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Can auditory deviant stimuli temporarily suspend cognitive processing? Evidence from patients with anxiety

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While anxiety is typically thought to increase distractibility, this notion mostly derives from studies using emotionally loaded distractors presented in the same modality as the target stimuli and tasks involving crosstalk interference. We examined whether pathological anxiety might also increase distractibility for emotionally neutral irrelevant sounds presented prior to target stimuli in a task where these stimuli do not compete for selection. Patients with anxiety and control participants categorized visual digits preceded by task-irrelevant sounds that changed on rare trials (auditory deviance). Both groups exhibited an equivalent increase in response times following a deviant sound but patients showed a reduction of response accuracy, which was entirely due to an increase in response omissions. We conclude that the involuntary capture of attention by unexpected stimuli may, in patients with anxiety, result in a temporary suspension of cognitive activity.

Keywords: Deviance distraction; Auditory–visual oddball task; Deviant sounds; Pathological anxiety.

Evidence indicates that the unexpected presentation of a sound deviating from a repeated or otherwise structured sequence of irrelevant sounds captures attention and triggers the involuntary orienting of attention toward the deviant sound (e.g., Berti, 2008; Schröger, 1996, 1997, 2007; Schröger & Wolff, 1998a, 1998b). Increasing evidence demonstrates that this effect marks the detection of a violation of the cognitive system's predictions or forward models by unexpected incoming stimuli (Bendixen & Schröger, 2008; Bendixen, Schröger, Ritter, & Winkler, 2012; Berti, 2012; Parmentier, Elsley, Andrés, & Barceló, 2011; Schröger, Bendixen, Trujillo-Barreto, & Roeber, 2007). In a context in which participants are performing and must maintain their focus on an ongoing primary task, this distraction effect is reflected in a reduction of response

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accuracy (e.g., Escera, Alho, Winkler, & Näätänen, 1998; Schröger, 1996), an increase in omissions (Parmentier, Maybery, & Elsley, 2010), or the lengthening of response times (e.g., Parmentier, 2008; Parmentier, Turner, & Perez, 2014; Schröger, 1996). Deviance distraction is thought to involve both bottom-up and top-down mechanisms. Attention capture is initially triggered by the detection of the mismatch between an incoming sensory input and the cognitive system's predictions (Bendixen et al., 2010; Schröger et al., 2007). However, following this capture, the reorientation of attention toward the task at hand is thought to invoke top-down influences (e.g., the reactivation of task goals in working memory; Berti, 2008). Furthermore, recent work indicates that deviance distraction can be reduced through cognitive control when participants are given cues announcing the imminent presentation of the deviant sound or as a function of the warning value of the sounds (Parmentier & Hebrero, 2013; Sussman, Winkler, & Schröger, 2003).

Deviance distraction is thought to reflect some fundamental attention mechanisms. Yet its sensitivity to certain disorders thought to affect cognition remains overall poorly specified. For example, there has been no examination of deviance distraction in patients with anxiety disorders even though this prevalent class of disorders is typically viewed as enhancing distraction, as described below.

Anxiety and anxiety disorders have been traditionally linked to a greater susceptibility to distraction by external or internal stimuli (Eysenck, Derakshan, Santos, & Calvo, 2007). By and large, past studies typically sought to examine the distinctive sensitivity or attentional bias towards negative, often threat-related, stimuli exhibited by anxious individuals (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007, for a review). Such negative stimuli impair cognitive performance when used as distractors (Derryberry & Reed, 2002) but are detected and processed more rapidly than neutral stimuli when used as target stimuli (Öhman, Flykt, & Esteves, 2001), reflecting an attentional bias toward negative information thought to play an important role in anxiety disorders (see MacLeod & Mathews, 2012, for a review). Interestingly, akin to what is observed with deviance distraction, top-down control is thought to be required in order to reduce distraction. The distractive effect of negative stimuli compared to neutral ones appears to reside in the greater difficulty in disengaging from the negative stimuli (Derryberry & Reed, 2002). Sheppes, Luria, Fukuda, and Gross (2013) recently reported that individuals with low and high trait-anxiety show similar levels of attentional engagement for threat-related stimuli but that high-anxiety participants show a comparatively less efficient disengagement from these, arguably because anxious participants typically exhibit reduced attentional control and regulatory abilities (Derryberry & Reed, 2002; Eysenck et al., 2007).

Whilst the vast majority of research on anxiety and anxiety disorders has been focused on the attentional bias toward threat-related stimuli, some work suggests that anxiety entails more general attentional dysfunctions that are not specific to negative stimuli but also apply to neutral ones (Berggren & Derakshan, 2014; Bishop, 2009). For example, in a study measuring alerting, orienting, and executive control and using neutral stimuli, Pacheco-Unguetti, Acosta, Callejas, and Lupiáñez (2010) found that executive control was mediated by trait-anxiety while alerting and orienting were mediated by state-anxiety. Interestingly, Pacheco-Unguetti, Acosta, Marqués, and Lupiáñez (2011) found that patients with anxiety disorders exhibited a reduced executive control and a greater difficulty in disengaging attention from neutral distractors. These findings can be explained as an imbalance between the top-down and bottom-up attention control systems, as is proposed in the attention control theory of anxiety (Eysenck et al., 2007).

While some evidence suggests that anxiety fundamentally alters attentional functions, as demonstrated in studies using emotionally neutral stimuli, it is important to note that this evidence relies on tasks in which both distractors and targets were presented in the same modality, namely the visual modality, and typically in tasks in which irrelevant and relevant information compete for selection. One can argue that a stronger test of whether distraction is enhanced by anxiety would be one using a task in which participants were required to ignore one sensory modality to focus on another and in which distractors and targets are also temporally separated, such as in the auditory–visual oddball task in which participants categorize visual targets preceded by some task-irrelevant auditory stimulus (e.g., Escera et al., 1998; Parmentier, Elford, Escera, Andrés, & San Miguel, 2008; Parmentier & Kefauver, 2015). Such conditions mean that participants do not have to voluntarily process distractors in order to discriminate them from targets and have the option of shutting down all stimuli from the distractors' modality. Evidence from oddball studies with participants with anxiety disorders produced mixed results, with some reporting an increased orienting response to oddball stimuli and others not (see Javanbakht, Liberzon, Amirsadri, Gjini, & Boutros, 2011, for a review). Critically, however, past oddball studies required participants to respond to rare targets and ignore other sounds instead of ignoring all sounds and focusing on visual targets. These studies focused the electrophysiological response to deviant sounds but, by design, did not allow the measurement of behavioural deviance distraction.

In this study, we sought to examine whether anxiety increases distraction by deviant sounds. To do so we compared patients with pathological anxiety (anxiety disorder or adjustment disorder with anxious mood) and matched controls without anxiety history in a cross-modal oddball task in which they categorized visual digits while ignoring task-irrelevant sounds. None of our stimuli, targets, or distractors were emotionally loaded. We predicted that patients should be more sensitive to deviance distraction because (a) deviance distraction invokes both bottom-up (involuntary capture of attention by deviant stimuli) and top-down (voluntary refocusing of attention on the primary task) processes (Berti, 2008), and anxiety is thought to disrupt the balance between these mechanisms by reducing executive control functioning and increasing stimulus-driven orienting (Pacheco-Unguetti et al., 2010, 2011), and (b) because anxiety disorders render attentional disengagement from a distractor less efficient (Pacheco-Unguetti et al., 2011).

EXPERIMENTAL STUDY

Method

Participants

Sixteen patients (mean age = 32 years, $SD = 7.60$, range = 19–50; 8 females) diagnosed with anxiety disorder or adjustment disorder with anxious mood (as defined by the diagnostic criteria of *Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition, Text Revision, DSM–IV–TR*; American Psychiatric Association, 2000) were included in this study. They were recruited and tested immediately after their clinical assessment and prior to treatment. Sixteen control participants matched in sex, age, computer skills, and education level (mean age = 32 years, $SD = 7.62$, range = 20–51; 9 females) reporting no history of pathological anxiety were also tested. All participants had normal or corrected-to-normal vision and were naive as to the purpose of the experiment. Informed consent was obtained from all participants prior to the task, and they did not receive any payment for taking part in the experiment. The experiment was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and was approved by the ethical committee of the Department of Psychology at the University of the Balearic Islands.

Questionnaires

All participants completed two questionnaires: the State subscale of the State–Trait Anxiety Inventory (STAI–SA; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and the Scale for Mood Assessment (EVEA; Sanz, 2001). The STAI–SA measures the individual's level of transient anxiety. This subscale contains 20 items describing symptoms on a 4-point Likert scale ranging from 0 to 80. The EVEA includes 16 items (adjectives referring to mood states) with four factors evaluated with Likert scales ranging from 0 to 10: Fear–Anxiety, Anger–Hostility, Sadness–Depression, and Joy–Happiness (see Sanz, Gutiérrez, & García-Vera, 2014, for a review of the psychometric properties of the EVEA).

Oddball task

Two 200-ms-long sounds were used throughout the experiment. The standard sound was a 600-Hz sinewave tone. The deviant sound was a burst of white noise. Both sounds were normalized by maximizing their intensity in the digital sound file and were edited to include 10-ms rise and fall ramps. Sounds were delivered binaurally through headphones at an intensity of approximately 70 dB(SPL).

Each trial involved the presentation of a sound followed by a visual digit (in white colour against a black screen) with a sound-to-digits stimulus onset asynchrony of 250 ms. Digits appeared for 200 ms at the centre of the screen and subtended an angle of approximately 2.6°, temporarily replacing the fixation cross otherwise always visible at the centre of the screen. Upon the digit's offset, the fixation cross reappeared for 700 ms, during which participants were required to press a key to categorize each digit as quickly as possible while trying to make no error. The task was programmed to record responses within a response window of 1000 ms starting from the digit's onset and running 100 ms into the next trial. The experiment took place in a sound-attenuated room and took approximately one hour to complete.

Participants completed two blocks of 180 test trials each. In each block, the digits 1–6 were used equally often in each of the two sound conditions (standard, deviant). The standard sound was used in 80% of trials, and the deviant sound in the remaining 20%, arranged in a random sequence (different for every participant and block) with the constraint that deviant sounds were never presented on subsequent trials. Participants categorized the digits as odd or even using the V and B keys on the computer keyboard (the mapping of key to response being counterbalanced across participants). Each block was preceded by 12 practice standard trials that were not included in the data analysis.

Procedure

The oddball task was administered individually to all participants under dimly lit conditions and in one session that lasted approximately 30 min. Informed consent was obtained from all participants before the task. All participants were asked to fill out the state subscale of the STAI and the EVEA questionnaires before the oddball task, with the explicit instruction to indicate how they felt at that moment. Participants were then given written and oral instructions regarding the cross-modal oddball task and emphasizing the need to respond as quickly as possible while trying to make no error.

Results

Questionnaire data

Control participants and patients were compared on each of our questionnaire measures (see Table 1). As expected, patients with anxiety disorders scored higher than controls on the two anxiety scales [STAI: $t(30) = 3.721$, $p < .001$; EVEA Fear–Anxiety: $t(30) = 2.373$, $p = .024$]. The two groups did not differ with respect to hostility [EVEA Anger–Hostility: $t(30) = 1.546$, $p = .133$] but controls scored higher than patients in happiness [EVEA Joy–Happiness: $t(30) = 4.069$, $p < .01$]. Finally, patients scored higher than controls on the depression measure [EVEA Sadness–Depression: $t(30) = 2.348$, $p < .05$].

Performance in the oddball task

Performance was examined using 2 (group: control vs patients) × 2 (sound condition: standard vs deviant) analyses of variance (ANOVAs) for mixed designs for each of three dependent variables: the mean proportion of correct responses, the mean proportion of omissions, and the mean response latency (measured from the visual target's onset).

The analysis of the proportion of correct responses confirmed the overall high levels of response accuracy in the simple parity judgement task. No main effect of group or sound condition was found [$F(1, 30) = 1.599$, $MSE = .027$, $\eta_p^2 = .051$, $p = .216$; $F(1, 30) = 2.529$,

Table 1. *Mean questionnaire scores in patients and control participants*

		EVEA			
Group	*STAI***	*Fear–Anxiety**	*Anger–Hostility*[ns]	*Sadness–Depression**	*Joy–Happiness***
Patients	43.37 (10.67)	2.98 (2.49)	1.21 (1.50)	2.62 (2.20)	4.65 (2.02)
Controls	30.06 (9.53)	1.28 (1.42)	0.50 (1.09)	1.01 (1.63)	7.56 (2.01)

Note: EVEA = Scale for Mood Assessment. Values in parentheses represent one standard deviation.
$^{*}p < .05$. $^{**}p < .001$. *ns* = nonsignificant.

$MSE = .002$, $\eta_p^2 = .078$, $p = .122$, respectively]. However, the Group × Sound Condition interaction was significant, $F(1, 30) = 7.338$, $MSE = .002$, $\eta_p^2 = .197$, $p < .05$, reflecting a negative effect of the deviant sound on accuracy in the patients (see Figure 1, Panel A). Contrasts confirmed this observation, revealing a significant difference between the deviant and standard conditions in patients, $F(1, 30) = 9.240$, $MSE = .002$, $p < .005$, $d = 0.23$, but not in controls, $F(1, 30) < 1$, $MSE = .002$, $p = .435$, $d = 0.64$.

The proportion of omissions was greater in the deviant condition than in the standard condition, $F(1, 30) = 9.515$, $MSE = .003$, $\eta_p^2 = .241$, $p < .005$, and greater in patients than in controls, $F(1, 30) = 5.013$, $MSE = .016$, $\eta_p^2 = .143$, $p < .05$. However, the increase in omissions induced by the deviant sounds was significantly greater in patients than in controls, as confirmed by a significant Group × Sound Condition interaction, $F(1, 30) = 6.154$, $MSE = .003$, $\eta_p^2 = .170$, $p < .05$ (see Figure 1, Panel B). Contrasts revealed no significant effect of sound condition for controls, $F(1, 30) < 1$, $MSE = .003$, $p = .672$, $d = 0.16$, but a significant effect in patients, $F(1, 30) = 15.487$, $MSE = .003$, $p < .001$, $d = 0.61$. Compared to control participants, patients produced the same amount of omissions in the standard condition, $F(1, 30) = 2.067$, $MSE = .006$, $p = .161$, $d = 0.54$, but more omissions in the deviant condition,[1] $F(1, 30) = 6.549$, $MSE = .127$, $p < .05$, $d = 0.97$. In order to assess the extent of the deviant sounds' impact on omissions, we analysed the number of successive omissions triggered by deviant sounds. To calculate this number, we measured how many trials went without a response from the presentation of a deviant sound. For example, if a participant failed to respond to a target on a deviant trial t and failed to produce a response on trials $t + 1$ and $t + 2$ but did respond on trial $t + 3$, the number of successive omissions was 3. Deviants triggered significantly more successive omissions in patients ($M = 1.056$, $SD = 0.539$) than in controls ($M = 0.733$, $SD = 0.467$), $t(30) = 3.007$, $p < .01$, $d = 0.66$.

Omissions arguably contributed to reduce response accuracy and might have been responsible for the Group × Sound Condition interaction observed for the proportion of correct responses. An F test comparing the two groups for deviance distraction (standard minus deviant) measured from the proportion of correct responses with

[1]Because our task allowed a limited time window for participants to respond (1000 ms), it is useful to ascertain that omissions did not constitute late and unrecorded responses. This issue is particularly relevant in patients and in the deviant condition where omissions were significantly more frequent. Several aspects of the data strongly indicate that omissions were not likely to reflect late unrecorded responses, however. First, if omissions represented the right tail of the reaction time (RT) distribution, such a hypothesis would require a shift of the distribution of RTs to longer values for patients (such that the tail of that distribution would fall outside the response window). As described in our Results section, such a shift was absent since patients were not slower than controls. Furthermore, the longest RT observed among our patients in the deviant condition was 900 ms, against 897 ms in controls. Finally, RTs ranging between 850 and 900 ms represented only 1.29% of the controls' responses and 1.54% of the patients' responses, with no difference between groups in this respect, $t(30) < 1$, $p = .72$. In summary, the evidence clearly indicates that the entire distribution of RTs fell well within the 1000-ms response window and that it is therefore reasonable to conclude that omissions did not represent late unrecorded responses.

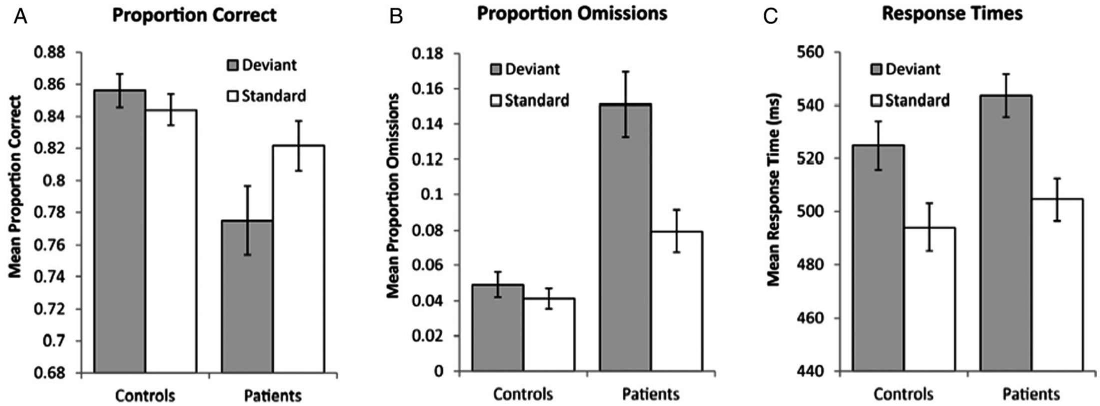

Figure 1. *Mean proportion of correct responses (Panel A), mean proportion of omissions (Panel B), and mean response times for correct responses (Panel C), for the standard and deviant conditions in patients with anxiety and control participants. Error bars represent one standard error of the mean.*

deviance distraction measured from omissions as a covariate revealed no significant difference, $F(1, 30) = 1.231$, $MSE = .002$, $\eta_p^2 = .041$, $p = .271$. In other words, the Group × Sound Condition interaction observed for the proportion of correct responses disappeared when controlling for omissions.

Finally, response latencies revealed a main effect of deviance distraction (greater reaction times, RTs, for deviant than standard trials), $F(1, 30) = 37.832$, $MSE = 504$, $\eta_p^2 = .558$, $p < .001$, but no main effect of group, $F(1, 30) < 1$, $MSE = 8685$, $\eta_p^2 = .031$, $p = .333$, or Group × Sound Condition interaction, $F(1, 30) < 1$, $MSE = 504$, $\eta_p^2 = .020$, $p = .441$ (see Figure 1, Panel C).

Discussion

The key aim of our study was to examine the extent to which patients with pathological anxiety exhibit behavioural distraction in a task involving emotionally neutral stimuli and in which distractors were segregated from target information both temporally and in terms of sensory modality. We used the cross-modal oddball task, a well-established task measuring the distractive effect of unexpected changes in a stream of task-irrelevant sounds on a visual categorization task. The results showed that patients and controls exhibited equivalent levels of distraction in terms of response times (longer response times following the deviant sound than the standard sound) and responded with the same speed overall. Remarkably, however, patients exhibited a specific reduction in the proportion of correct responses in the deviant condition while controls did not. Further analysis showed that this effect disappeared when controlling for omissions, which patients produced significantly more than controls and, importantly, more so in the deviant condition than in the standard condition. Our data also indicate that deviants had a longer lasting impact in patients (increasing the number of resulting consecutive omissions). In a nutshell, upon the presentation of the deviant sound, patients with anxiety disorders exhibited a greater tendency than controls to suspend behaviour. Remarkably, however, when they did respond, they did so with the same accuracy and speed as control participants.

Response accuracy is typically less sensitive to deviance distraction than response latencies (Parmentier, 2008, 2014). Few of the studies observing a reduction in response accuracy reported omission rates, and the importance of the latter is unclear: Some reported an increase in commission errors and not in omissions (Gumenyuk, Korzyukov, Alho, Escera, & Näätänen, 2004) while others reported no increase in such errors but an increase in omissions (Parmentier, Maybery, & Elsley, 2010). To our knowledge, our study is unique in reporting a selective increase on omissions by deviant sounds in the absence of any effect on response times. The absence of effect in response times rules out the possibility that the increase in omissions may have been due to patients taking so long to respond that the next trial would have begun before they produced their response. Put simply, deviant sounds appeared to yield, in patients and in a certain proportion of trials, some temporary suspension of cognitive functioning. Functionally, the data suggest that deviant sounds resulted in behavioural inhibition or stopping of actions. That performance was in every other way comparable to that of controls suggests that this suspension of responding may reflect the existence of an early threshold-type mechanism. When an unexpected stimulus is encountered, an early inhibitory mechanism may be triggered to stop ongoing behaviour until this stimulus is assessed. In the context of a laboratory experiment where participants know that no threatening stimuli will be encountered, those sounds should be ignored, and given our use of an emotionally neutral deviant sound, the threshold for behavioural inhibition would be high in control participants, thereby yielding no more response omissions in the deviant condition than in the standard. This threshold may be lower and noisier in patients, however.

The notion of a mechanism able to suspend behaviour in the face of unexpected stimuli is interesting in at least two respects. First, it constitutes a new development in our understanding of deviance distraction, for past studies have not contemplated the existence of such a system. Second, it provides a relatively simple explanation of the unique pattern of data observed in our patients. Interestingly, our proposition of an early mechanism able to interrupt and suspend ongoing behaviour fits with Gray's biopsychological theory of personality and more specifically the contention of a behavioural inhibition system (BIS; Gray, 1982). According to Gray's theory, the BIS responds to threatening stimuli but also to novel or unexpected ones by inhibiting goal-directed cognitive processing and thereby response production. Some evidence does support the view of a heightened early sensory sensitivity to unexpected sounds. For example, novel sounds yield greater N1 response than standard sounds in typically developing children with high trait anxiety compared to children with low trait anxiety (Hogan, Butterfield, Phillips, & Hadwin, 2007).

Support for the notion of a system able to stop responses can also be found in the notion of a "circuit breaker" (Corbetta, Patel, & Shulman, 2008). According to these authors, attentional orienting is controlled in humans by two interacting systems. One, dorsolateral, underpins goal-directed processing (e.g., activation of stimulus–response mappings). The other, ventral, detects stimuli outside the focus of attention and serves as a circuit breaker to interrupt ongoing cognitive processes and allow the shift of attention toward unexpected stimuli. This notion echoes the proposition of a global suppression system responsible for blocking all motor output in order for new information to be sampled (Wiecki & Frank, 2013; see Verbruggen, McLaren, & Chambers, 2014, for a discussion of action control). We propose that this "circuit breaker" may correspond to the threshold-based system that we described above and that pathological anxiety essentially enhances its stopping on ongoing behaviour, potentially using mechanisms at play when actions must be suspended and a "stop response" selected (e.g., Verbruggen, Aaron, Stevens, & Chambers, 2010; Verbruggen, MacLaren, & Chambers, 2014). This proposition fits well with the recent suggestion that this circuit breaker is triggered by novel sounds. Indeed, Wessel and Aron (2013) showed that the brain activity corresponding to action stopping in a stop signal task is also observed in response to novel sounds in an auditory–visual oddball task, especially so when novel sounds yielded significant response time delays. Furthermore, using transcranial magnetic stimulation and measuring corticospinal excitability, these authors demonstrated that novel sounds have a general motor suppressive effect.

In sum, the selective increase in response omission observed in our patients in response to the deviant sound suggests the more frequent and stronger activation of an early inhibitory system suspending behaviour, compatible with the Gray's BIS (Gray, 1982) or the notion of a circuit breaker (Corbetta & Shulman, 2002; Wessel & Aron, 2013).

One further aspect of our results worth commenting on is the fact that our patients scored higher than control participants on the EVEA Sadness–Depression subscale. This is not unexpected, since anxiety, even when identified as main diagnostic, is sometimes accompanied by signs of depressed mood. Although the patients' scores on the EVEA Sadness remain below the threshold for clinical depression, these scores must be considered carefully, since Pacheco-Unguetti and Parmentier (2014) recently reported that sadness (an emotion typically reported by depressed patients) significantly increases deviance distraction. To discard the possibility that the increase in distraction caused by the deviant sounds in our patients may reflect the effect of a subclinical depressive mood rather than that of anxiety disorders, we carried out further analyses aimed to examine whether the difference in distraction between our groups (measured from the proportion of correct responses and from the proportion of omissions) remained significant when controlling for depressed mood (using the score from the EVEA Sadness–Depression). These analyses confirmed that, even when controlling for the sadness–depression score, distraction by deviant sounds was greater in patients than in controls.[2] In other words, our findings cannot be attributed to differences in sadness–depression scores between our controls and patients.

Finally, it is useful to indicate that deviance distraction is not to be confounded with an acoustic startle response (ASR). The ASR is a protective response to sudden or threatening stimuli and is typically observed after a "brief (e.g., 40 ms) burst of white noise with an abrupt onset and an intensity ranging from 90 to 115 A-weighted decibels dBA" (Grillon, 2002, p. 960). In contrast, our deviant sound was comparatively long (200 ms), its intensity was ramped, and it was presented at a level well below that intensity range required to induce an ASR. Furthermore, there is evidence indicating that the ARS is reduced when the startling stimulus is presented in a sensory modality different to that attended by participants (Silverstein, Graham, & Bohlin, 1981). In addition, when the ASR is elicited while participants are performing a task, responses in that task are either speeded up—not delayed (e.g., Carlsen, Chua, Inglis, Sanderson, & Franks, 2003; Carlsen, Dakin, Chua, & Franks, 2007)—or remain unaffected, as summarized by Lang, Davis, and Ömhan (2000): "The acoustic stimulus used to evoke the blink is relatively modest—typically a 50-ms burst of white noise at around 95 dB, which, while prompting a clear blink response, rarely interferes with ongoing foreground tasks" (p. 142). In contrast, deviant sounds systematically delay responses in the ongoing visual task (Parmentier, 2014). In sum, we argue that the distraction induced by our deviant sound cannot be attributed to an ASR. What we cannot rule out, however, is that our patients may have, compared to our control participants, subjectively perceived the deviant sound (white noise) as more unpleasant or threatening. For example, there is evidence from the visual domain that neutral distractors can be perceived as more threatening to highly anxious individuals than to individuals with low anxiety (e.g., Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). It is questionable, however, whether a short burst of white noise well below the intensity level required to induce an ASR would be perceived as threatening by participants (even if these suffer from some anxiety disorder).

[2]The distraction effect was measured for the proportion of correct responses (standard minus deviant) and for the proportion of omissions (deviant minus standard). Both measures were subjected to an analysis of covariance (ANCOVA) with the group as between-subjects factor and the score on the EVEA Sadness–Depression as covariate. The ANCOVA on the proportion correct revealed no significant effect of the covariate, $F(1, 29) < 1$, $MSE = .004$, $\eta_p^2 = .018$, $p = .473$, while performance remained significantly better in the controls than in the patients, $F(1, 29) = 4.771$, $MSE = .004$, $\eta_p^2 = .141$, $p < .05$. A similar analysis carried out on the proportion of omissions revealed similar findings: no effect of the covariate, $F(1, 29) < 1$, $MSE = .005$, $\eta_p^2 = .007$, $p = .645$, while the difference between controls and patients remained significant, $F(1, 29) = 4.274$, $MSE = .005$, $\eta_p^2 = .128$, $p < .05$.

Because we did not ask our participants to rate the subjective threatening value of our deviant sound, we cannot rule this possibility out, and future work should report such a measure. However, even under the hypothesis that patients with anxiety disorders might perceive the deviant sound as more unpleasant or threatening, this would not necessarily imply that it caused the increase in response omissions that we observed. Indeed, the emotional appraisal of a sound may be independent from its impact on behaviour. It may even be that the subjective ratings are influenced by the commission of omissions (individuals attributing unpleasantness to the sound because it perturbed their performance).

In conclusion, compared to control participants, patients with anxiety showed a reduction of performance in the visual task following the presentation of the deviant sound but this reduction consisted in a greater number of response omissions. Performance was equivalent in the patient and control groups in all other respects. We conclude that pathological anxiety might lower the threshold of activation of a circuit breaker interrupting ongoing cognitive processes and resulting, with a greater probability than in controls, in the temporary suspension of responses. These results suggest that such suspension can occur for stimuli that are unexpected, emotionally neutral, sounds.

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