and orienting attentional networks, which are involved in maintaining the cognitive level suitable to perceive stimuli and to select the appropriate information from numerous sensory stimuli. The results of the current experiments add to these findings by showing that under high load, both high- and low-state-anxious participants have reduced capacity to process irrelevant distractors (this being the reason for not observing differences between face types) so that cognitive control mechanisms are less needed to adjust response criterion. However, under low load where spare resources are free to process the distractors, the low-anxious group adopts a stricter response style for the inhibition of angry distractors, in contrast to high-anxious individuals.

Corbetta and Shulman (2002) proposed that attention is implemented in two networks of brain areas: the goal-driven attentional system (top-down control) and the stimulus-driven attentional system (bottom-up control). Previous work has dissociated trait and state anxiety as mainly related to an altered functioning of the first and the second attentional system, respectively (Bishop et al., 2007; Pacheco-Unguetti et al., 2010). The alteration in the functioning of the bottom-up system, which is involved in the detection of relevant and unexpected stimuli, could be caused by high-anxious participants having more difficulties to adjust efficiently their response style.

In conclusion, our results demonstrate that high-state-anxious individuals have greater difficulties in inhibiting responses in the presence of negative stimuli. This is due to a certain weakness in their use of external information to help them select a response style that is adequately adjusted to the task demands. It is plausible that this could be one reason why previous studies have not found a general deficit of cognitive control in state-anxious participants but have done so in trait-anxious ones (Bishop, 2009; Bishop et al., 2007; Pacheco-Unguetti et al., 2010), as this deficit is associated more closely with regulation or with situational aspects that are determined by the materials used in the experiments and the kind of tasks they are required to perform.

Future work is necessary in order to further determine the role of perceptual load in selective attention of anxious people and the functioning of the cognitive control mechanisms needed to adjust their responses to emotional information. The differences between state and trait anxiety are also important on this context.

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