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Startle modulation during emotional anticipation and perception

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Abstract

The startle reflex is potentiated when anticipating emotional, compared to neutral, pictures. This study investigated the time course of reflex modulation during anticipation and the impact of informative cuing on picture perception. Colors were used to signal the thematic content of emotional and neutral scenes; blink response modulation was measured by presenting acoustic startle probes 3, 2, or 1 second before picture onset or 2 seconds after picture onset. During anticipation of neutral scenes, blink magnitude showed increasing attenuation as picture onset approached, consistent with a modality-directed vigilance account. Conversely, when anticipating emotional scenes, reflex magnitude did not change over time, and blinks elicited closest to picture onset were potentiated compared to neutral. During perception, the expected reflex potentiation for unpleasant pictures was not found, suggesting that cuing may dampen defensive activation.

Keywords

anticipation; perception; emotion; pictures; startle

The blink component of the startle reflex has been a useful tool in probing emotional processing. A considerable body of research shows that, relative to emotionally neutral picture viewing, the blink reflex is potentiated during perception of highly arousing unpleasant pictures and is attenuated when viewing arousing pleasant pictures — reflecting the net influence of motivation (defensive or appetitive) and attention (Bradley, Codispoti, & Lang, 2006). During anticipation rather than perception of emotional pictures, however, a different pattern of startle modulation is found. When startle probes are delivered during a cue signaling the affective content of an upcoming picture (rather than during the picture itself), reflexes are potentiated when anticipating either unpleasant or pleasant, compared to neutral, pictures (Sabatinelli, Bradley, & Lang, 2001; Nitschke, Larson, Smoller, Navin, et al., 2002; Dichter, Tomarken, & Baucom, 2002). In anticipation, therefore, startle modulation appears to index emotional salience rather than specific hedonic (pleasant or unpleasant) content.

Earlier studies examining reflex modulation during anticipation of neutral stimuli (e.g., tones, lights, etc.) have found that blink magnitude varies depending on the sensory modality of the awaited stimulus and changes as the onset of this stimulus approaches (Anthony, 1985; Patrick & Berthot, 1995). For instance, during anticipation of visual or

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vibrotactile “go” signals, noise-elicited startle blinks become increasingly attenuated across the anticipatory interval (e.g., Bauer, 1982; Anthony, 1985; Anthony & Putnam, 1985). When expecting an acoustic stimulus, on the other hand, noise-elicited blinks are potentiated, rather than attenuated (Putnam & Meiss, 1981; Patrick & Berthot, 1995). In each case, effects are more pronounced as stimulus onset approaches, suggesting increasing vigilance towards the modality of the expected event across the cuing interval (see Anthony, 1985 for a review). Modulation of startle reflexes across the anticipatory interval has not been as thoroughly addressed for emotional stimuli. Previous studies have either used a single startle probe that was presented just prior to picture onset (Nitschke et al., 2002; Dichter et al., 2002) or two probe delays that were both proximal (within 1.5 seconds) to onset (Sabatinelli et al., 2001).

The current study investigated the time-course of reflex modulation when individuals anticipate highly arousing emotional pictures by presenting acoustic startle probes 3, 2, or 1 second prior to picture onset. Six-second color cues were used to signal the thematic content of an upcoming scene from one of three different categories (“violence,” “romance,” or “everyday events”), each comprised entirely of normatively rated unpleasant, pleasant, or emotionally neutral pictures. Based on previous findings (e.g., Bauer, 1982; Anthony & Graham, 1985), we expected that the acoustically-elicited blink reflex would show increasing attenuation across the cuing interval when anticipating neutral pictures. The central question concerned changes in reflex modulation across the anticipatory interval for emotional stimuli. If attentional vigilance characterizes emotional anticipation, we expected that reflexes would be similarly attenuated as picture onset approached, despite an overall elevation in reflex magnitude for emotional relative to neutral cues. To the extent that a different pattern of modulation across time occurs for emotional anticipation, it would suggest that the processes mediating reflex modulation are different when anticipating highly arousing emotional, compared to neutral, events.

A second issue addressed in this research concerns the impact of *a priori* information regarding picture content on reflex modulation during actual picture perception. Classical conditioning studies have shown that emotional reactions to an aversive stimulus are dampened when a cue reliably signals its occurrence, suggesting that prior knowledge or expectation can attenuate stimulus aversiveness (Lykken & Tellegen, 1974). For example, in eye blink conditioning studies using an air puff as an unconditioned stimulus (UCS), responses to the UCS decrease more rapidly over trials when this stimulus is reliably preceded by the conditioned stimulus (CS) than when the UCS is presented on only a portion of the CS trials and is thus unpredictable (Dufort & Kimble, 1958; Kimble & Ost, 1961). Knowing the content of an aversive picture prior to its presentation may have a similar attenuating effect on reflex modulation during perception. Thus, startle probes were presented during picture perception on some trials in the current study; based on the conditioning data, reduced modulation of the startle response, particularly for aversive scenes, was predicted.

Method

Participants

Thirty-eight undergraduates (19 female) from the University of Florida participated in this study for course credit. Startle data from 4 participants were not used (1 due to excessive movement and 3 due to very low startle probability).

Design and Materials

Cues were red, blue, and green rectangles (360 X 360 pixels) presented centrally for 6 seconds. Each cue signaled the upcoming 3-second presentation of a picture depicting "violence," "romance," or an "everyday event." Sixty grayscale pictures from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) were selected such that each content category contained 20 images representing a clear and easily communicated content theme.[1] Based on normative ratings (Lang et al., 2008), sets were constructed such that, 1) violence was rated as significantly more unpleasant and romance as more pleasant than everyday events (which were affectively neutral), and; 2) violence and romance were more arousing than everyday event pictures.[2] A variable-length inter-trial interval (12-21 seconds) followed picture offset.

The startle probe was a 96-decibel white noise burst (50 ms, instantaneous rise time) presented binaurally over headphones. One probe was presented on every trial, either: 1) 3, 2, or 1 second prior to picture onset; 2) during picture perception (2 seconds after picture onset), or; 3) during the inter-trial interval (7.5 seconds after picture offset). An equal number of probes (4) occurred at each presentation time for violence, romance and everyday event trials. Sixty analyzed trials were presented; 4 additional startle habituation trials were not analyzed. Different presentation orders were generated such that, across orders, a startle probe was presented at each of the different times for every IAPS picture, and each picture was presented in the beginning, middle, and end of the study. Orders were arranged into 5 blocks of 12 trials; in each block, one startle probe was presented at each time (3, 2, and 1 second prior to picture onset or during picture viewing) for each content (violence, romance, everyday events). Blocks within each order were balanced such that each type of trial occurred equally often in the beginning, middle, and end of a block, and no more than two violence, romance or everyday event trials occurred in a row.

[1]Pictures of violence depicted scenes of *attack* and *mutilation*, pictures of romance depicted *erotica* and *romantic couples*, and pictures of everyday events depicted people working or in typical settings. IAPS Numbers: Violence, 2811, 3000, 3001, 3010, 3053, 3060, 3064, 3069, 3080, 3120, 3130, 3500, 3530, 6212, 6313, 6315, 6520, 6550, 6563, 6821; Romance, 4597, 4598, 4599, 4604, 4612, 4619, 4624, 4628, 4640, 4641, 4643, 4658, 4659, 4668, 4690, 4693, 4695, 4697, 4698, 4800; Everyday, 2032, 2036, 2102, 2191, 2273, 2308, 2309, 2359, 2374, 2377, 2382, 2383, 2384, 2390, 2396, 2397, 2411, 2521, 2840, 2850

[2]Normative ratings of hedonic valence (1 = very unpleasant, 9 = very pleasant, 5 = neutral) and arousal (1 = not arousing, 9 = very arousing) are available for the IAPS. As intended, violence pictures were more unpleasant ($M = 1.91$; $t(60) = 5.19$; $p < .001$) and romance pictures were more pleasant ($M = 6.70$; $t(60) = 3.11$; $p < .01$) than everyday event pictures, which were neutral ($M = 5.34$). Both violence ($M = 6.77$) and romance ($M = 6.03$) were more arousing than everyday events ($M = 3.45$; violence, $t(60) = 4.99$, $p < .001$; romance, $t(60) = 4.24$, $p < .001$). Because *romantic couple* pictures are generally less arousing than *erotic*, *mutilation*, and *attack* pictures, the romance category was also somewhat less arousing than violence ($t(60) = 2.41$, $p < .05$).

Procedure

Following consent and sensor attachment, the participant was informed about the nature of the study and told which color would signal “violence,” “romance,” and “everyday event” contents. The participant was also instructed to press a button if the picture presented after a cue was incorrect (to encourage sustained attention; no trials were presented in which the cue and the picture mismatched). Finally, the participant was told to ignore noises heard over headphones.

After the experiment and sensor removal, the participant rated the pleasantness of anticipating and of viewing each picture type on separate 1 (very unpleasant) to 7 (very pleasant) scales (4 = neutral). Both the anticipation and the perception of violence were rated as more unpleasant than everyday events ($t(33)$'s = 5.38 & 7.96, respectively, $p < .001$), and anticipation and perception of romance were each rated as more pleasant than everyday events ($t(33)$'s = 2.73 & 2.63, respectively, $p < .001$).

Data Collection & Analysis

Sensors placed over the left orbicularis oculi muscle measured raw electromyographic signal, which was sampled at 1000 Hz (50ms pre-probe to 250ms post-probe), amplified, band-pass filtered (90-250 Hz), rectified and integrated (20ms time constant). Offline, magnitude of each blink response was scored using the Balaban, Losito, Simons & Graham (1987) procedure as implemented in VPM (© Cook; Cook, 1997), in which the peak of the response is deviated from the midrange of the 10 data points sampled immediately prior to blink onset. For analysis, startles were standardized for each participant relative to the mean and standard deviation of blinks elicited during the inter-trial interval and expressed as t-scores ([z*10]+50; mean inter-trial interval magnitude = 50).

Data from the anticipatory interval were analyzed in a 3 (Content: violence, romance, everyday events) X 3 (Probe Time: 3 s, 2 s, 1 s prior to picture onset) repeated-measures Analysis of Variance (ANOVA). The significant interaction was followed up with simple main effects tests, as well as linear trend tests across 3, 2, and 1-second probes for each content and pairwise comparisons of contents for each individual probe time.

Startle modulation during perception was analyzed in a repeated-measures ANOVA using thematic content (romance, everyday events, violence) as a factor. An exploratory analysis was also conducted to examine affective modulation across the experiment, in which reflexes elicited during the first presentation of each content (e.g., violence, romance and everyday event) were compared to reflexes elicited on later (i.e., 3rd and 4th) trials in a 2 (Trial: early, late) X 3 (Content) repeated-measures ANOVA.

Greenhouse-Geisser corrected *F*-values are reported for all significant omnibus tests; effect size estimates (partial eta-squared for ANOVA, Cohen's *d* for *t*-tests) are also reported.

Results

Anticipation

Figure 1 illustrates startle modulation across the anticipatory interval. Startle reflex modulation varied as function of picture content and probe presentation time (Content X Probe Time interaction $F(2,32) = 3.37$, $p < .05$, $\eta^2 = 0.09$). When anticipating pictures of everyday events, reflexes were increasingly attenuated as picture onset became more proximal, evidenced by a significant linear decrease across the anticipatory interval (linear trend $F(1,33) = 3.77$, $p < .05$, $\eta^2 = 0.11$). Conversely, during anticipation of violence or romance pictures, magnitude of the blink response to acoustic probes remained the same across the cue interval (linear trend for each content was non-significant; see Figure 1). As a result of these modulatory patterns, blinks were larger when anticipating pictures of violence ($t(33) = 3.76$, $p < .001$, $d = 0.75$) or romance ($t(33) = 2.07$, $p < .05$, $d = 0.48$) compared to pictures of everyday events for probes presented 1 second prior to picture onset (Content main effect, $F(2,32) = 5.90$, $p < .01$, $\eta^2 = 0.16$). Differences as a function of content were not significant for the 3- or 2-second probes.

Perception

Figure 2 depicts startle magnitude during perception of violence, romance, and everyday event pictures. Startle was modulated as a function of content during picture viewing ($F(2,32) = 3.62$, $p < .05$, $\eta^2 = 0.10$), with blinks significantly attenuated during perception of romance pictures compared to either everyday scene ($t(31) = 2.51$, $p < .05$, $d = 0.52$) or violence ($t(31) = 2.15$, $p < .05$, $d = 0.48$) pictures. When averaged over all trials, blink magnitude did not differ for violence and everyday events. However, exploratory analyses that examined change in blink response modulation across trials showed different modulatory patterns during early and late portions of the experiment ($F(2,32) = 3.94$, $p < .05$, $\eta^2 = 0.12$). A typical pattern of modulation was found on the first trial (Content main effect, $F(2,24) = 3.29$, $p < .05$, $\eta^2 = 0.08$); compared to pictures of everyday events, blinks were potentiated when viewing pictures of violence ($t(25) = 2.29$, $p < .05$, $d = 0.59$) and attenuated when viewing pictures of romance ($t(25) = 1.96$, $p < .05$, $d = 0.31$). Conversely, for late trials (Content $F(2,27) = 3.51$, $p < .05$, $\eta^2 = 0.09$), blinks were attenuated, compared to everyday events, both when viewing pictures of romance ($t(33) = 2.29$, $p < .05$, $d = 0.53$) and also when viewing pictures of violence ($t(33) = 1.99$, $p < .05$, $d = 0.35$).

Discussion

In this study, startle reflexes elicited just prior to picture onset were enhanced when anticipating emotional (violence or romance) compared to neutral pictures, consistent with previous findings (Sabatinelli et al., 2001; Nitschke et al., 2002; Dichter et al., 2002). Furthermore, whereas reflexes became increasingly attenuated over time with the approaching onset of a neutral picture, magnitude of the blink response during emotional cues was sustained across the anticipatory interval. Finally, during picture perception, reflexes were attenuated for unpleasant compared to neutral pictures on later trials, suggesting that anticipation may dampen the defensive activation usually prompted by arousing aversive content.

The reduction in startle magnitude across the cuing interval during anticipation of neutral pictures is consistent with a cross-modal attention mechanism (Anthony, 1985). According to this account, anticipation is a vigilant process in which attention is directed towards the sensory modality of the to-be-presented stimulus; thus, when anticipating visual events, the noise-elicited startle reflex is increasingly attenuated, reflecting direction of attention towards the visual, and away from the auditory, sensory channel (e.g., Anthony, 1985; Anthony & Graham, 1985). Other research suggests that the startle reflex can be modulated by multiple processes in emotional contexts, e.g., reflex inhibition with increased attention/vigilance and reflex potentiation attributed to emotional arousal (e.g., Bradley et al., 2006). Consistent with this multi-process view, whereas modality-directed vigilance prompted blink inhibition in anticipation of low-arousing neutral content, cues signaling presentation of emotionally arousing pictures resulted in sustained startle responding across the anticipatory interval.

A pattern of relative potentiation of the startle reflex that is sustained across time for emotional compared to neutral cues is similar to the pattern found in studies of emotionally arousing imagery. Thus, startle reflexes are reliably potentiated when individuals vividly imagine either unpleasant or pleasant compared to neutral events (Vrana & Lang, 1990; Witvliet & Vrana, 1995; Witvliet & Vrana, 2000; Miller, Patrick, & Levenston, 2002), and reflex potentiation is sustained across the imagery interval (Robinson & Vrana, 2000). These similarities suggest that emotional anticipation may evoke spontaneous imagery of the awaited emotional content. Consistent with this hypothesis, neuroimaging research has reported functional activity in similar limbic and neocortical regions (e.g., amygdala, supplementary motor area, and inferior frontal gyrus) during emotional anticipation and emotional imagery (Nitschke, Sarinopoulos, Mackiewicz, Schaefer, & Davidson, 2006; Bermpohl, Pascual-Leone, Amedi, Merabet, et al., 2006; Sabatinelli, Lang, Bradley, & Flaisch, 2006). Together, the data support a hypothesis that anticipation of emotionally evocative events involves mental imagery and not solely modality-directed vigilance. Within-subject studies measuring startle response and brain activation during both emotional anticipation and emotional imagery could directly test this hypothesis.

During picture perception, startle reflexes were significantly attenuated (compared to neutral pictures) for pleasant pictures that were reliably cued, consistent with the classic pattern of modulation observed during un-cued picture perception (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1997). On the other hand, startle probes presented during unpleasant picture viewing did not consistently prompt the potentiation of blink magnitude that has previously been observed. This response diminution may be similar to the reduced response to an aversive UCS observed in conditioning studies when a CS is its invariant, reliable predictor. This phenomenon, termed “negative preception,” assumes that anticipatory uncertainty augments the aversiveness of a UCS, such that, as the UCS becomes more predictable, its perceived intensity is reduced (Lykken & Tellegen, 1974; Ison, Sanes, Foss, & Pinckney, 1990). In the current study, not only were aversive cues reliably followed by presentation of aversive pictures, but the cue also indicated the specific unpleasant content (i.e., violence). In effect, reliable, specific cuing provides considerable information about upcoming picture content, apparently reducing defensive mobilization.

Assuming it reduces defensive activation, anticipation could be considered a natural mechanism for coping with aversive events. This is consistent with a suggestion from the clinical literature that anticipatory coping may be overactive in psychiatric disorders marked by persistent worry and apprehension (e.g., generalized anxiety disorder; Borkovec & Inz, 1990). A similar anticipatory mechanism, on the other hand, could be deficient in focal fear disorders that are marked by exaggerated response to fear stimuli and cognitive or behavioral avoidance (e.g., specific phobia). For instance, in a previous study, cues that reliably signaled the upcoming presentation of snake pictures did not reduce defensive activation in snake-fearful participants (Sabatinelli et al., 2001). An interesting future study would directly compare reflex modulation during anticipation and perception of fear-relevant and fear-irrelevant aversive pictures to determine if specific fear maintains defensive responding in spite of *a priori* cues.

In summary, blink startle magnitude was increasingly attenuated when anticipating the presentation of a neutral picture (consistent with a hypothesis of modality-directed vigilance), but was potentiated and sustained during anticipation of emotional pictures (similar to reflex modulation during emotional imagery). Anticipation also attenuated startle potentiation during aversive picture perception, suggesting that anticipation may dampen defensive responding. Because animal research shows that the amygdala is a critical brain structure mediating defensive startle potentiation (e.g., Hitchcock and Davis, 1986), and functional imaging research in humans finds robust amygdala activation during unpleasant perception (Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005), future research could determine whether amygdala activity during picture viewing similarly varies when cues predict picture content.

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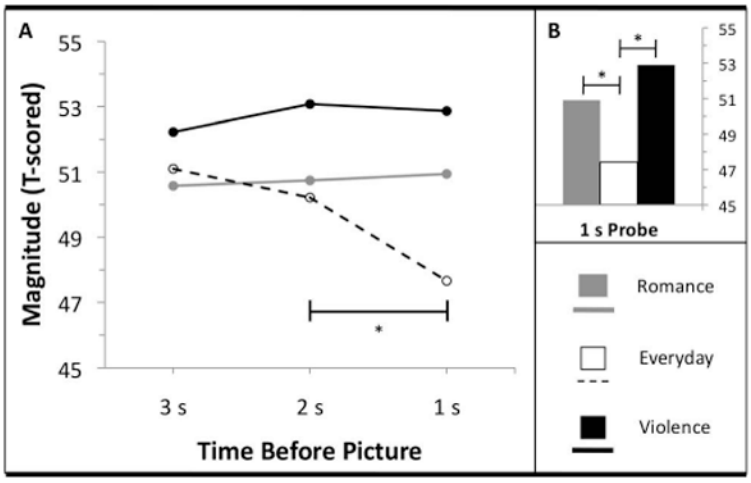

Figure 1.

Modulation of blink startle response during anticipation. A) Standardized blink magnitude averaged for each probe delay. B) Averaged magnitude for probes presented just prior to picture onset. *Note:* Inter-trial interval=50.

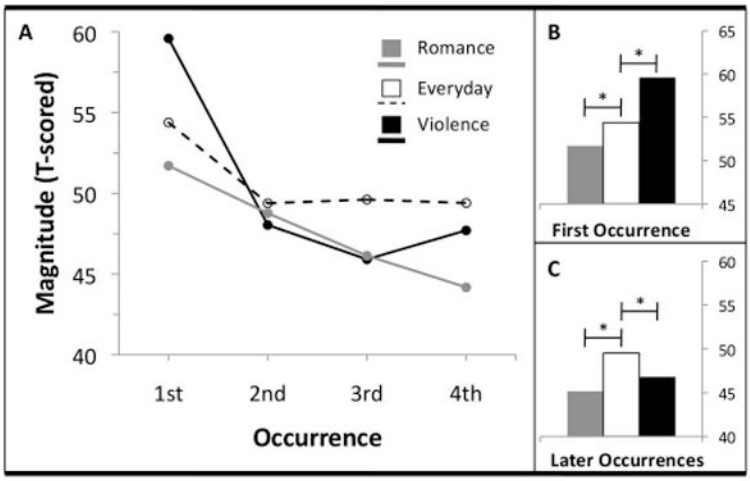

Figure 2.

Modulation of the blink startle response during perception. A) Standardized blink magnitude for each picture probe occurrence across trials. B) Blink magnitude for the first probe occurrence. C) Blink magnitude averaged across 3rd and 4th probe occurrences. *Note:* Inter-trial interval=50.