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Attention and Anxiety: Different Attentional Functioning Under State and Trait Anxiety

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Abstract

Anxiety modulates the functioning of attention. Although the existence of this relationship is clear, its nature is still poorly defined. Added are the facts that different types of anxiety—state or trait—may influence attention differently and that attention is not a unitary system. We studied the influence of such types of anxiety by means of a task that, using emotionally neutral information, assesses the efficiency of three attentional networks: orienting, alerting, and executive control. Results showed a double dissociation. Trait anxiety was related to deficiencies in the executive control network, but state anxiety was associated with an overfunctioning of the alerting and orienting networks.

Keywords

trait anxiety, state anxiety, attention network test, ANT

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Researchers of emotion, personality, and psychopathology have long tried to understand the psychological processes underlying the concept of anxiety. The relationship between anxiety and attention has become a hot topic (see Mathews & MacLeod, 2005, for a review) and has given rise to a few theoretical models (Beck & Clark, 1997; Eysenck, 1992, 1997; Eysenck, Derakshan, Santos, & Calvo, 2007; Mathews & Mackintosh, 1998; Öhman, 2000; Williams, Watts, MacLeod, & Mathews, 1997). These psychological models are now being empirically tested thanks to the data that are gathered from cognitive and affective neuroscience studies (Phelps, 2006).

Personality research has traditionally distinguished between state anxiety and trait anxiety and has generally understood that both are characterized by a lack of control (Lazarus, 1991; Mandler, 1984). From a cognitive standpoint, anxiety has been related to hypervigilance (Eysenck, 1997) and attentional biases, which in turn ease the detection of negative affective content (Williams et al., 1997). However, the effects of the different subtypes of anxiety (state vs. trait) on these processes have not been clearly established. Williams et al. (1988) proposed that the two types of anxiety bias attention differently: Whereas state anxiety increases the threat value assigned to a stimulus or situation, trait anxiety gives rise to a tendency to constantly direct attention toward the source of threat. Mathews and Mackintosh (1998) made similar predictions and suggested that state anxiety, or fear, decreases a person's threat threshold and that this occurs more frequently in individuals who score highly on measures of trait anxiety. Other researchers have assigned the same functional relevance to results obtained under both state anxiety and trait anxiety conditions (e.g., Fox, Russo, Bowles, & Dutton, 2001).

The relationship between different subtypes of anxiety and attention processes could be better understood if we acknowledge that attention is not a unitary system, but rather a set of networks that are functionally and structurally independent, although they may work cooperatively (see Corbetta, Patel, & Shulman, 2008, and Posner, Rueda, & Kanske, 2007, for reviews). Posner and Petersen (1990) and Posner et al. (2007) have distinguished three major attentional networks: *alerting*, *orienting*, and *executive control*. Alerting is involved in maintaining an appropriate sensitivity level to perceive and process stimuli and has been related to activation of right frontal and parietal brain areas. The orienting network involves the selection of information from among numerous sensory stimuli and has been associated to activations in the superior parietal lobe, frontal eye fields, and temporoparietal junction. The executive

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control network specializes in conflict resolution and voluntary action control and is related to midline frontal areas, anterior cingulate gyrus, and lateral prefrontal cortex. A task to evaluate the efficiency of each network (the attention network test, or ANT) was recently created (Fan, McCandliss, Sommer, Raz, & Posner, 2002) and subsequently modified to allow for the collection of information about both the individual effects of each network and their interactions (the attention network test—interactions, ANT-I; Callejas, Lupiáñez, & Tudela, 2004).[1]

Similarly, Corbetta and Shulman (2002; see also Corbetta et al., 2008) distinguished between two attention networks: one directed by expectations and another one mediated by stimulus relevance. The first system is responsible for directing attention toward the target and is related to top-down processes, and the second is sensitive to unattended to but task-relevant stimuli and is thus more related to bottom-up processing.

These conceptual frameworks could be useful to disentangle the effect of different types of anxiety on attention processes. On the one hand, state anxiety rises as a consequence of the events occurring in a particular situation, and it is linked to the stimuli presented in such situation. It is related to the current interpretation of what is happening, and therefore it might be closely related to bottom-up processes. On the other hand, the nature of trait anxiety is related to attitudes and strategies, and it is not linked to situational triggers. It is thus more associated with top-down mechanisms. Although previous literature has studied anxiety in the context of emotionally laden tasks (i.e., tasks including emotional vs. neutral words or faces), we believe that the biases found in anxious individuals may be of a cognitive structural nature and could be observed (and thus influence behavior) even under task conditions that do not involve affective material. For example, Derryberry and Reed (2002) found a high negative correlation between trait anxiety scores and self-reports of attentional control. It also has been noticed that children who perform better on emotionally neutral spatial conflict tasks also score highly on measures of voluntary control and lower on measures of negative affect (Rothbart, Ellis, Rueda, & Posner, 2003). Recently, Bishop (2009) reported neuroimaging evidence supporting this relationship. Trait anxiety was related to a reduced recruitment of prefrontal structures known to be critical for cognitive control mechanisms. Also, participants' difficulties inhibiting distracting information were manifest even when such information was not emotional in nature.

Given that attention is a multinetwork system and that different networks may be affected by anxiety in different ways, the ANT-I task (Callejas et al., 2004) could be the perfect tool to study the effect of anxiety on the different attentional networks. Taking into account the above arguments, our predictions were that trait anxiety would be related to deficits in the control network, whereas state anxiety would be more related to deficits in the orienting and alerting networks.

We carried out two experiments to test these hypotheses. In the first experiment, we used two groups of participants whose trait anxiety values were either high or low. Participants in the second experiment were selected on the basis of having average scores for trait anxiety. Half of them underwent anxiety induction before the task, and the other half received a positive mood induction. We used these manipulations to check the functional differences between high and low trait and state anxiety in alerting, orienting, and executive control. That is, our aim was to dissociate the attentional biases specifically associated with trait anxiety and state anxiety. To test the strong hypothesis that trait anxiety and state anxiety are related to general attentional biases, not only to emotionally specific ones, we measured attentional functioning with emotionally neutral stimuli (Bishop, 2009). According to the literature, we would predict that the executive control network would be less effective in participants with high scores on measures of trait anxiety than in participants with low scores and that high state anxiety would predominantly activate bottom-up processes (orienting and alerting) as opposed to low state anxiety.

Experiment 1: Trait Anxiety and Attention

Method

Participants. Forty-eight psychology students (age: 17–32 years; 43 females and 5 males) were selected to participate in the study for course credit. The selection criterion was their score in the Spanish version of the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch & Lushene, 1970/1982).[2] Twenty-four participants were in the high-trait-anxiety group (score $\geq$ 34, 80th percentile), and 24 were in the low-trait-anxiety group (score $\leq$ 14, 15th percentile). Informed consent was obtained from all participants before the task.

Procedure. The ANT-I task (Callejas et al., 2004) was administered to both groups. This task combines a spatial cuing paradigm with a flanker procedure. On a computer screen, a plus sign appeared as a fixation point for 400 to 1,600 ms. In half the trials, an alerting tone was then presented for 50 ms. After 400 ms, for two thirds of the trials, an asterisk was presented either above (for one third) or below (for one third) the fixation point for 50 ms. No asterisk was presented in the remaining third of the trials. Then the asterisk disappeared, leaving only the fixation point. After 50 ms, an arrow, flanked by four distractor arrows (two on each side), appeared. The distractors pointed either in the same direction (i.e., congruent trial) or in the opposite direction (i.e., incongruent trial) as the central arrow target. Participants indicated the direction that the target was pointing (either right or left) by hitting one of two keys. The sequence of events in the task can be seen in Figure 1.

After completing the ANT-I task, participants filled out the Trait Anxiety subscale again to ensure that they had been assigned to the appropriate group. Also, mood was evaluated with the Escala de Valoración del Estado de Ánimo [The Mood Evaluation Scale] (EVEA; Sanz, 2001), to control for State Anxiety.[3] Debriefing followed.

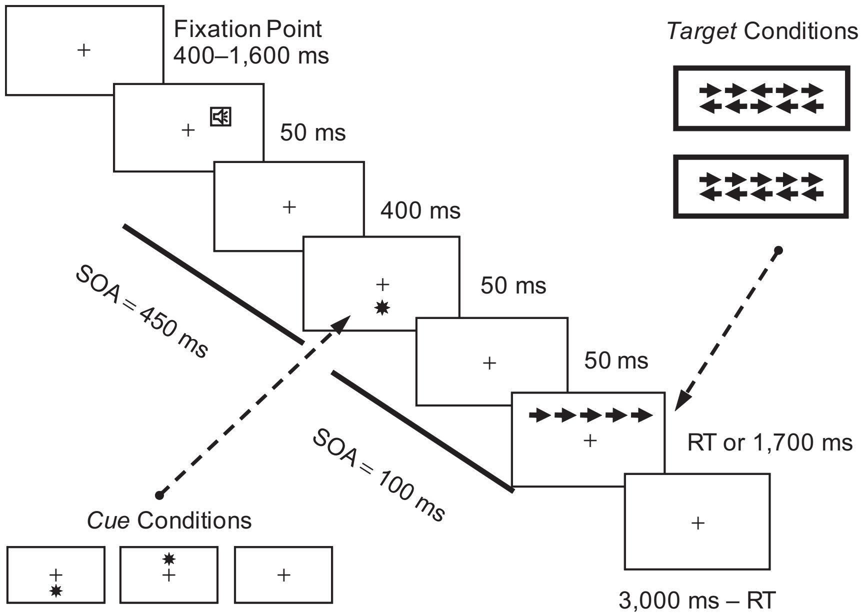

Fig. 1. Sequence of events for each trial of the attention network test—interactions, for Experiments 1 and 2. For each trial, a plus sign was presented on a computer screen as a fixation point for 400 to 1,600 ms. On half the trials, an alerting tone was then presented for 50 ms. After 400 ms, for two thirds of the trials, an asterisk cue was presented either above (for one third) or below (for one third) the fixation point for 50 ms. Then the asterisk disappeared, leaving only the fixation point. After 50 ms, an arrow, flanked by four distractor arrows (two on each side) appeared. The distractors pointed either in the same direction as the central arrow target (i.e., congruent trial) or in the opposite direction (i.e., incongruent trial). Participants indicated the direction that the target was pointing (either right or left) by hitting one of two keys. After the response, the fixation point was presented for up to 3,000 ms. RT = reaction time; SOA = stimulus onset asynchrony.

Design. The experiment featured a mixed design with group (high vs. low trait anxiety) as a between-groups factor and alerting (presence vs. absence of tone), orienting (no-cue vs. cued vs. uncued trials), and congruency (congruent vs. incongruent) as within-group factors.

Results and discussion

Two unifactorial analyses of variance (ANOVAs) were carried out with the Trait Anxiety scores for both groups as the dependent variable. One analysis (the preanalysis) included the STAI scores gathered before the experiment, and the other (the postanalysis) included those obtained after the experiment. The main effect of group was significant in both analyses, $F(1, 46) = 1068.56$, $p < .0001$, $\eta_p^2 = .96$, and $F(1, 46) = 187.23$, $p < .0001$, $\eta_p^2 = .80$, for the pre- and postanalyses, respectively). These results demonstrated the existence of a greater anxiety level in the high- than in the low-trait-anxiety group. Table 1 provides the mean reaction times (RTs) and error rates in all conditions.

Reaction time analysis. Mean RTs per experimental condition were introduced into a 2 (group) × 2 (alerting) × 3 (orienting) × 3 (congruency) factorial mixed measures analysis of covariance (ANCOVA), introducing the Anxiety score on the EVEA as a covariate.

In keeping with the results of Callejas et al. (2004; Callejas, Lupiáñez, Funes, & Tudela, 2005), the main effect of each within-participants variable was significant, as were the interactions between alerting and congruency, alerting and orienting, and orienting and congruency. None of these interactions were, however, modulated by group.

Crucial for our hypothesis was the modulation of the congruency effect by trait-anxiety group, $F(1, 45) = 12.83$, $p = .0008$, $\eta_p^2 = .22$. Although participants in both groups were slower with incongruent flankers ($p < .0001$), those in the high-anxiety group showed a greater interference effect (i.e., difference between incongruent and congruent trials) than those in the low-anxiety group (mean RTs: 101 ms vs. 76 ms respectively).

Attentional index analysis. Following Callejas et al. (2004), we computed an efficiency index for each attentional network with the following RT subtractions: alerting = no-tone and tone conditions (restricted to the no-cue condition), orienting = uncued and cued trials, and executive control = incongruent and congruent trials.

Table 1. Mean Reaction Times and Error Rates for Each Experimental Condition of Experiments 1 and 2

Group and congruency condition	Without alerting tone						With alerting tone					
	No cue		Cued		Uncued		No cue		Cued		Uncued	
	RT	Error rate	RT	Error rate	RT	Error rate	RT	Error rate	RT	Error rate	RT	Error rate
Experiment 1												
High trait anxiety												
Congruent	577 (67.24)	.012	538 (67.92)	.000	569 (66.79)	.006	534 (68.09)	.007	510 (62.88)	.000	561 (73.71)	.003
Incongruent	659 (93.35)	.013	618 (90.82)	.008	687 (109.19)	.025	645 (91.57)	.022	599 (80.79)	.018	687 (98.18)	.035
Low trait anxiety												
Congruent	573 (58.95)	.003	517 (52.01)	.005	554 (51.98)	.005	536 (56.45)	.003	503 (54.82)	.001	548 (51.79)	.005
Incongruent	622 (62.13)	.013	589 (56.43)	.008	654 (70.35)	.032	605 (49.21)	.010	569 (54.77)	.011	649 (50.02)	.040
Experiment 2												
Negative mood induction												
Congruent	613 (71.02)	.005	564 (67.85)	.005	602 (74.59)	.006	557 (70.21)	.007	533 (63.26)	.005	590 (65.94)	.008
Incongruent	670 (72.71)	.023	636 (70.99)	.027	699 (75.36)	.043	641 (64.76)	.048	606 (64.87)	.023	703 (66.11)	.070
Positive mood induction												
Congruent	598 (77.85)	.007	563 (88.92)	.006	586 (79.30)	.006	549 (85.32)	.006	524 (77.38)	.008	569 (80.18)	.003
Incongruent	661 (100.34)	.033	637 (103.93)	.033	684 (100.33)	.051	644 (96.82)	.025	609 (98.52)	.033	691 (97.10)	.060

Note: Reaction times (RTs) are in milliseconds. Standard deviations are given in parentheses.

We subsequently carried out a mixed-measures ANCOVA, with the variable network (functional index for each attentional network) as a within-participants variable and group as a between-groups factor. Again, state anxiety was introduced as a covariate. The Group × Network interaction was significant, $F(2, 90) = 4.42$, $p = .0147$, $\eta_p^2 = .09$, indicating that although groups did not differ on the alerting and orienting indices (both Fs < 1), they did differ on the executive control network index, $F(1, 45) = 12.83$, $p = .0008$, $\eta_p^2 = .22$, as shown in Figure 2. In contrast, the interaction between state anxiety and network was not significant, $F(2, 90) = 1.22$, $p = .2929$, $\eta_p^2 = .03$.

Results showed that high-trait-anxiety participants had greater difficulties than low-trait-anxiety participants in controlling interference (see also Pacheco-Unguetti, Lupiáñez, & Acosta, 2009). However, the functioning of alerting and orienting networks was equivalent in both groups. Note that this greater difficulty of high-trait-anxiety participants in inhibiting distractor information or in favoring the relevant target seems to be general or structural, because no affective stimuli were presented.

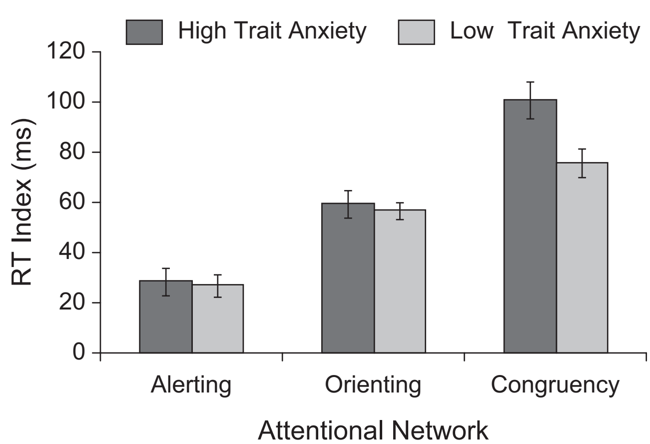

Fig. 2. Results of Experiment 1: reaction time (RT) indexes of the three attentional networks as a function of participant group (high trait anxiety or low trait anxiety). Error bars represent standard errors of the mean.

Experiment 2: State Anxiety and Attention

Method

Participants. Sixty-six psychology students (age: 17–28 years; 57 females and 9 males) were selected on the basis of their scores on the STAI Trait scale (inclusion criteria: scores between 14 and 32; average score: 21).

Procedure. Participants were randomly assigned to one of two groups on arrival to the testing site: anxious-mood induction and nonanxious-mood induction. Informed consent was obtained from all participants before the task.

To check the actual effect of mood induction, participants filled out the State subscale of the STAI questionnaire before and after mood induction in the same room where the experimental task was carried out. Once the inventory was filled out for the first time, participants were informed that they would see a series of pleasant or unpleasant pictures (depending on the group) and that their task was to get emotionally involved.

The mood-induction procedure consisted of two sets of 10 pictures, each presented through Microsoft Office PowerPoint and accompanied by a brief text. The pictures were drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Normative ratings on valence and arousal obtained for the Spanish population (Vila et al., 2001) were used to configure both picture sets. One set of pictures had positive emotional content (i.e., couples, babies, or landscapes), and another had negative emotional content (i.e., mutilations, victims of natural disasters, or violence). The mean valence values were 7.9 and 1.9, respectively (IAPS values range from 1 to 9).

The text associated with each image was presented for 6 s before the appearance of the picture and remained on the screen for a total of 12 s. In the anxious-mood-induction set, the verbal information emphasized the lack of control over the negative circumstances represented in the picture (e.g., a picture of a person with a slit throat and the following text: “No one is free from danger. Anyone can be a victim of crime and violence”). In the nonanxious-mood-induction set, the material referred to goal achievement (e.g., picture of a medal ceremony with this text: “When we achieve our goal we feel reinforced. There are always personal achievements in our life”). After the mood induction, participants filled out the STAI State subscale again and then completed the same experimental task as in Experiment 1.

Design. The design and dependent variables were the same as in Experiment 1, with the exception that the between-groups variable was now mood induction.

Results and discussion

Two participants in the anxious-mood-induction group were eliminated because of a large number of errors. A comparison of the STAI State subscale scores obtained before and after the mood induction yielded significant differences for each group, $F(1, 62) = 103.01$, $p < .0001$, $\eta_p^2 = .62$. As expected, prelevels were similar for both the anxious- and the nonanxious-mood-induction groups (13.90 vs. 15.36, respectively), $F(1, 62) = 0.59$, $p = .44$, $\eta_p^2 = .009$, but postlevels were higher in the anxious- than in the nonanxious-mood-induction group (32.97 vs. 12.39, respectively), $F(1, 62) = 106.07$, $p < .0001$, $\eta_p^2 = .63$, showing the effectiveness of our procedure. Table 1 provides the mean RTs and error rates in all conditions.

Reaction time analysis. Analyses similar to those performed in Experiment1 were carried out. Again, the same main effects and interactions between networks originally reported by Callejas et al. (2004) were replicated (see Table 1). Therefore, specific analyses were performed on the attentional indexes, to test whether mood induction differentially modulated the functioning of each attentional network.

Attentional index analysis. Indexes were computed as in Experiment 1. Scores on the STAI Trait subscale were introduced as a covariate in the analyses. Again, the Group × Network interaction was significant, $F(2, 122) = 4.13$, $p = .0183$, $\eta_p^2 = .06$, whereas the interaction between STAI Trait and network was not, $F(2, 122) = 1.01$, $p = .3667$, $\eta_p^2 = .02$. Analyses showed no differences between state anxiety groups regarding executive control ($p > .2$). In contrast, significant differences between groups were observed in alerting, $F(1, 61) = 6.93$, $p = .0107$, $\eta_p^2 = .10$, and orienting, $F(1, 62) = 4.91$, $p = .0305$, $\eta_p^2 = .07$. As shown in Figure 3, the anxious-mood-induction group showed greater alerting effects (43 ms vs. 32 ms) and orienting effects (64 ms vs. 49 ms) than the nonanxious-mood-induction group.

Our mood-induction procedure was effective, as shown by the STAI pre- and postscores. More important, performance on the ANT-I task showed that contrary to trait anxiety, which seems to be related to an impoverished functioning of the executive control network, state anxiety is related to greater orienting and alerting effects, thus making participants more sensitive to bottom-up processing.

General Discussion

Both experiments indicate that anxiety significantly modulates the functioning of the attentional networks. As predicted, Experiment 1 showed that for high-trait-anxiety participants, anxiety had more of an effect, causing them to have more difficulty responding to the experimental task’s demands. Because this difference was more pronounced in the incongruent condition, it is reasonable to think that the executive systems of high-trait-anxiety participants were less efficient than those of the low-trait-anxiety participants. Most important, no processing of affective information was required, so it can be inferred that the nature of this impoverished attentional control is more structural and stable than circumstantial (Bishop, 2009; see also Ansari, Derakshan, & Richards, 2008).

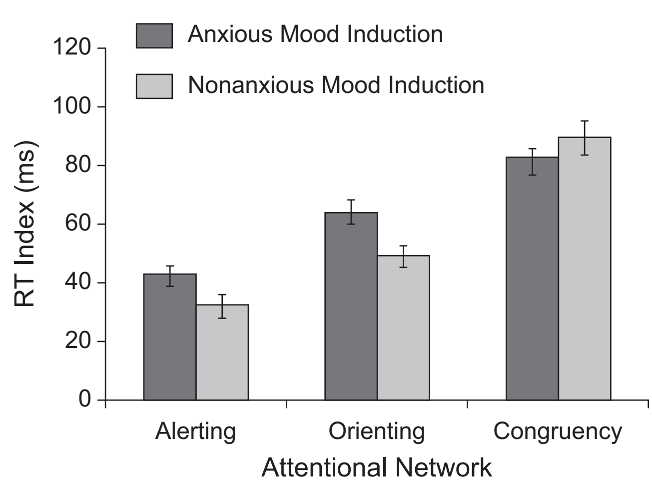

Fig. 3. Results of Experiment 2: reaction time (RT) indexes of the three attentional networks as a function of participant group (anxious-mood-induction condition or nonanxious-mood-induction condition). Error bars represent standard errors of the mean.

As shown in Experiment 2, state anxiety also modulates attention. However, it specifically affects the alerting and orienting networks. The situational nature of this type of anxiety affects those attentional networks that are more prone to be influenced by contextual sensitivity or vigilance processes, which improve receptivity on the basis of the salience or relevance of the stimulation.

Our results are in line with recent findings regarding the dissociation between trait anxiety and state anxiety in a functional imaging study (Bishop, Jenkins, & Lawrence, 2007). Participants searched for an *X* or an *N* in a six-letter string under either low or high perceptual load (low perceptual load: all letters in the string were the same; high perceptual load: the target letter was embedded among nontarget letters). Letters appeared superimposed on a background of neutral or fearful faces. Results showed that under high perceptual load, brain activations were similar regardless of anxiety levels and valence of distractor faces. However, under low-perceptual-load conditions, when face distractors were fearful, high state anxiety was associated with a heightened response in the amygdala and superior temporal sulcus (STS), whereas high trait anxiety was related to a reduced prefrontal response. That is, participants with high state anxiety activated regions associated with the assessment of the valence of facial expression (amygdala and STS), but those with high trait anxiety showed reduced activity in regions associated to control processes. A later study in which no emotional material was used showed again a reduced prefrontal activation in high trait anxiety (Bishop, 2009), thus supporting our conclusion that trait anxiety, but not state anxiety, is associated with a reduced general cognitive control capacity.

It is possible that the attentional biases previously reported in the literature for anxious participants were a mixture of both mechanisms that would be more or less involved depending on the nature of the task and the valence of the stimuli used. Hence, the mechanisms proposed by Bishop et al. (2007; see also Bishop, 2009) could be useful to interpret these and our results. The modulation that trait anxiety exerts on the executive control network could be better understood as an impoverished level of activity in the prefrontal cortex. This proposition is supported by a review article by Bush, Luu, and Posner (2000), in which they concluded that the anterior cingulate gyrus and the lateral prefrontal cortex are involved in the detection and autoregulation of both cognitive and emotional material. Alternatively, the modulation of state anxiety on the alerting and orienting networks could be explained by the activation of the amygdala and other cerebral areas involved in threat evaluation, which continued in our Experiment 2 even after the induction procedure concluded. Therefore, trait anxiety would modulate top-down processes, whereas state anxiety would be more related to bottom-up processes.

In a similar fashion, Eysenck et al. (2007) differentiated between an attentional system involved in top-down control and another one in charge of bottom-up control. They suggested that anxiety alters the equilibrium between both systems by lowering the influence of the former and increasing that of the latter and that this attentional deterioration will occur even when non-threat-related task-irrelevant stimuli are presented. The results we report in this article not only support this distinction but also shed light on the tight link between high trait anxiety and the damage to processes involved in top-down control, on the one hand, and high state anxiety and the alteration in processes involved in bottom-up control, on the other hand.

In summary, our results outline the mechanisms that could be involved in the relationship between anxiety and attention. The dissociation between trait anxiety and state anxiety is useful for understanding the ways anxiety influences attentional processes, and it emphasizes the need to not only study the modulations exerted by circumstantial factors such as emotional states but also the structural ones such as affective personality traits.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interests with respect to their authorship and/or the publication of this article.

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Notes

1. For a free copy of the E-Prime program to run the ANT-I, contact Juan Lupiáñez (jlupiane@ugr.es) or Alicia Callejas (callejasa@npg.wustl.edu).
2. The Spanish version of the STAI includes 20 items, each scored from 0 to 3, so that the total varies from 0 to 60, rather than from 20 to 80, as in the English version. The alpha coefficients of the scale are .92 for State Anxiety and .84 for Trait Anxiety.
3. The EVEA is a scale with four factors: Fear-Anxiety, Anger-Hostility, Sadness-Depression, and Joy-Happiness. The alpha coefficients for these factors fluctuate from .88 to .93. The correlation between the Anxiety factor of the EVEA and STAI-State was .81 in a sample of 350 participants. The EVEA includes only 16 items (adjectives referring to mood states; 4 for each factor), which are evaluated in a Likert scale (ranging from 0 to 10). The alpha coefficient of the Anxiety factor is .92.

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