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Short communication
**Startle modulation before, during and after exposure to
emotional stimuli**

Gabriel S. Dichter, Andrew J. Tomarken*, Brian R. Baucom

Department of Psychology, Vanderbilt University, 301 Wilson Hall, South Nashville, TN 37240, USA

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Abstract

Although affective modulation of the startle reflex is a highly replicable effect, the majority of studies have administered startle probes during exposure to affective stimuli. To examine more comprehensively the temporal course of startle potentiation, we assessed blink modulation before, during and immediately after exposure to positive, negative and neutral pictures. During each trial, cues about the affective content of pictures were presented, after which acoustic startle probes were delivered either before picture onset, during picture onset or immediately after picture offset. As expected, we observed a linear relation between picture valence and startle amplitude during picture viewing. Surprisingly, startle amplitude was larger while anticipating pleasant and unpleasant pictures relative to neutral pictures. No significant effects were observed during the offset phase. These results indicate that startle modulation is conditional upon temporal factors linked to stimulus onset and offset. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

There is a variety of evidence that the startle reflex to exteroceptive stimuli with an abrupt onset is modulated by the emotional state of the organism (e.g. Vrana et al., 1988; Bradley et al., 1993). Research has shown that when individuals

view pictures that range in valence (i.e. unpleasant/pleasant) and arousal (i.e. excited/calm), eyeblink response is modulated by the emotional content of the picture (e.g. Lang et al., 1990).

The clear majority of studies with humans have investigated startle modulation during exposure to affective stimuli. It is important, however, to examine the full chronometry of a physiological response (Tomarken, 1999). The purpose of this study was to assess startle modulation while individuals are anticipating and viewing affective stimuli and after individuals have viewed such sti-

* Corresponding author. Tel.: +1-615-243-7539; fax: +1-815-371-0232.

E-mail address: gabriel.s.dichter@vanderbilt.edu (G.S. Dichter).

muli during an offset phase. We predicted a linear relation between picture valence and startle amplitude during all three experimental phases. This relation during picture viewing is a well-replicated effect (e.g. Vrana et al., 1988; Bradley et al., 1993).

Several studies have investigated startle potentiation during the anticipation of noxious stimuli. For example, Grillon and colleagues (Grillon et al., 1991, 1993) observed potentiated startle responses while participants anticipated a shock. Other researchers have found a similar effect when participants anticipated a noxious noise blast (Patrick and Berthot, 1995) and aversive pictures (Cook et al., 1992). These authors concluded that it was the valence (i.e. unpleasantness) of the anticipated stimuli that potentiated the startle response. However, these studies did not evaluate startle modulation during the anticipation of pleasant, as well as unpleasant, stimuli, and thus it is unclear whether startle potentiation in these contexts was due to the valence or arousal of the anticipated stimuli.

Finally, we are aware of two studies that investigated startle modulation after the offset of affective stimuli. Larson et al. (1998) reported a linear relation between stimulus valence and startle amplitude after exposure to affective pictures, although these effects appeared to be weaker than those observed during exposure to affective stimuli. In addition, the effects were not replicable across experimental sessions. Bradley et al. (1993) reported no relation between valence and startle magnitude after picture offset. Thus, the few studies that have addressed post-offset startle modulation have yielded somewhat inconsistent results.

In summary, in the current study we attempted: (1) to replicate affective startle modulation while participants viewed emotional pictures; (2) to evaluate whether anticipatory startle modulation is contingent on stimulus valence or arousal; and (3) to determine whether affective startle modulation occurs after the offset of emotional pictures. Because pictures generally induce only a transient emotional impact, we predicted that the relation between picture valence and startle mag-

nitude would be stronger while viewing pictures than during the other two conditions.

2. Method

Participants were 43 introductory psychology students (23 female, 20 male, mean age = 18.2 years, S.D. = 0.61 years). Participants were told that they would see pictures on a monitor, and that a meaningful arrow would precede the presentation of each picture. An 'up-arrow' indicated that a pleasant picture was to follow, a 'down-arrow' indicated that an unpleasant picture was to follow, and a 'sideways-arrow' indicated that a neutral picture was to follow. Arrows were large, black block figures on a white background. Startle probes were presented over Telephonics TDH-49P headphones. Participants were told that they would periodically hear brief sounds and that they should try to ignore these sounds.

Pictures were selected from the International Affective Picture System (IAPS, Lang et al., 1997). These pictures depict a variety of stimuli and elicit a range of responses on the dimensions of valence and arousal. On the basis of their normative valence and arousal ratings, we selected six sets of 67 pictures (three sets each for males and females, each participant viewed one set). Seven pictures in each set were used during a habituation phase before exposure to the experimental stimuli. The remaining 60 pictures were divided equally into the three valence categories of pleasant, unpleasant and neutral. Based on picture-by-picture matching, the six sets were equated on the mean and distribution of valence and arousal ratings. Each trial consisted of a 2 s cue arrow indicating picture valence, 4 s of no visual stimulation ('anticipatory phase'), 6 s picture presentation ('viewing phase'), and 9 s no visual stimulation ('offset phase'). The inter-trial interval (ITI) was 16–24 s (mean = 20 s). Acoustic startle probes were presented during the anticipatory, viewing or offset phases. Anticipatory probes were presented 1.5–2.5 s (mean = 2 s) after offset of the informational cue. Viewing probes were presented 3.5–4.5 s (mean = 4 s) after the onset of

the picture. Offset probes were presented 1.5–2.5 s (mean = 2 s) after the offset of the picture.

Two of the trials in the habituation set contained anticipatory probes, two contained viewing probes, two contained offset probes and one trial contained no probe. During the 60-trial experimental phase, 18 trials contained anticipatory probes, viewing probes and offset probes, respectively, and six trials contained no probes. Thus, there were six trials in each of the nine cells produced by the crossing of valence category (pleasant/neutral/unpleasant) \times phase (anticipatory/viewing/offset). Probes from each of the cells were equally distributed throughout the series of trials. To diminish predictability, six probes were also presented during ITIs.

The eyeblink component of the startle reflex was measured by bipolar recording of the electromyographic (EMG) activity below the left eye with two miniature Ag–AgCl electrodes filled with electrolyte paste. A ground electrode was placed on the forehead. All electrode impedances were below 20 k Ω . The acoustic startle probe was a binaurally presented 50 ms, 100 dB white-noise burst with an instantaneous rise time. The raw EMG signal was filtered (bandpass from 10 to 500 Hz), amplified (gain = 2000) and sampled at 1024 Hz. The digitized EMG was band-pass filtered off-line to highlight signals between 80 and 240 Hz. The data were then digitally rectified and low-pass filtered off-line by integrating values in 32 ms time windows. We computed the peak EMG amplitudes in search windows between 10 and 250 ms after the onset of the startle probes. After deletion of trials with artifact (less than 0.3% of the trials), we averaged amplitude measures across each of the nine levels of the valence (pleasant/neutral/unpleasant) \times probe presentation (anticipatory/during/after) design.

Following the presentations of both the habituation and experimental sets, the same two sets were presented again without startle probes. Participants controlled picture exposure duration and rated each picture with respect to emotional valence and arousal using a nine-point Likert scale. The time spent viewing each picture was recorded as a behavioral measure of interest (Hamm et al., 1997).

All analyses were performed on data from the experimental sets only. We tested for startle modulation effects with a gender (male, female) \times valence (pleasant, neutral, unpleasant) \times probe presentation (anticipation, viewing, offset) repeated measures ANOVA as well as planned linear contrasts across levels of the valence factor within each viewing phase. We tested for effects of picture rating and picture viewing time during the ratings portion of the study with gender (male, female) \times valence (pleasant, neutral, unpleasant) repeated measures ANOVAs as well as planned linear and quadratic contrasts across levels of the valence factor. All omnibus repeated measures effects were evaluated using multivariate test criteria, which do not require that repeated measures data meet the assumption of sphericity (e.g. Vasey and Thayer, 1987). Significant omnibus effects on startle measures were followed up by post-hoc quadratic trend polynomial contrasts, which supplemented the planned linear trend contrasts.

3. Results and discussion

There were no main effects or interactions involving gender on any of the primary dependent variables, all P 's > 0.05. Fig. 1 shows the magnitudes of startle responses to positive, negative

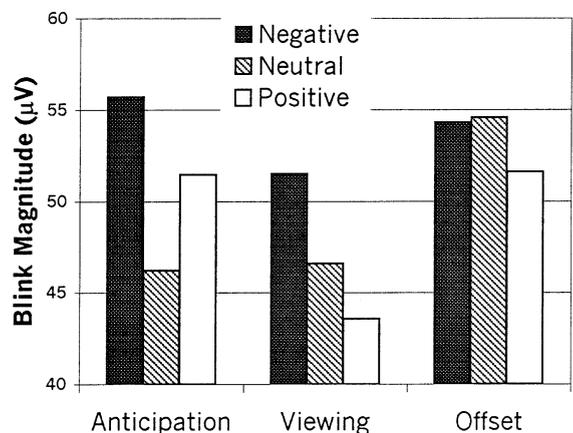


Fig. 1. Startle reflex magnitudes (in μ V) while anticipating, viewing and after offset of pleasant, neutral and unpleasant pictures.

and neutral pictures averaged across gender during the three probe presentation conditions. The ANOVA on startle amplitude revealed main effects for phase, $F_{(2,40)} = 4.95$, $P < 0.02$, and valence, $F_{(2,40)} = 4.83$, $P < 0.02$. However, as indicated by Fig. 1, the effects of valence were conditional upon phase, valence \times phase $F_{(4,38)} = 6.00$, $P < 0.001$. Simple effects analyses assessing the effects of valence within each of the three phases indicated a significant effect during the anticipatory phase, $F_{(2,40)} = 5.92$, $P < 0.01$, a nearly significant effect during the viewing phase, $F_{(2,40)} = 3.09$, $P < 0.06$, but no significant effect during the offset phase $F_{(2,40)} = 1.86$, $P > 0.15$. Perhaps most importantly, planned and post-hoc trend analyses conducted within each phase indicated a highly significant quadratic effect during the anticipatory phase, trend $F_{(1,41)} = 12.12$, $P < 0.001$ and a significant linear effect during the viewing phase, trend $F_{(1,41)} = 6.14$, $P < 0.02$. As depicted in Fig. 1, during the anticipatory phase, pleasant and unpleasant pictures elicited larger responses than neutral pictures. In contrast, consistent with previous findings (e.g. Lang et al., 1990), blink magnitudes during the viewing phase were largest when participants viewed unpleasant pictures and smallest when participants viewed pleasant pictures.

The design structure for the analyses of participants' self-report and behavioral measures was identical to that used for the startle measures, with the exception that planned quadratic contrasts were used on the arousal and viewing time measures. As would be expected, analyses of the self-report responses to pictures indicated a main effect for valence on valence ratings, $F_{(2,40)} = 376.92$, $P < 0.0001$. Pictures categorized as negative were judged most unpleasant and positive pictures were judged most pleasant, yielding a significant linear trend, $F_{(1,41)} = 714.66$, $P < 0.0001$. The three types of pictures also elicited significantly different arousal ratings, $F_{(2,40)} = 117.54$, $P < 0.0001$. Pictures categorized as both unpleasant and pleasant were judged more arousing than neutral pictures, quadratic trend $F_{(1,41)} = 194.84$, $P < 0.0001$. There was a main effect of valence on viewing time, $F_{(2,39)} = 15.98$, $P < 0.0001$. Both pleasant and unpleasant pictures

were viewed for significantly longer than neutral pictures, quadratic $F_{(1,40)} = 30.76$, $P < 0.001$.

While the linear trend observed during the viewing phase is a well-established finding, our most novel and provocative finding was the quadratic effect observed during the anticipatory phase. Pictures that elicited high levels of arousal (pleasant and unpleasant) clearly induced greater startle amplitudes than low-arousing neutral pictures. Previous findings by Grillon and colleagues (Grillon et al., 1991, 1993) indicate larger startle responses during an anticipatory phase in threat, relative to non-threat, conditions. These results left unclear whether it is the pleasantness vs. unpleasantness of anticipated stimuli or their arousing properties that elicits startle potentiation. Our findings indicating larger responses to both pleasant and unpleasant stimuli suggest that such potentiation is linked to the anticipation of arousing stimuli.

After the completion of the present study, we became aware of two other studies examining startle modulation in anticipation of affective stimuli. Sabatinelli et al. (in press) examined startle modulation in snake phobic participants while a neutral cue signaled whether an upcoming picture portrayed snakes, erotica or household objects. These authors presented startle probes 4.0 or 5.5 s after onset of the cue. Consistent with our results, they found a quadratic relation between anticipated picture valence and startle amplitude such that larger blinks were elicited when participants anticipated either pictures of erotica or snakes, relative to neutral pictures. Our findings extend these results to a more general array of stimuli and unselected participants.

In an unpublished experiment that used a paradigm similar to that of the present study, Erickson (1996) examined anticipatory startle modulation in response to pleasant and unpleasant pictures. Startle responses to probes occurring relatively early during a 6 s anticipatory interval (3.25 s after the onset of the cue) showed a quadratic relation to cue valence. These findings are consistent with our results that were obtained by probing 3.5–4.5 s after warning cue onset. Startle responses to probes occurring relatively late during this interval (5.25 s after the

onset of the cue) showed a linear relation to cue valence. Thus, the effects that we observed may be conditional upon the precise timing of startle probes relative to the onset of the warning cue and/or the onset of the anticipated affective stimulus.

The psychological mechanisms underlying our anticipatory findings are unclear. Bradley et al. (1993) observed a quadratic pattern indicating attentional modulation of the startle response when probes were delivered soon after picture onset (e.g. 300 ms) during the viewing phase. They observed larger responses to neutral pictures than to arousing pictures. Note that our quadratic pattern during the anticipatory phase is essentially the inverse of this pattern. We suspect, however, that our findings also reflect attentional processes.

Combining our results and those of Sabatinelli et al. (in press) and Erickson (1996), we speculate that there may be two distinct phases during the anticipation of a stimulus that modulate startle potentiation. Soon after an informative cue about a future stimulus, the organism acts conservatively to withdraw attentional resources from the immediate external environment. Such withdrawal may reflect an adaptive attempt to go 'off-line' temporarily to conserve resources for later use. Furthermore, we speculate that such preservation of resources may be greater when the organism anticipates an arousing stimulus that will recruit more attentional resources. From this perspective, the expectation of a pleasant or unpleasant picture may produce greater withdrawal of attentional resources from the immediate environment than the anticipation of a neutral picture. As the onset of the target stimulus approaches, a second anticipatory phase develops during which there is a shift toward greater allocation of resources to the external environment. While this notion is speculative, it is consistent with the current findings, as well as the findings of Erickson (1996). To test this hypothesis further, future studies should vary both the length of the anticipatory interval and the time points at which probes occur during this interval.

We did not find any relation between startle

magnitude and picture valence after picture offset. Although this null finding appears consistent with the results of Bradley et al. (1993) and inconsistent with the results of Larson et al. (1998), recall that the results of even the latter study were not robust. These generally weak post-offset effects may be due to the rapid degradation of the emotional state induced by pictorial stimuli. To find effects during the offset period, researchers may need to use emotional manipulations likely to produce more enduring emotional or motivational states. In addition, researchers should assess the role of individual differences (e.g. proneness to rumination) that may be linked to the tendency to maintain emotional states after the offset of affective stimuli (Davidson, 1998).

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