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BRIEF REPORT

Instructional Learning of Threat-Related Attentional Capture Is Modulated by State Anxiety

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The present study aimed to determine whether persistent threat-related attentional capture can result from instructional learning, when participants acquire knowledge of the aversive qualities of a stimulus through verbal instruction. Fifty-four nonclinical adults first performed a visual search task in which a green or red circle was presented as a target. They were instructed that one of these two colors might be paired with an electric shock if they responded slowly or inaccurately, whereas the other color was never associated with shock. However, no shocks were actually delivered. In a subsequent test phase, in which participants were explicitly informed that shocks were no longer possible, former-target-color stimuli were presented as distractors in a visual search task for a shape-defined target. In both tasks, although participants were never exposed to the electric shock, we observed a significant correlation between threat-related attentional priority and state anxiety. Our results demonstrate that exposure to a stimulus with the belief that it could be threatening is sufficient to generate a persistent attentional bias toward that stimulus, but this effect is modulated by state anxiety. Attentional biases for fear-relevant stimuli have been implicated in anxiety disorders, and our findings demonstrate that for anxious participants, attentional biases can be entirely the product of erroneous beliefs concerning the linking between stimuli and possible outcomes.

Keywords: instructional learning, selective attention, attentional prioritization, associative learning, threat

Supplemental materials: https://doi.org/10.1037/emo0001291.supp

The ability to efficiently detect stimuli that represent a potential danger is crucial for adaptation and survival. This aptitude promotes the execution of rapid and appropriate behavioral responses in order to prevent or minimize aversive outcomes (LeDoux, 1996; Vuilleumier, 2005). As a consequence, the human attentional system is preferentially drawn to threat-related cues (see Mulckhuyse, 2018; Watson et al., 2019 for reviews). Attentional bias toward threat-associated stimuli plays a critical role in anxiety disorders by contributing to the etiology, maintenance, or exacerbation of emotional disturbances (Van Bockstaele et al., 2014). A better understanding of this phenomenon could thus inform approaches to the treatment and alleviation of fear-related psychopathologies such as posttraumatic stress disorder and specific phobias.

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The authors declare no competing interests. All materials and data of this study can be found at https://osf.io/ywrt9/.

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Experimental research has shown that stimuli previously paired with electric shock bias attention in visual search tasks, independent of perceptual salience (e.g., Schmidt et al., 2015a). Distraction by punishment-associated cues was also reported after conditioning with white noise (e.g., Koster et al., 2004; Smith et al., 2006), monetary loss (e.g., Wentura et al., 2014), or negative social feedback (Anderson, 2017; Anderson & Kim, 2018). Oculomotor capture by threat-signaling stimuli occurs even though fixating punishment-related cues increases the probability of receiving punishment (Anderson & Britton, 2020; Nissens et al., 2017) and is explicitly counterproductive (Mikhael et al., 2021), suggesting that threat-related stimuli are automatically prioritized by our attentional system.

Attentional capture by threat-associated signals has been predominantly studied after participants experienced repeated pairings between an initially neutral stimulus (the conditioned stimulus [CS]) and an aversive unconditioned stimulus (US). The present study examines whether attention can be shaped by a threat-related stimulus that was never physically paired with an aversive US. Participants were instructed that a specific target color might be paired with shock (CS+) in a visual search task if they responded slowly or inaccurately, whereas a second target color was never associated with shock (CS−). In a subsequent test phase, in which participants were explicitly informed that the delivery of shock was no longer possible, former-target-color stimuli were presented as distractors in a visual search task for a shape-defined target. Crucially, participants never experienced the pairing between the CS+ and the electric shock and were instead led to believe, in accordance with task instructions, that they successfully escaped all possible shocks. Thus, any observed threat-related attentional capture could not result from direct exposure to the CS–US pairings but only from the belief that the US could have been delivered contingent upon the CS.

Instructed fear conditioning studies reported that participants who never actually received an aversive US (preventing them from learning through experience) expressed negative emotional reactions, measured by skin conductance responses, to the CS+ (e.g., Morato et al., 2021; Olsson & Phelps, 2004). Attention is biased toward a stimulus instructed to be threatening both when participants believe it currently could be followed by the US or when they know it will be in the future (Deltomme et al., 2018), possibly reflecting active threat monitoring. In Deltomme et al. (2018), participants might indeed actively worry about the threatening stimulus in general, or just remain in a prepared state for when it will next be paired with shock. The design used in the present study consisted of a learning-test paradigm with a variant of the additional singleton task (Theeuwes, 1992), which was previously employed to examine threat-driven attention (e.g., Nissens et al., 2017; Schmidt et al., 2015a). Developed in the context of reward-history-dependent effects (Anderson et al., 2011), this paradigm is also well established to be sensitive to the involuntary capture of attention by conditioned stimuli (e.g., Anderson & Yantis, 2012; Nissens et al., 2017), which contrasts with the dot-probe paradigm used by Deltomme et al. (2018), which is generally regarded as more sensitive to effects on attentional disengagement (see Fox et al., 2001). The present study thus provides a strong test of the involuntary nature of the attentional bias, insofar as the stimuli presumably associated with shock in the learning phase were task-irrelevant, explicitly not paired with shock, and nonsalient apart from their learning history in the critical test phase. Thus, our main objective was to ascertain whether instructed fear could induce persistent threat-related attentional capture as a result of prior exposure to an instructed CS+.

Hypervigilance of attention toward potentially threatening stimuli is a core feature of anxiety disorders (Kimble et al., 2014; Valadez et al., 2022). Furthermore, previous studies revealed a relationship between aversive conditioning effects and anxiety. For instance, Blanchette and Richards (2013) showed that Stroop interference to negatively conditioned stimuli was greater for high-anxious than low-anxious participants. Dunsmoor et al. (2011) also reported that generalization of conditioned fear was positively correlated with trait anxiety levels. The second objective of this study was to investigate the role of anxiety on the instructional learning of threat-driven attention by examining correlations between threat-modulated attentional biases and anxiety scores assessed with the State-Trait Anxiety Inventory (STAI; Gauthier & Bouchard, 1993) in anticipation of the experimental task.

Method

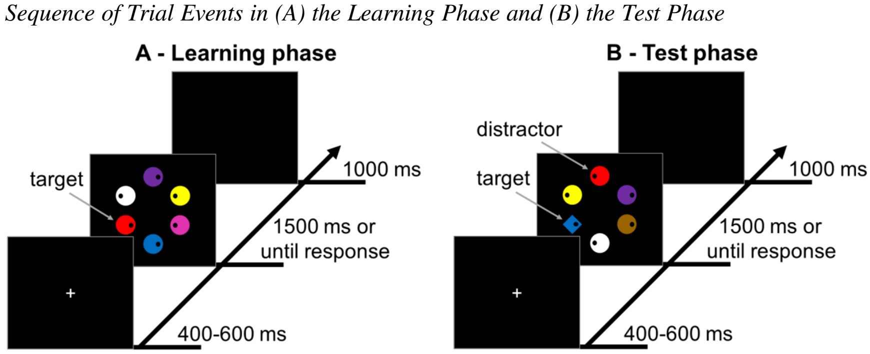
Participants

Given no previous study seems to have tested the effects of instructed fear on selective attention in a test phase, we conducted a power analysis for the comparison between CS+ and CS− conditions based on a medium effect size ($d_z = 0.5$), which is smaller than the effect size reported by Deltomme et al. (2018) in each of their two experiments. Specifically, the analysis indicated that a sample size of 54 would be sufficient to detect an effect at 95% statistical power (computed using G*Power 3.1). As a result, 54 participants (33 female), between the ages of 18 and 31 inclusive ($M = 19.43$ years, $SD = 1.93$), 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. According to self-report, none had neurological or psychiatric antecedents or were taking medication known to affect the central nervous system. 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.

Apparatus and Stimuli

See the online supplemental materials and Figure 1. The search display contained six filled shapes of different colors, the center of which was equally distributed on an imaginary circle (8.4° in diameter) around the center of the screen. Each shape was uniquely

Figure 1
Sequence of Trial Events in (A) the Learning Phase and (B) the Test Phase



Note. In both phases, each trial began with the presentation of a fixation cross at the center of the screen for a random duration between 400 and 600 ms. Then, the search array was displayed for 1,500 ms or until the participant's response. A 1,000-ms blank screen followed the search display. If the participant responded incorrectly or failed to respond within the timeout limit (1,500 ms), a 1,000-ms feedback display indicating "Incorrect" or "Too slow," respectively, at the center location was added just after the search display. See the online article for the color version of this figure.

colored. The full set of colors included eight prototypical colors: red, green, blue, purple, pink, brown, yellow, and white.

Design and Procedure

The learning phase comprised 60 CS+ trials and 60 CS− trials (120 trials in total), randomly ordered for each participant. Targets were defined as a red or a green circle, exactly one of which was presented on every trial. Participants were instructed to report whether the black dot was on the left or right side of the target (by pressing the key "N" or "M," respectively, with their dominant hand). Importantly, participants were informed that one of the two target colors might be paired with shock (CS+) if they responded slowly or inaccurately, whereas the other target color was never associated with shock (CS−). The (presumed) shock-color association was counterbalanced across participants. On each trial, the colors of the five nontarget circles were randomly selected from the full set of colors except for red and green. All possible positions of the target were presented an equal number of times in each condition. The learning phase was designed to minimize the likelihood that participants would realize they could not be shocked even if they were slow or inaccurate. Thus, we used a relatively small number of trials and a task known to have a high proportion of correct responses (above 95%, e.g., Gaspelin et al., 2015) to limit the number of potential noncorrect responses in the CS+ condition, while still maintaining a number of CS+ trials sufficient to generate robust attentional biases (e.g., Schmidt et al., 2015b).

The test phase comprised 60 CS+ trials, 60 CS− trials, and 60 no-distractor trials (180 trials in total), randomly ordered for each participant. The target was defined as the unique shape, which was never rendered in red or green. On each of the CS+ and CS− trials, one of the nontarget shapes was colored either red or green (this stimulus is henceforth called the distractor). The colors of the remaining shapes were randomly selected (without replacement) from the full set of colors except for red and green. On the CS+ trials, the distractor was rendered in the color presumably associated with shock in the learning phase. On the CS− trials, the distractor was rendered in the color never explicitly associated with shock in the learning phase. On each no-distractor trial, the colors of the six shapes were randomly selected (without replacement) from the full set of colors except for red and green. In each condition, the target was a circle in half of trials and a diamond in the other half of trials. In each of the CS+ and CS− conditions, the target and distractor positions were fully crossed and counterbalanced for each target shape. Similarly, in the no-distractor condition, each shape target was presented equally often at each of the six possible locations. Participants were instructed to report whether the black dot was on the left or right side of the unique shape as fast and accurately as possible. Furthermore, participants were informed that no shock will be delivered during this phase.

In both phases, the dot appeared on the left and right sides of the target shape equally often in each condition. The position of the dot for the nontarget shapes was pseudo-randomized with the restriction that the dot appeared equally often on the left and right sides of the six shapes on each trial.

Prior to the experiment, each participant completed the STAI to evaluate their state and trait anxiety levels, consistent with the method used in previous studies (e.g., Grégoire et al., 2020; Quezada-Scholz et al., 2019). Participants were introduced to the electrical stimulator and informed that they might receive electrical stimulations during the experiment prior to completing the STAI. Thus, our measure of state anxiety captured anticipatory anxiety when it was presumably strongest, before any (presumed) CS+ trials were presented without shock. Then, the participant was connected to the isolated linear stimulator, and a shock calibration procedure was conducted to achieve a level that was "unpleasant, but not painful" (Anderson & Britton, 2020; Grégoire & Greening, 2019, 2020; Grégoire et al., 2021). Although no shock was delivered during the experiment, this procedure aimed to equate expectations participants could have about the electric stimulation (and avoid, for example, a significant alteration of performance for participants highly concerned about the physical sensation induced by the potential shock) and to ensure the credibility of the threat-of-shock instructions. Each phase was split into runs of 60 trials, with a self-paced break between runs. A practice comprising 12 trials with no time limit followed by 12 trials with a time limit was performed before each phase.

Data Analysis

Response time (RT) was measured from the onset of the search display until one of the response keys was pressed. Response times exceeding three *SD* of the mean were trimmed for each participant (Grégoire et al., 2013, 2015), in the training (1.43%) and the test phase (1.59%). For each *t* test, data were checked for normality of distribution with the Kolmogorov–Smirnov test. A Wilcoxon signed-ranks test was used when data were not normally distributed. Repeated-measures analyses of variance (ANOVAs) were conducted with condition (CS+, CS−, no distractor) as a within-subject variable, separately for mean RTs and accuracy (proportion of correct responses), in the test phase. Sphericity was tested with Mauchly's test of sphericity, and when the sphericity assumption was violated, degrees of freedom were adjusted using the Greenhouse–Geisser epsilon correction. In each phase, an attentional bias score was computed for each participant by subtracting the mean RT obtained for the CS− condition from the mean RT obtained for the CS+ condition. Similarly, an attentional bias score was computed for accuracy in the test phase. Attentional bias scores were calculated to perform correlational analyses with anxiety scores.

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All data and research materials are available at https://osf.io/ywrt9/ (Grégoire & Anderson, 2023). Data were analyzed using SPSS Version 23.0 statistic software package. This study was not preregistered.

Results

STAI Scores

State and trait anxiety scores were $M = 32.63$ ($SD = 8.34$) and $M = 39.67$ ($SD = 10.41$), respectively.

Learning Phase

Response times were significantly faster in the CS+ condition than in the CS− condition, $t(53) = 7.53$, $p < .001$, $d_z = 1.02$. The proportion of correct responses did not differ significantly between the CS+ condition and the CS− condition, $Z = -1.22$, $p = .221$ (Figure 2A). We observed a significant negative correlation between the attentional bias score for RT and both state anxiety score and trait anxiety score, $r(52) = -.299$, $p = .028$ (Figure 2B), and $r(52) = -.288$, $p = .035$, respectively (Figure 2C).

Test Phase

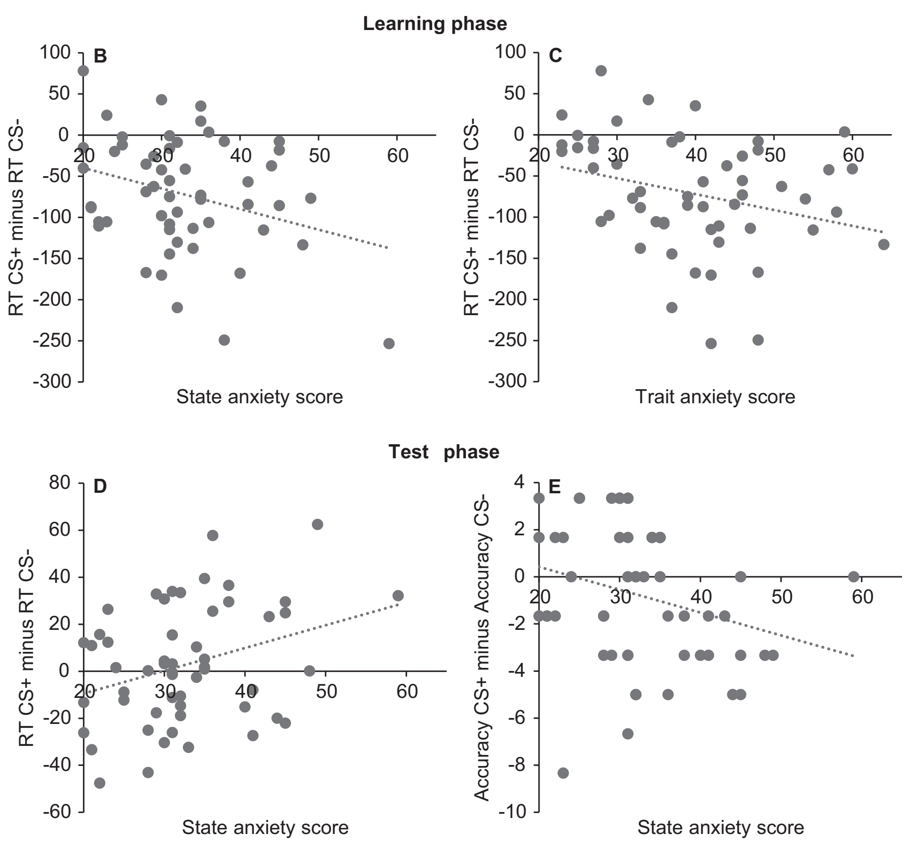
The ANOVA performed on mean RTs revealed no significant main effect of condition, $F(1.80, 95.32) = 0.38$, $p = .664$. The same analysis performed on accuracy revealed no significant main effect of condition, $F(2, 106) = 2.26$, $p = .109$. We observed a significant positive correlation between the attentional bias score for RT and state anxiety score, $r(52) = .323$, $p = .017$ (Figure 2D). We also observed a significant negative correlation between the attentional bias score for accuracy and state anxiety score, $r(52) = -.272$, $p = .047$ (Figure 2E). In both cases, threat-related attentional capture was greater for more anxious participants. No such correlations were observed with trait anxiety score ($ps > .27$, see the online supplemental materials).

Since Deltomme et al. (2018) reported that the effects of instructed fear occurred only in the first half of the extinction phase (Experiment 1), we divided the test phase in two halves. We

Figure 2
Behavioral Results

A	CS+	CS -	No distractor
Learning phase			
Correct response times (ms)	577.74 (64.73)	649.15 (87.69)	-
Proportion of correct responses	98.33 (2.22)	97.50 (3.30)	-
Test phase			
Correct response times (ms)	700.45 (83.89)	697.69 (80.38)	697.68 (77.96)
Proportion of correct responses	96.02 (3.64)	96.82 (3.48)	96.14 (3.75)

Note. Standard deviations are in parentheses.



Note. (A) correct RTs and proportion of correct responses as a function of experimental conditions in learning and test phases. Relationship between threat-related attentional bias (RT CS+ Minus RT CS−), (B) State anxiety score, and (C) trait anxiety score in the learning phase. Relationship between state anxiety score and threat-related attentional bias measured by (D) RT (RT CS+ Minus RT CS−) and (E) accuracy (accuracy CS+ minus accuracy CS−) in the test phase. CS = conditioned stimulus. RT = response time.

computed attentional bias scores (for RT and accuracy) for the first and the second half of the trials. Then, we calculated correlations between attentional bias and state anxiety scores in each half. We compared the correlation coefficients between the first and the second half of the trials using the Fisher's r-to-z transformation. For both RT and accuracy, the comparisons were not significant ($\Delta r = .016$, $p = .936$, and $\Delta r = .256$, $p = .184$, respectively), suggesting that the effects of instructed fear did not differ between the first and the second part of the test phase. This conclusion was corroborated by randomization tests in which the probability of the observed difference in correlation coefficients was compared against an empirically derived sampling distribution in which observed attentional bias scores and state anxiety scores were randomly paired over 100,000 iterations ($ps > .189$).

Discussion

This study aimed to determine whether instructed fear could induce persistent threat-related attentional capture without direct experience of the CS–US pairing. Participants first performed a visual search task in which a green or red circle was presented as a target. They were instructed that one of these two colors might be paired with an electric shock if they responded slowly or inaccurately, whereas the other color was never associated with shock. Participants were faster when the target color was presumably associated with shock, relative to the neutral target color. Furthermore, the attentional bias score, computed by subtracting the mean RT obtained in the CS− condition from the mean RT obtained in the CS+ condition, was negatively correlated with both state and trait anxiety scores assessed before the experiment, suggesting that attentional capture by the CS+ color increased with anxiety level.

In a subsequent test phase, former-target-color stimuli were presented as distractors in a visual search task for a shape-defined target. Importantly, participants were explicitly informed that shocks were no longer possible. Attentional bias measured by the RT difference between CS+ and CS− conditions was positively correlated with state anxiety, indicating that the more participants were anxious about the experiment and the associated prospect of shock, the more they were distracted by the color presumably paired with shock in the learning phase.[1] Consistent with this interpretation, attentional bias measured by the accuracy difference between CS+ and CS− conditions was negatively correlated with state anxiety. It is worth adding that the effects of instructed fear did not differ between the first and the second part of the test phase, whereas Deltomme et al. (2018) reported that these effects were short-lived. This fits with the idea that the effects observed in Deltomme et al. may have to some degree reflected a residual influence of voluntary fear-related attentional priorities, which may be more subject to extinction; the type of involuntary fear-related attentional biases measured in learning-test paradigms are generally robust to extinction (e.g., Kim & Anderson, 2021).

We observed no main effect of condition (for RT and accuracy) in the test phase. This result is inconsistent with previous studies in which attention was biased by stimuli previously paired with aversive outcomes (e.g., Hu et al., 2013; Kim & Anderson, 2021). However, correlational analyses suggest that instructional fear effects on attention are modulated by state anxiety level. The absence of a group-level effect in the test phase of the present study could be because of generally low state anxiety in our sample and/or our experimental paradigm may have been less sensitive to attentional biases in less-anxious participants because of the strong manipulation of task-irrelevance in the test phase. Attentional bias might be less sensitive to anxiety when participants are directly exposed to aversive outcomes.

In this study, state anxiety scores reflect anxiety felt by participants in anticipation of completing the experiment. This measure is probably a more sensitive indicator of anxiety perceived by participants with respect to the prospect of electric shock than trait anxiety scores. Trait anxiety refers to the stable tendency to experience negative emotions across many situations (Gidron, 2013). Thus, a high trait anxiety score is not necessarily indicative of state anxiety in a specific situation. In other words, an individual can be generally anxious, but relatively unperturbed by a specific situation, and vice versa. This could explain, at least partially, why we did not observe significant correlations in the test phase for trait anxiety scores. Note also that the mean trait anxiety score measured in this study is commonly classified as "moderate" (Gauthier & Bouchard, 1993). A clinical sample of high-anxious participants would be more susceptible to feel anxiety in a large variety of situations. As a consequence, they might exhibit significant threat-related attentional capture at a group level in the test phase and, given relatively elevated levels of state anxiety, demonstrate attentional biases more pronounced than those observed in the present study. Future research could investigate this possibility further.

Our results reveal that threat-related attentional capture can ensue from instructional learning, but this bias is modulated by state anxiety. We demonstrate that encountering a stimulus believed to be threatening can have persistent consequences for attention even if those beliefs are never actually reinforced, as a function of how anxiety-provoking the belief is. The attentional bias observed in this study could possibly be related to worry and rumination. Lewis et al. (2019) reported that visual attention is biased to negative information, relative to neutral information, for both participants induced to worry and those induced to rumination. Thus, instructions of the learning phase might induce worry or rumination about aversive outcomes (i.e., repetitive negative thinking about the possibility to receive electrical stimulations) and subsequently affect attentional processing of stimuli presumably associated with shock.

Our findings complement those of Deltomme et al. (2018), demonstrating that in particularly anxious individuals, instructed threat can have a persistent influence on the capture of attention by task-irrelevant stimuli, which speaks to the involuntary nature of the effect and its direct influence on the orienting of attention specifically. The present study more broadly extends empirical (e.g., Nissens et al., 2017; Schmidt et al., 2015a, 2015b) and theoretical (Mulckhuyse, 2018) knowledge about threat-driven attention and could provide valuable insight to better understand the formation of anxiety disorders. Attentional bias toward threat-associated stimuli indeed represents a core feature of anxiety disorders, such as

[1] Note that in the learning phase, a negative attentional bias score for RT is indicative of an attentional bias toward the CS+ color because the CS+ and CS− colors are task-relevant. In the test phase, a *positive* attentional bias score for RT is indicative of an attentional bias toward the CS+ color because the CS+ and CS− colors are task-*irrelevant*. The correlation between the attentional bias score and the state anxiety score was negative in the learning phase and positive in the test phase but denotes in both situations that attentional capture by the CS+ color increased with anxiety level.

posttraumatic stress disorder (Block & Liberzon, 2016) or specific phobias (Barry et al., 2015), and largely contributes to the etiology, maintenance, or exacerbation of emotional disturbances (Van Bockstaele et al., 2014). Our findings open up the possibility that erroneous beliefs about the threatening nature of a stimulus can have a persistent effect on how information is processed in the future, which in particularly anxious individuals may play a role in maladaptive behaviors.

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