Psychological Research
https://doi.org/10.1007/s00426-020-01321-4

ORIGINAL ARTICLE

The influence of threat on the efficiency of goal-directed attentional control

Andy Jeesu Kim[1] · **David S. Lee**[1] · **Brian A. Anderson**[1]

Received: 24 June 2019 / Accepted: 14 March 2020

Abstract

Anxiety has consistently been found to potentiate attentional capture by physically salient stimuli, which could be due to enhanced distractor processing, impaired goal-directed attention, or both. At the same time, a recent study demonstrated that a threat manipulation reduces attentional capture by reward-associated stimuli, suggesting that anxiety does not increase distractibility or, otherwise, interfere with the control of attention generally. Here, we experimentally induced anxiety via threat-of-shock in the adaptive choice visual search task to examine whether the experience of threat influences goal-directed attentional control. Participants chose to search through one of two task-relevant colors on each trial, where searching through the less abundant color would be optimal for maximizing performance. Performance was evaluated with and without the threat of unpredictable electric shock. Under threat, participants were more optimal in their visual search and missed fewer targets. Performance improvements were demonstrated on trials that the optimal target color switched, demonstrating that threat is beneficial in adapting to changing attentional demands. Our findings demonstrate that threat can facilitate the efficiency of goal-directed attentional control and are at odds with an antagonistic relationship between anxiety and the control of attention.

Introduction

Attention selectively filters sensory information, prioritizing and suppressing input from the environment, and ultimately determines what is cognitively represented. Cognitive models of visual attention have demonstrated that attention can be biased both voluntarily toward goal-relevant stimuli (Wolfe, Cave, & Franzel, 1989) and also involuntarily toward physically salient objects (Theeuwes, 1992). In addition, attention can be biased by previous deployments of attention known as “selection history”; previously rewarded objects (e.g., Anderson, Laurent, & Yantis, 2011), high-probability target locations (e.g., Jiang, Swallow, Rosenbaum, & Herzig, 2013), and aversively conditioned objects (e.g., Anderson & Britton, 2019) tend to automatically draw attention. An interesting question concerns how the control of attention, as reflected in these mechanisms, is modulated by negatively valenced emotional states such as threat and anxiety.

Anxiety is an adaptive neural state that promotes rapid responses with heightened vigilance when survival is threatened. The orienting of attention to fearful or threatening stimuli is an automatic process (Vuilleumier, 2005, for a review). Anxious individuals, as indicated by significantly higher trait-level anxiety, have continuously demonstrated more pronounced attentional orienting toward threat-related stimuli (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007, for a meta-analysis). One potential interpretation of these findings is that a state of anxiety enhances attention to potentially threatening stimuli at the expense of goal-directed control, in support of the Attentional Control Theory (see Eysenck et al., 2007, for a review). Other theoretical frameworks have modeled the interactions between emotional and cognitive processing including the Dual-Competition Model (Pessoa, 2009) and Attentional Narrowing models (e.g., Easterbrook, 1959). However, divergent findings in support of both resource limitation and cognitive breadth models (e.g., Hu et al., 2012; see also Hu et al., 2015) highlight the need for a more nuanced account of how emotional processing interacts with cognitive performance.

The influence of anxiety on the control of attention more generally, beyond the processing of threat-related stimuli, has been a topic of research interest as it speaks to broader

---

✉ Andy Jeesu Kim
jskim628@tamu.edu

[1] Department of Psychological and Brain Sciences, Texas A&M Institute for Neuroscience, Texas A&M University, 4235 TAMU, College Station, TX 77843-4235, USA

relationships between anxiety and cognition that could inform our understanding of the causes and consequences of pathological anxiety. Anxiety has been shown to increase attentional capture by physically salient, valence-neutral stimuli (Esterman et al., 2013; Moser, Becker, & Moran, 2012), suggesting increased distractibility. Furthermore, negative arousal drives perception towards stimuli with high attentional priority (often operationalized as physically salient stimuli) at the expense of less-salient stimuli (e.g., Sutherland & Mather, 2012, 2015), consistent with the arousal-biased competition hypothesis (Mather & Sutherland, 2011). However, Kim and Anderson (2019) recently demonstrated that attentional capture by previously reward-predictive stimuli is reduced under threat, indicating that threat does not generally increase attentional capture, but rather its consequence for attention depends on the nature of the eliciting stimulus. In the case of reward cues, the processing of threat (negative valence) may have competed with processing of learned value (positive valence) to guide attention, consistent with a dual-competition framework (Pessoa, 2009).

The aforementioned findings raise an important question concerning the relationship between anxiety and the goal-directed control of attention. Findings relating anxiety to increased attentional processing of physically salient stimuli (Esterman et al., 2013; Moser et al., 2012) do not differentiate between enhanced distractor processing and decreased goal-directed attentional control. Attention might be preferentially deployed to physically salient stimuli, because such stimuli are afforded greater attentional bias under threat, because goal-directed attention is less effective at suppressing the selection of such stimuli and enhancing the representation of potentially task-relevant stimuli that compete with salient stimuli for selection, or both. Furthermore, the findings of Kim and Anderson (2019) indicate that it cannot be assumed that anxiety necessarily impairs goal-directed attentional control, and anxiety could potentially facilitate goal-directed attention via increased vigilance and arousal. Such facilitation could explain the reduced distraction under threat in that study, assuming that physically salient stimuli (but not reward cues) are special in their ability to bias attention under threat as might be predicted from the arousal-biased competition account (Mather & Sutherland, 2011). The manner in which anxiety influences the goal-directed control of attention, therefore, remains to be clarified.

In the present study, we provide a direct test of the impact of anxiety on the efficiency of goal-directed attentional control. To this end, we employed a modified version of the Adaptive Choice Visual Search (ACVS) task developed by Irons and Leber (2016, 2018) that requires efficient environmental appraisal for performance maximization. To create an experimentally induced state of anxiety, we manipulated the threat of unpredictable electric shock, as in our prior study (Kim & Anderson, 2019; see also, Schmitz & Grillon, 2012). If anxiety generally interferes with the goal-directed control of attention, visual search should be less efficient when under threat of electric shock, whereas if anxiety enhances the goal-directed control of attention, visual search should instead be more efficient under threat.

Materials and methods

Participants

39 participants (27 females), between the ages of 18 and 35 inclusive ($M = 19.1$ years, $\mathrm{SD} = 0.89$ years), were recruited from the Texas A&M University community. All participants were English-speaking, reported normal or corrected-to-normal visual acuity and normal color vision. All procedures were approved by the Texas A&M University Institutional Review Board and were conducted in accordance with the principles expressed in the Declaration of Helsinki. Written informed consent was obtained for each participant.

The sample size was informed by a power analysis. We estimated the effect size for detecting threat-dependent modulations in the control of attention from Kim and Anderson (2019), which used the same threat-of-shock manipulation in a within-subjects design (Experiment 3), which was $f = 0.408$. Using G*Power 3.1, a sample size of at least 18 participants would provide $\beta > 0.90$ at $\alpha = 0.05$ for a within-subjects test with two measurements (task performance under threat and no threat). We decided to obtain a final sample size (see "Data analysis") that matched the number of participants used in Experiment 3 of Kim and Anderson (2019).

Apparatus

A Dell OptiPlex 7040 (Dell, Round Rock, TX, USA) equipped with Matlab software (Mathworks, Natick, MA, USA) and Psychophysics Toolbox extensions (Brainard, 1997) was used to present the stimuli on a Dell P2717H monitor. Responses were entered using a standard US-layout keyboard. The participants viewed the monitor from a distance of approximately 70 cm in a dimly lit room. Paired electrodes (EL500, BioPac Systems, Inc., Goleta, CA, USA) were attached to the left forearm of each participant, and electric shocks were delivered through an isolated linear stimulator under the constant current setting (STMISOLA, BioPac Systems), which was controlled by custom Matlab scripts.

Stimuli

Each trial consisted of a fixation display, the visual search display, and an inter-trial-interval (see Fig. 1). The fixation display consisted of a box containing an image of either a lightning bolt (during the shock block) or a lightning bolt with a red hash over it (during the no-shock block) for 1000 ms. The visual search display was composed of 54 colored squares (each approximately 1.1° × 1.1° visual angle) arranged in three concentric rings around the center of the screen for 5500 ms. The inner (radius 7.3°), middle (radius 10.1°), and outer rings (radius 13.0°) were composed of 12, 18, and 24 squares, respectively, positioned equidistant from each other. Each search trial contained red, blue, and green color squares. Each square contained a digit between 2 and 9, subtending 0.4° × 0.4°. If no response was recorded within the given time limit, a feedback display was given displaying the words "Too Slow" for 1500 ms. Finally, the inter-trial-interval displayed a blank screen for 1000 ms.

Design

We adapted the design of the ACVS task from Irons & Leber (2018) with a few modifications. In addition to 14 green squares, each trial contained either 13 red squares and 27 blue squares (red-optimal trials) or 27 red squares and 13 blue squares (blue-optimal trials). Participants were informed that one red and one blue square each contained a digit from 2 to 5 and that their task was to find and report one of these two target squares. That is, targets were defined by the combination of a color (red or blue) and a digit (2–5). Each trial contained both a red and blue target square, but only one of them had to be identified. The two digits used for targets on a given trial were always different from each other to allow the behavioral response to be diagnostic of which color target was found (e.g., 3 for red and 4 for blue). All other red and blue squares contained digits from 6 to 9. Green colored squares were irrelevant to the task and contained digits between 2 and 9 to prevent participants from searching based on digit identity without respect to color. All digits inside non-target squares were assigned randomly using the aforementioned constraints. Each target color (red or blue) would be the optimal (i.e., less numerous) target color for a length of 1, 2, 3, 4, or 5 trials, with each length occurring twice per target color per run. Each shock/no-shock block consisted of a total of 180 trials. After each run of 60 trials within a block, the participant was prompted to take a 20 s break. Which color began as the optimal color was fully counterbalanced, and the length of trials between switches in the optimal color was randomly selected without replacement from the aforementioned set of possibilities.

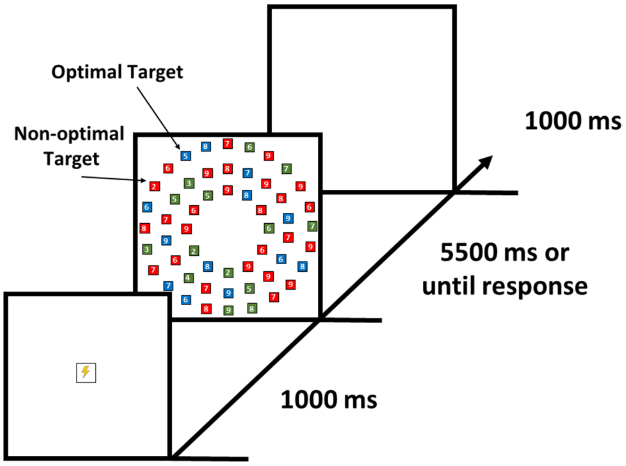

Fig. 1 Sequence of trial events. Participants were shown a white box containing an image of a lightning bolt or one with a red hash over the lightning bolt, depending on whether they were completing the threat or no-threat block, respectively. Then, the stimulus array would be displayed for 5500 ms or until a keyboard press was recorded. If participants did not indicate a response within the time-limit, a feedback display of "Too Slow" would be displayed for 1000 ms. Finally, the inter-trial-interval lasted 1000 ms

Procedure

All participants completed the state component of the State-Trait Anxiety Inventory (Ferreira & Murray, 1983) at the beginning of the experiment to assess baseline state anxiety. Next, participants practiced the ACVS task for 20 trials. All participants were given instructions on the ACVS task and were told to search through either the red or blue colored squares to find a target number on each trial. In addition, we emphasized the utility of searching through the less-prevalent target color (optimal strategy) on each trial to help ensure that baseline performance was moderately optimal, maximizing our ability to detect changes in optimality due to the threat manipulation; not emphasizing the presence of an optimal strategy can result in selection that is ~60% optimal (Irons & Leber, 2016), which would leave little room to detect a potential threat-related reduction in optimality. Responses were indicated by pressing the "Z", "X", "N", and "M" keys for the digits 2 through 5, respectively. If participants did not choose the optimal target color at least 85% of the time during practice, the experimenter re-explained the task and the participant was required to redo the practice until meeting this minimum requirement.

Following practice, each participant completed both the shock and no-shock block, order counterbalanced. Before completing the shock block, each participant was connected to the isolated linear stimulator and a shock calibration procedure was conducted for each participant to achieve a level that was "unpleasant, but not painful" (e.g., Anderson & Britton, 2019; Kim & Anderson, 2019). Following calibration, participants again completed the STAI-state questionnaire before completing the task to validate the anxiety-inducing nature of the threat of electric shock. During the shock block, participants were instructed that they would unpredictably receive periodic electric shocks over the course of the block. A shock was administered a total of nine times during each 60-trial run of the shock block, no fewer than two and no more than four times every 20 trials, and never consecutively without an intervening search trial. Each shock was delivered by inserting an additional "trial" in which, immediately following the fixation period, a 1000 ms blank screen occurred in place of the visual search task and a brief shock was administered (2 ms pulse at the calibrated intensity). To match the length and experience of the shock block, the no-shock block contained nine trials every run with the same blank screen but no shock. Following completion of the shock block, participants were disconnected from the stimulator and, if they completed the shock block first, given a short break to allow the anxiety-inducing nature of the stimulator to dissipate (see Kim & Anderson, 2019).

Data analysis

We excluded data from participants who did not select the optimal target color significantly above chance level (selecting the optimal target on > 56.67% of trials, which corresponds to $p < 0.05$ via binomial test), reasoning that such participants would not be informative for the question of whether anxiety improves or impedes goal-directed attention if these participants were not influenced by the color manipulation. Such participants may have misunderstood the task or decided not to try to optimize performance as instructed. This exclusion resulted in 32 retained data sets which were ultimately analyzed in relation to the threat manipulation. Measures of interest were the probability of selecting the optimal target color and the probability of failing to find either target before the time limit expired, separately in the threat and no-threat blocks.

Results

State anxiety increased from the beginning of the experiment in anticipation of completing the shock block, $t(31) = 3.95$, $p < 0.001$, $d = 0.70$ ($M = 39.5$ vs. 32.3 for threat and no-threat blocks, respectively). Overall, participants robustly selected the optimal target color over the non-optimal target color during both the no-threat ($M = 80.4\%$, SD = 9.7%) and threat blocks ($M = 85.1\%$, SD = 7.9%). Missed trials occurred infrequently during both the no-threat ($M = 4.0\%$, SD = 2.4%) and threat blocks ($M = 3.1\%$, SD = 2.1%). Under threat, participants were significantly more optimal in their visual search, $t(31) = 3.43$, $p = 0.002$, $d = 0.61$, and also missed significantly fewer targets, $t(31) = -2.13$, $p = 0.041$, $d = 0.38$ (see Fig. 2). The threat-of-shock did not cause participants to switch target colors more or less frequently overall, $t(31) = 0.46$, $p = 0.650$ ($M = 56.6$ vs. 57.3 times for threat and no-threat blocks, respectively). In addition, there were no differences in response time when searching for the optimal target under threat, $t(31) = 0.474$, $p = 0.639$ ($M = 2507$ ms vs. 2520 ms for threat and no-threat blocks, respectively).

To characterize whether the threat-of-shock improved the optimality of search immediately when the more prevalent color changed, we assessed performance on the trials where the optimal color switched and on the trials immediately prior to a switch (maximal opportunity to have adjusted to a change in the optimal target color). We found that the threat-of-shock improved performance immediately following a switch of the optimal target color, $t(31) = 2.88$, $p = 0.007$, $d = 0.51$, whereas performance ceased to differ by the trial preceding the next optimal color switch, $t(31) = 1.48$, $p = 0.149$. Similarly, we evaluated the frequency of switches in the found target color when the optimal color changed. We only included trials on which participants found the optimal color immediately preceding a switch in the optimal color, such that a switch in the target color found would reflect optimal performance. On trials immediately following a switch in the optimal color, participants were more likely

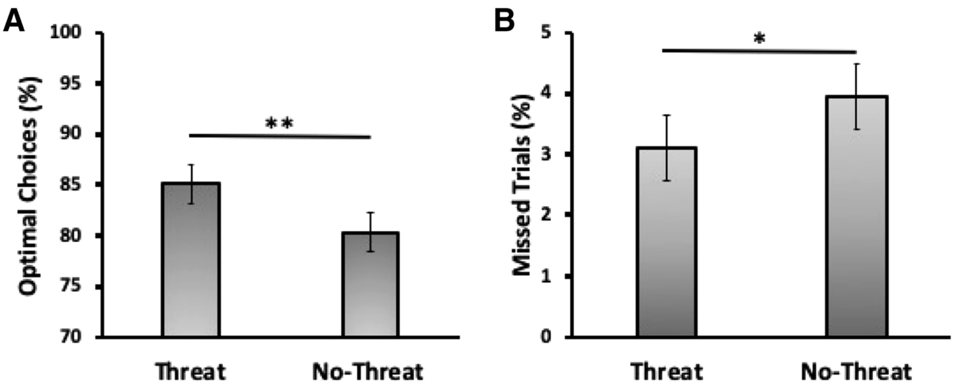

Fig. 2 Behavioral performance with and without the threat of shock. **a** Percentage of trials in which the optimal color target was chosen. **b** Percentage of trials in which a response was not recorded within the timeout limit. Error bars depict within-subjects confidence intervals calculated using the Cousineau method with a Morey correction. $^{**}p < 0.01$, $^{*}p < 0.05$

to switch which target color they found under threat compared to no threat, $t(31) = 3.13$, $p = 0.003$, $d = 0.57$, whereas the likelihood of having switched was generally higher and ceased to significantly differ by the fifth trial following the switch, $t(31) = 0.98$, $p = 0.337$ (Fig. 3).

Discussion

In the present study, we used the ACVS task (Irons & Leber, 2016, 2018) to assess the influence of threat-induced anxiety on the efficiency of goal-directed attentional control. The threat of unpredictable electric shock improved the frequency with which participants optimally allocated their attention to potential targets in a demanding visual search task. The experience of threat was additionally associated with fewer missed targets, further consistent with more efficient goal-directed attention. The beneficial impact of threat on attention was evident immediately following a change in the optimal target color. That is, under threat, participants were less likely to miss an opportunity to adjust their search goals to maximize performance. Altogether, goal-directed attentional control was facilitated by our threat manipulation.

One interpretation of these findings is that threat specifically enhanced the ability to appraise the environment and update search goals when task considerations changed. On the other hand, Irons & Leber (2018) argue that performance in the ACVS task is unrelated to one's attentional control ability per se but rather reflects the "strategic use" of attentional control. Although participants were instructed and trained to search optimally in our experiment, a second possibility is that participants were similarly capable of goal-directed attentional control with and without the threat-of-shock, but were more willing or motivated to engage the optimal strategy under threat. These two possible mechanisms by which threat might be facilitating goal-directed attentional control are not mutually exclusive, and further research will be necessary to parse between them.

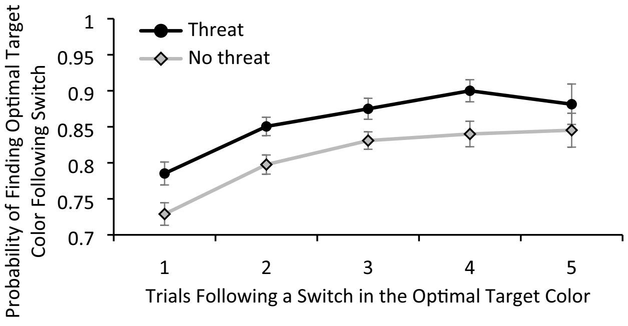

Fig. 3 Probability of finding the optimal target color box as a function of the number of trials following a switch in the optimal target color, separately for threat and no-threat blocks. Error bars depict within-subjects confidence intervals calculated using the Cousineau method with a Morey correction

Prior studies evaluating the effects of experimentally induced anxiety on information processing have demonstrated at times conflicting results. Similar to the results found in the present study, threat-induced anxiety has been linked to improvements in cognitive processes such as assessing risk in decision-making and navigating ability (Clark et al., 2012; Cornwell, Arkin, Overstreet, Carver, & Grillon, 2012). On the other hand, studies have also demonstrated impaired cognitive control as well as null effects from experimentally induced anxiety (Gillan et al., 2019; Robinson, Vytal, Cornwell, & Grillon, 2013; Yang, Miskovich, & Larson, 2018). Eysenck et al. (2007) proposed the Attentional Control Theory which postulates that anxiety devotes excessive resources to the detection of potential threat and "impairs efficient functioning of the goal-directed attentional system" (p. 336). However, the present study and recent studies such as those previously described demonstrate that the type of cognitive task and the processing mechanisms recruited by the task may determine the modulatory influence of threat. We examined the efficiency of goal-directed attention in visual search specifically and found evidence for an anxiety-related improvement, suggesting that although anxiety may impair certain cognitive functions, the ability to modulate the control of attention in a changing environment is in fact facilitated, perhaps owing to the importance of goal-contingent sensory information processing to adaptive behavior and survival.

In the present study, we manipulated anxiety via threat-of-shock, which reflects situational anxiety brought about by anticipation of an unpredictable and unpleasant event (e.g., Davis et al., 2010; Schmitz & Grillon, 2012). This manipulation contains elements of negative arousal (as in, e.g., Lee et al., 2012, 2014; Sutherland & Mather, 2012, 2015), which produces effects similar to the threat-of-shock on attention to physically salient stimuli (Kim & Anderson, 2019), but the negative arousal is specifically future-oriented in the case of threat-of-shock. Such anxiety and negative arousal contrasts with both pathological and high trait-anxiety, which reflect protracted anxiety that is not situationally specific and, especially in the case of anxiety disorders, tends to be maladaptive (see Robinson et al., 2013, for a review). Pathological anxiety and high trait-anxiety are more consistently associated with impairments in attention and cognition (e.g., Eysenck et al. 2007; Etkin et al., 2010; Etkin and Schatzberg, 2012; Krug & Carter, 2012; Moser et al. 2012), and results opposite ours might be hypothesized in these cases. Given the aforementioned differences, we restrict our conclusions to the kind of situational and adaptive anxiety that is manipulated via threat-of-shock.

In the context of other studies manipulating anxiety via threat-of-shock, as described above, at times divergent patterns of results have been observed, with anxiety both facilitating and hindering performance under different task conditions (e.g., Cornwell et al., 2012; Grillon & Charney, 2011; Grillon, 2008; Hu et al., 2012; Lindstrom & Bohlin, 2012; Miu et al., 2008; Robinson et al., 2011, 2013; Vytal et al., 2013; Yang et al., 2018). Although the reasons for these discrepancies in the literature remain to be clarified, we note that our visual search task was low in working memory and cognitive demand and would benefit from more effective filtering of task-irrelevant information once an attentional strategy has been selected (restricting attention to the optimal color until the target is found), which is consistent with both dual competition (Pessoa, 2009) and attentional narrowing accounts (e.g., Easterbrook, 1959). We also note that the degree of anxiety may play a role, such that manipulations resulting in more pronounced anxiety could potentially impair performance in our task, consistent with the Yerkes–Dodson Law (Yerkes & Dodson, 1908); however, the threat-of-shock as manipulated in our experiment is a common approach in the study of anxiety, with the same threat-of-shock manipulation producing increased distraction by physically salient stimuli but reduced distraction by previously reward-associated stimuli (Kim & Anderson, 2019), leaving it an open question how such anxiety influences the goal-directed control of attention to which our study speaks.

It is important to note that the paradigm we used, the ACVS paradigm, specifically probed the efficiency of goal-directed attention in a dynamically changing environment, requiring vigilant monitoring of the visual field for changes in the complexion of the objects presented. This form of goal-directed attentional control may be especially facilitated by a state of anxiety, and a similar manipulation of anxiety-inducing threat might result in a different pattern of performance in a more sustained goal-directed attention task. Future research should examine the modulatory influence of threat-induced anxiety across a range of different goal-directed attention tasks to obtain a more complete picture of the manner in which anxiety influences the attention system.

Our findings have important implications for theories linking anxiety and negative arousal to the attentional processing of physically salient but affectively neutral stimuli (Esterman et al., 2013; Moser et al., 2012; Sutherland & Mather, 2012, 2015). The present study suggests that such preferential processing of salient stimuli likely reflects greater attentional priority afforded to salient stimuli directly and specifically, rather than an indirect increase in the processing of salient stimuli due to less efficient goal-directed attentional modulation (i.e., a reduced ability to suppress salient signals and/or bias attention in favor of less-salient but potentially relevant stimuli that compete for attention), as predicted by theories of arousal-biased competition (Mather & Sutherland, 2011). Our findings also lend insight into the seemingly paradoxical findings of Kim and Anderson (2019) in which attentional capture by previously reward-associated stimuli was reduced under threat. The results of that study were interpreted as reflecting the consequence of competition between the processing of threat and reward. In addition to this potential explanation, to the degree to which arousal-biased competition is particular to physically salient stimuli rather than any stimulus that evokes a stronger response than competitors in an attentional priority map, the reduced attentional capture observed by Kim and Anderson (2019) may reflect an anxiety-related increase in the efficiency of goal-directed attention that led to reduced distraction by reward cues.

Acknowledgements This study was supported by grants from the Brain & Behavior Research Foundation [NARSAD 26008] and National Institutes of Health [R01-DA046410] to BAA.

Funding This study was supported by Grants from the Brain & Behavior Research Foundation [NARSAD 26008] and National Institutes of Health [R01-DA046410] to BAA.

Data availability statement The data sets during and/or analyzed during the current study are available in the Open Science Framework repository (https://doi.org/10.17605/OSF.IO/TEJKF).

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval All procedures were conducted in accordance with the ethical standards of the Texas A&M University Institutional Review Board and with the 1964 Helsinki declaration and its later amendments.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

Anderson, B. A., & Britton, M. K. (2019). On the automaticity of attentional orienting to threatening stimuli. *Emotion*. https://doi.org/10.1037/emo0000596.

Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences of the United States of America, 108*(25), 10367–10371.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*(1), 1–24.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision, 10*(4), 433–436.

Clark, L., Li, R., Wright, C. M., Rome, F., Fairchild, G., Dunn, B. D., et al. (2012). Risk-avoidant decision making increased by threat of electric shock. *Psychophysiology, 49*(10), 1436–1443.

Cornwell, B. R., Arkin, N., Overstreet, C., Carver, F. W., & Grillon, C. (2012). Distinct contributions of human hippocampal theta to spatial cognition and anxiety. *Hippocampus, 22*(9), 1848–1859.

Davis, M., Walker, D. L., Miles, L., & Grillon, C. (2010). Phasic vs sustained fear in rats and humans: Role of the extended amygdala in fear vs anxiety. *Neuropsychopharmacology, 35*, 105–135.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66*, 183–201.

Esterman, M., DeGutis, J., Mercado, R., Rosenblatt, A., Vasterling, J. J., Milberg, W., et al. (2013). Stress-related psychological symptoms are associated with increased attentional capture by visually salient distractors. *Journal of the International Neuropsychological Society, 19*(7), 835–840.

Etkin, A., Prater, K. E., Hoeft, F., Menon, V., & Schatzberg, A. F. (2010). Failure of anterior cingulate activation and connectivity with the amygdala during implicit regulation of emotional processing in generalized anxiety disorder. *American Journal of Psychiatry., 167*, 545–554.

Etkin, A., & Schatzberg, A. (2012). Common abnormalities and disorder-specific compensation during implicit regulation of emotional processing in generalized anxiety and major depressive disorders. *American Journal of Psychiatry, 168*, 968–978.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*, 336–353.

Ferreira, R., & Murray, J. (1983). Spielberger state-trait anxiety inventory—measuring anxiety with and without an audience during performance on a stabilometer. *Perceptual and Motor Skills, 57*(1), 15–18.

Gillan, C.M., Vaghi, M.M., Hezemans, F.H., van Ghesel, G.S., Dafflon, J., Bruhl, A. B., Savulich, G., & Robbins, T. W. (2020). *Psychol Med* https://doi.org/10.1017/S0033291720000203

Grillon, C. (2008). Models and mechanisms of anxiety: evidence from startle studies. *Psychopharmacology (Berlin), 199*, 421–437.

Grillon, C., & Charney, D. R. (2011). In the face of fear: Anxiety sensitizes defensize responses to fearful faces. *Psychophysiology, 48*(12), 1745–1752.

Hu, K., Bauer, A., Padmala, S., & Pessoa, L. (2012). Threat of bodily harm has opposing effects on cognition. *Emotion, 12*(1), 28–32.

Hu, K., Fan, Z., & He, S. (2015). Uncovering the interaction between emphatic pain and cognition. *Psychological Research Psychologische Forschung, 79*(6), 1054–1063.

Irons, J. L., & Leber, A. B. (2016). Choosing attentional control settings in a dynamically changing environment. *Attention Perception Psychophysics, 78*(7), 2031–2048.

Irons, J. L., & Leber, A. B. (2018). Characterizing individual variation in the strategic use of attentional control. *Journal of Experimental Psychology: Human Perception and Performance, 44*(10), 1637–1654.

Jiang, Y. V., Swallow, K. M., Rosenbaum, G. M., & Herzig, C. (2013). Rapid acquisition but slow extinction of an attentional bias in space. *Journal of Experimental Psychology: Human Perception and Performance, 39*(1), 87–99.

Kim, A. J., & Anderson, B. A. (2019). Threat reduces value-driven but not salience-driven attentional capture. *Emotion*. https://doi.org/10.1037/emo0000599.

Krug, M. K., & Carter, C. S. (2012). Proactive and reactive control during emotional interference and its relationship to trait anxiety. *Brain Research, 1481*, 13–36.

Lee, T. H., Itti, L., & Mather, M. (2012). Evidence for arousal-biased competition in perceptual learning. *Front Psychol, 3*, 241.

Lee, T. H., Sakaki, M., Cheng, R., Velasco, R., & Mather, M. (2014). Emotional arousal amplifies the effects of biased competition in the brain. *Social Cognitive and Affective Neuroscience, 9*(12), 2067–2077.

Lindstrom, B. R., & Bohlin, G. (2012). Threat-relevance impairs executive functions: Negative impact on working memory and response inhibition. *Emotion, 12*(2), 384–393.

Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspectives on Psychological Science, 6*(2), 114–133.

Miu, A. C., Heilman, R. M., & Houser, D. (2008). Anxiety impairs decision-making: Psychophysiological evidence from an Iowa Gambling Task. *Biological Psychology, 77*(3), 353–358.

Moser, J. S., Becker, M. W., & Moran, T. P. (2012). Enhanced attentional capture in trait anxiety. *Emotion, 12*(2), 213–216.

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13*(4), 160–166.

Robinson, O. J., Letkiewicz, A. M., Overstreet, C., Ernst, M., & Grillon, C. (2011). The effect of induced anxiety on cognition: threat of shock enhances aversive processing in healthy individuals. *Cognitive Affective Behavioral Neuroscience, 11*, 217–227.

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013). The impact of anxiety upon cognition: perspectives from human threat of shock studies. *Frontiers in Human Neuroscience, 7*, 203.

Schmitz, A., & Grillon, C. (2012). Assessing fear and anxiety in humans using the threat of predictable and unpredictable aversive events (the NPU-threat test). *Nature Protocols, 7*(3), 527–532.

Sutherland, M. R., & Mather, M. (2012). Negative arousal amplifies the effects of saliency in short-term memory. *Emotion, 12*(6), 1367–1372.

Sutherland, M. R., & Mather, M. (2015). Negative arousal increases the effects of stimulus salience in older adults. *Experimental Aging Research, 41*(3), 259–271.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics, 51*(6), 599–606.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585–594.

Vytal, K. E., Cornwell, B. R., Letkiewicz, A. M., Arkin, N. E., & Grillon, C. (2013). The complex interaction between anxiety and cognition: Insight from spatial and verbal working memory. *Frontiers in Human Neuroscience, 7*, 93.

Wolfe, J. M., Cave, K. R., & Franzel, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance, 15*(3), 419–433.

Yang, Y., Miskovich, T. A., & Larson, C. L. (2018). State anxiety impairs proactive but enhances reactive control. *Frontiers in Psychology, 9*, 2570.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(5), 459–482.