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# Prediction and perception: Defensive startle modulation

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**Abstract**

Previous research indicates that predictive cues can dampen subsequent defensive reactions. The present study investigated whether effects of cuing are specific to aversive stimuli, using modulation of the blink startle reflex as a measure of emotional reactivity. Participants viewed pictures depicting violence, romance/erotica, or mundane content. On half of all trials, a cue (color) predicted the content of the upcoming picture; on the remaining trials, scenes were presented without a cue. Acoustic startle probes were presented during picture viewing on trials with predictive cues and trials without a cue. Replicating previous studies, blink reflexes elicited when viewing violent pictures that had not been preceded by a cue were potentiated compared to uncued mundane scenes, and reflexes were attenuated when viewing scenes of erotica/romance that had not been cued. On the other hand, reflex potentiation when viewing scenes of violence (relative to mundane scenes) was eliminated when these pictures were preceded by a predictive cue, whereas scenes of romance prompted reliable reflex attenuation regardless of whether pictures were cued or not. Taken together, the data suggest that cuing elicits an anticipatory coping process that is specific to aversive stimuli.

**Descriptors:** Perception, Anticipation, Emotion, Pictures, Startle

The startle reflex is a reliable index of defensive engagement when individuals are confronted with aversive stimuli (for a review, see Lang & Davis, 2006). When the startle reflex is elicited during unpleasant picture viewing, the blink component of the reflex is enhanced compared to blinks elicited when viewing emotionally neutral pictures (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001). Moreover, blink enhancement continues to be apparent after repeated exposure to unpleasant pictures (Bradley, Lang, & Cuthbert, 1993), persisting even when the same picture is repeated across as many as thirty contiguous trials (Ferrari, Bradley, Codispoti, & Lang, 2011). Thus, startle potentiation during aversive picture viewing is a remarkably robust phenomenon.

While defensive startle potentiation is not reduced by repetition, we recently found that, when unpleasant pictures are preceded by a cue that reliably identifies their negative hedonic content, enhancement of startle relative to cued neutral picture viewing is markedly reduced (Sege, Bradley, & Lang, 2014). A similarly reduced response has been observed in classic conditioning experiments; thus, reactions to an unconditioned aversive stimulus (e.g., shock) are dampened over trials when that stimulus is reliably preceded by a conditioned cue (e.g., Schell & Grings, 1971). Conditioning researchers have hypothesized that cuing reduces reactions to an aversive stimulus by increasing its predictability and thus decreasing its perceived intensity (Ison, Sanes, Foss, & Pinckney, 1990; Lykken, Mackindoe, & Tellegen, 1972; Lykken & Tellegen, 1974). It is possible that a similar process occurs during anticipation of complex aversive stimuli as well, such as when individuals are able to anticipate the presentation of an unpleasant picture.

The aims of the present research are twofold. First, we aim to directly test the hypothesis that cuing accounts for the reduced aversive response previously observed (Sege et al., 2014) by comparing probe startle reactions to predictable, valence-cued pictures with startle reactions to similar pictures that are not preceded by a predictive cue. Second, this research aims to determine if response modulation subsequent to cuing is unique to unpleasant stimuli—as suggested by the conditioning-based hypothesis—or, alternatively, if cue-based modulation of the probe startle response occurs when either pleasant or unpleasant pictures are cued—that is, if cuing reduces the affective impact of any arousing stimulus. Thus, in the present study, participants viewed pleasant and unpleasant arousing pictures, as well as neutral pictures. If the arousal hypothesis is correct, we expect reduced startle potentiation when viewing cued unpleasant pictures (relative to neutral scenes) and, for cued pleasant pictures, an absence of the startle probe attenuation (again, relative to neutral) that is typically found when viewing arousing pleasant images that have not been cued (e.g., Bradley et al., 2001; Vrana, Spence, & Lang, 1988).

## Method

### Participants

Thirty-two undergraduates (16 women; $M_{age}$ 19.4, age range: 18–23) from a general psychology course at the University of Florida participated in this study for course credit. Study procedures were approved

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by the University of Florida Psychology Institutional Review Board; participants provided informed consent prior to participation and were allowed to withdraw at any time if they so chose. Reflex data from two participants were excluded due to excessive movement ($n = 1$) or equipment failure ($n = 1$), leaving a final sample of 30 participants with complete data.

### Design and Materials

Ninety-six pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) to comprise three hedonic content categories: romance (erotica and romantic scenes), violence (mutilated bodies and attack scenes), and people working (people engaged in mundane work activities).[1] Based on normative ratings (Lang et al., 2008), picture sets were constructed such that (a) violence was rated significantly more unpleasant than work, (b) romance was rated significantly more pleasant than work, and (c) both violence and romance scenes were rated significantly higher in arousal than work pictures.[2] Thirty-two different pictures comprised each content set; of these, 16 pictures were preceded by an anticipatory cue, and 16 were presented without a cue.

Cues were red, blue, and green rectangles presented full screen (1,024 × 768 pixels); cue color indicated the specific hedonic content that would be seen next (e.g., green = work, red = violence, blue = romance). Colors were counterbalanced across participants such that each content was predicted by each color. Cues were presented for 6 s and followed by the 3-s presentation of a grayscale picture from the anticipated content; a variable-length intertrial interval (ITI; 9 or 12 s) followed picture offset. Five additional pictures were presented during practice (startle habituation) trials at the beginning of the study; these trials were not analyzed.

The defensive blink startle reflex was elicited by a 50-ms, near-instantaneous rise time, 98.5-decibel white noise burst presented binaurally over headphones. A startle probe occurred 2 s after picture onset on half of all trials; the other half of trials did not include a probe. Probes were also presented during the ITI, 7.5 s after picture offset, on 10 trials.

Different presentation orders were generated such that, across orders, each picture was presented in the beginning, middle, and end of the experiment. Each order was arranged into eight blocks of 12 trials; each block contained two uncued and two cued pictures from each content category, one presented with a startle probe and one without. The sequence of trials within each presentation order was counterbalanced across orders such that (a) each trial type occurred equally often in the first or second half of a block, and (b) no more than two romance, violence, or work trials occurred in a row.

### Procedure

Following informed consent and sensor attachment, participants were told that they would see a variety of scenes depicting violence, romance, or people working, some preceded by a cue and others occurring without a cue. For the cued trials, participants were told which color would signal which hedonic content. Participants were also told to ignore noises heard over headphones throughout the study. Correct report of the color predicting each content was required prior to starting the experiment.

After the experiment and sensor removal, participants rated the pleasantness of viewing each picture category on 1 (*very unpleasant*) to 9 (*very pleasant*) scales (5 = *neutral*). Viewing violent pictures was rated as more unpleasant than viewing scenes depicting work activities, $t(29) = 8.34$, $p < .001$, and scenes of romance were rated as more pleasant than viewing everyday work pictures, $t(29) = 2.20$, $p = .03$. Ratings were not affected by the order of picture presentation (order, $F(2,32) = 0.73$, $p = .49$; Order × Content, $F(4,64) = 1.07$, $p = .38$).

### Data Collection and Analysis

Blinks were measured using 5-mm Ag/AgCl sensors, filled with appropriate electrolyte and placed over the left orbicularis oculi muscle. The raw electromyographic signal was sampled at 1000 Hz (50 ms preprobe to 250 ms postprobe), amplified by 30,000, band-pass filtered (90–250 Hz), rectified, and integrated (20 ms time constant). Offline, the peak magnitude of each blink response was scored using the Balaban, Losito, Simons and Graham (1986) procedure as implemented in VPM (Cook, 2001).

Following Bonnet, Bradley, Lang, and Requin (1995), blinks elicited during picture viewing were standardized for each subject using the mean and standard deviation of blinks elicited during ITIs (i.e., Picture-$ITI_{mean}/ITI_{SD}$). The resulting *z*-score values were linearly transformed to *T* scores for analysis and presentation ($[z*10] + 50$). This standardization uses an independent distribution of blinks (i.e., it does not include the experimental conditions) and provides a standard metric that can be used to interpret each score (i.e., average blink magnitude during the ITI is 50, so blinks elicited during picture viewing can be meaningfully compared to baseline based on whether they are significantly higher or lower than 50). As recommended (Blumenthal et al., 2005), raw untransformed startle data were also analyzed. Because the results of the raw and standardized startle analyses were statistically identical, only statistics using standardized data are presented (but see Table 1 for mean raw magnitude).

To examine cuing effects on blink reflex magnitude during picture viewing, reflex data were analyzed in a 3 (Hedonic Content: violence, romance, work) × 2 (Cue Type: uncued, cued) repeated measures analysis of variance (ANOVA) with follow-up paired-sample *t*-test comparisons. Greenhouse-Geisser-corrected degrees of freedom were used in omnibus analyses (see Jennings, 1987).

1. IAPS numbers: violence, 2811, 3000, 3001, 3010, 3015, 3030, 3053, 3060, 3064, 3068, 3069, 3080, 3102, 3120, 3130, 3131, 3168, 3170, 3500, 3530, 6212, 6313, 6350, 6520, 6550, 6563, 6571, 6821, 9163, 9413, 9414, 9423; romance, 4525, 4597, 4598, 4599, 4601, 4603, 4607, 4609, 4612, 4619, 4623, 4626, 4628, 4640, 4641, 4643, 4645, 4658, 4659, 4668, 4669, 4670, 4676, 4680, 4687, 4690, 4692, 4693, 4695, 4697, 4698, 4800; people working, 2038, 2039, 2102, 2191, 2217, 2221, 2235, 2308, 2309, 2372, 2377, 2382, 2383, 2390, 2394, 2397, 2400, 2410, 2411, 2488, 2515, 2570, 2575, 2579, 2597, 2598, 5455, 7550, 7632.

2. Normative ratings of hedonic valence from the IAPS (Lang et al., 2008) indicated that, compared to scenes of people working ($M = 5.1$), pictures of violence were more unpleasant ($M = 1.8$; $t(91) = 32.7$, $p < .001$) and romance pictures were more pleasant ($M = 6.8$; $t(91) = 15.8$, $p < .001$). Normative arousal ratings for scenes of violence ($M = 6.7$) and romance ($M = 5.9$) were more arousing than pictures of people working ($M = 3.4$; violence, $t(91) = 23.0$, $p < .001$; romance, $t(91) = 17.6$, $p < .001$). Because romantic scene pictures are generally less arousing than pictures depicting erotic couples, mutilation, or attack, the romance category was also less arousing than violence, $t(91) = 5.5$, $p < .001$.

**Table 1.** *Mean (Standard Deviation) Blink Reflex Magnitudes When Viewing Pictures Preceded by a Predictive Cue and Pictures Not Preceded by a Cue*

| | Standardized startle magnitude (*t* score) | | | |
|---|---|---|---|---|
| | Violence | People working | Romance | Content $F(2,28)$ |
| With a predictive cue | 54. 3 (11.5)[a] | 53.3 (9.9)[a] | 50.9 (11.7)[b] | 4.1* |
| Without a predictive cue | 57.4 (11.4)[a] | 52.5 (10.9)[b] | 49.8 (10.6)[c] | 22.2*** |
| | Raw startle magnitude (μv) | | | |
| With a predictive cue | 12.6 (8.1)[a] | 12.0 (6.6)[a] | 10.7 (6.7)[b] | 4.2* |
| Without a predictive cue | 14.1 (7.4)[a] | 11.3 (7.1)[b] | 10.0 (6.3)[c] | 22.1*** |

*Note*. Following Bonnet et al. (1995), blinks elicited during picture viewing were standardized using the mean and standard deviation of the blinks elicited during ITIs. This method standardizes blink magnitudes relative to a distribution that does not include experimental conditions, and provides a standard metric in which a *t* score of 50 equals the average blink response during the ITI. As recommended by Blumenthal et al. (2005), raw, untransformed startle data are also presented for comparison.
[a,b,c]Significant differences between individual contents within each cue type.
*$p < .05$. ***$p < .001$.

## Results

Figure 1 illustrates that different patterns of blink reflex modulation were apparent when viewing pictures that were preceded by a predictive cue and pictures that were not preceded by a cue: Content × Cue Type, $F(2,28) = 5.92$, $p = .005$, $\eta_p^2 = .17$. For pictures that did not include a cue, a main effect of hedonic content, $F(2,28) = 22.20$, $p < .001$, $\eta_p^2 = .43$, replicated previous studies: Blink reflexes were enhanced when participants viewed scenes of violence compared to pictures of mundane work activities, $t(29) = 5.04$, $p < .001$, $d = .43$, or romance, $t(29) = 5.55$, $p < .001$, $d = .69$, and reflexes were attenuated when viewing romance compared to work, $t(29) = 2.50$, $p = .018$, $d = .26$. On the other hand, the pattern of reflex modulation apparent when participants viewed pictures that had been predicted by a preceding cue: content, $F(2,28) = 4.12$, $p = .022$, $\eta_p^2 = .13$, was different than what has previously been found. Thus, when viewing violent scenes that were preceded by a cue, blink magnitude was no longer enhanced compared to blinks elicited when viewing work scenes that had been predicted, $t(29) = 1.10$, $p = .28$, $d = .09$. Alternatively, reflexes continued to be attenuated when viewing scenes of romance that had been predicted, compared to scenes of people working, $t(29) = 1.94$, $p = .046$, $d = .21$, or violent scenes, $t(29) = 2.74$, $p = .010$, $d = .25$, that were preceded by a cue.

A direct comparison of reflexes elicited during pictures preceded by a cue to reflexes elicited during pictures not preceded by a cue confirmed that differences were confined to the violent images: Thus, blink startle reflexes were smaller when viewing violent pictures that had been predicted by a cue than they were when viewing violent pictures that had not been predicted, $t(29) = 2.57$, $p = .016$, $d = .27$. Conversely, reflex strength did not differ when viewing predicted or unpredicted romantic scenes, $t(29) = 1.36$, $p = .18$, $d = .14$, nor did reflexes differ when viewing cued or uncued pictures of people working, $t(29) = 0.68$, $p = .50$, $d = .07$.

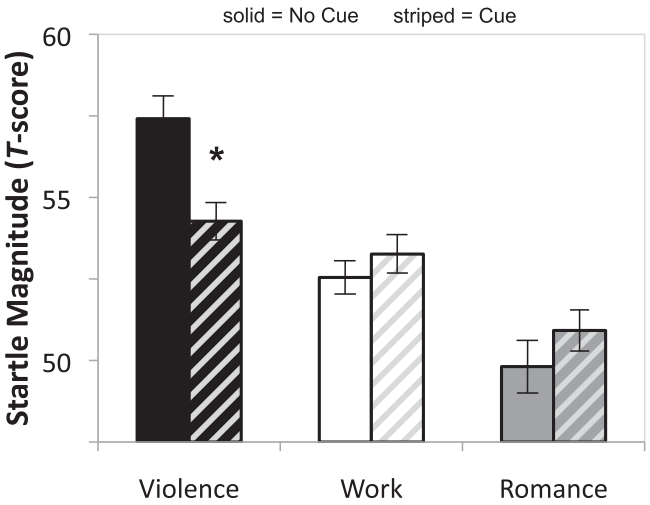


**Figure 1.** Blink startle modulation (and standard error) when viewing pictures that were not preceded by a predictive cue (solid) and pictures that were preceded by a cue (striped).

## Discussion

The typical pattern of enhanced startle reflexes during aversive (relative to neutral) picture viewing was not apparent when violent pictures were preceded by a cue that predicted the upcoming aversive content. Thus, the startle blink was not enhanced when a cue predicted upcoming violent content, whereas startle was reliably augmented in the absence of a predictive cue, replicating many previous studes (e.g., Bradley et al., 2001). Furthermore, whereas blinks were attenuated when viewing scenes of violence that had been preceded by a cue compared to uncued violent images, prior knowledge regarding upcoming content did not alter reflex modulation for pleasant scenes; rather, blink reflexes were attenuated when participants viewed scenes of erotica and romance (compared to neutral work scenes) regardless of whether these pictures were preceded by a cue or not. These data support the idea that having prior knowledge regarding upcoming picture content specifically attenuates defensive reactions to aversive events, rather than generally modulating both unpleasant and pleasant reactions.

Reduced defensive engagement when an aversive event is preceded by a cue could reflect decreased perceived aversiveness when individuals can prepare for an unpleasant event (Ison et al., 1990; Lykken et al., 1972; Lykken & Tellegen, 1974). Conditioning researchers suggest that preparatory coping might involve an increase in sensory thresholds that reduces the perceived intensity of an aversive stimulus such as a shock (Lykken & Tellegen, 1974). Alternatively, a more complex coping process could also be involved. For instance, Monat, Averill, and Lazarus (1972) assessed the degree to which participants employed avoidant

(e.g., "I thought about things not related to this experiment") or vigilant (e.g., "I thought about what the shock would feel like") coping strategies when anticipating predictable or unpredictable electric shocks; in that study, reports of vigilant coping increased when shock timing was made predictable by cuing, and participants also generally preferred cued, compared to uncued, shocks.

Regardless of the specific anticipatory process that dampens reactions to an aversive event, close coupling between a predictive cue and an aversive stimulus appears to be important, as less reliable signaling does not reduce defensive reactions as effectively, presumably due to increased event uncertainty (Ison et al., 1990; Monat et al., 1972). This might explain why repeated exposure to an unsignaled aversive picture does not reduce startle potentiation even when repetitions are massed across many contiguous repetitions (Ferrari et al., 2011). Although massed repetition might be expected to induce active anticipation, whether the upcoming scene will remain the same or change still remains uncertain even in a massed repetition context, perhaps making anticipatory coping of less utility. In addition, explicit cuing could engage a specific preparatory process that facilitates coping with the aversive event when it occurs, a preparatory process that is not engaged by mere repetition.

The fact that startle modulation during pleasant picture viewing was not altered by prior information regarding specific content is consistent with a hypothesis that coping is particularly important for aversive, but not for appetitive, events (Ison et al., 1990; Zvolensky, Lejuez, & Eifert, 2000; cf. Mineka & Hendersen, 1985). According to this view, knowing that an aversive event is about to occur reduces the degree to which the event disrupts ongoing homeostatic/consummatory processes and causes stress (Mineka & Hendersen, 1985), whereas this type of coping is not functional for positive events. Although predictability might not prompt active coping for pleasant events, Lykken and Tellegen (1974) suggest that anticipating a positive stimulus could be useful in facilitating detection of those events, and some research has shown that informative cuing does improve detection of stimuli that are presented at sensory threshold (Triesman & Howarth, 1959). If anticipation primarily facilitates detection of pleasant stimuli, then startle reflex attenuation might be enhanced specifically for cued, compared to uncued, pleasant scenes that are difficult to discern. In the current study, however, pleasant stimuli were readily discernible, such that content cuing did not have an impact on startle reactions.

Clinical theorists have hypothesized that anticipatory coping mechanisms like the one described here might be ineffective for highly anxious or fearful individuals (e.g., Baas, 2013; Delgado et al., 2009). Consistent with this hypothesis, a prior study found that men reporting very high fear of snakes continued to show startle enhancement when viewing pictures of snakes even when these pictures were reliably cued (Sabatinelli, Bradley, & Lang, 2001). It could be that, for these highly fearful individuals, anticipatory coping is ineffective in countering the defensive engagement that is induced by aversive or fear-relevant events. Alternatively, given that high-fear individuals show exaggerated startle augmentation when viewing fear-relevant pictures (e.g., Hamm, Cuthbert, Globisch, & Vaitl, 1997), anticipatory coping could reduce, but not completely eliminate, startle potentiation in high-fear individuals. Given these alternative possibilities, additional studies that include predictable and unpredictable fear-relevant stimuli would assist in determining whether anticipatory coping is less effective for high-fear and/or highly anxious individuals.

In summary, cuing the specific content of an upcoming aversive picture reduced defensive engagement as measured by the startle blink reflex. In future studies, it will be important to determine the neural mediators of cue-related defensive attenuation. Human functional imaging studies have identified several brain regions that show enhanced activation when viewing unpleasant, compared to neutral, pictures (see Sabatinelli et al., 2011), as well as regions that are active during aversive anticipation (e.g., Bermpohl et al., 2006; Mechias, Etkin, & Kalisch, 2010). Measuring neural activity during exposure to cued and uncued aversive pictures could help to determine if reduced activation in regions involved in unpleasant picture processing (e.g., the amygdala), or rather increased activation in regions that mediate anticipatory coping (e.g., the dorsomedial prefrontal cortex), represents the substrate for the reduced defensive engagement that occurs when aversive stimuli are reliably cued.

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