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ScienceDirect
International Journal of Psychophysiology 66 (2007) 266 – 270
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

Fast track report

Impact of motivational salience on affect modulated startle at early and late probe times

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Received 17 January 2007; received in revised form 11 April 2007; accepted 14 May 2007
Available online 21 May 2007

Abstract

This study systematically manipulated both picture content and noise probe time in order to evaluate the effects of motivational salience (as distinguished from affective valence) on both early and late modulation of the startle response. Specifically, modulation was compared for erotic versus action/adventure scenes, and for direct threat versus victim scenes, at early (300 and 800 ms) and late (3500 ms) probe times — all relative to neutral. Blink inhibition was observed at all probe times during presentation of erotic pictures, and blink potentiation was evident at all times during presentation of direct threat pictures. Patterns of blink modulation were less consistent for action and victim picture contents. These findings are consistent with the hypothesis that under conditions of high motivational salience, affective startle modulation indexes the activation of appetitive-approach and defensive motivational states, even at early stages of picture processing.
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Keywords: Approach; Avoidance; Motivation; Affective Startle; Emotion; Pre-pulse Inhibition

Numerous studies have revealed modulatory effects of affectively positive or negative foreground stimuli on the startle blink reflex, especially at later probe times (e.g., Balaban, 1995; Bradley et al., 1999; Cook et al., 1992; Lang, 1995; Stritzke et al., 1995). Specifically, in relation to startle reactivity during a neutral picture foreground, the startle blink response is inhibited during viewing of pleasurable picture stimuli and potentiated during viewing of aversive picture stimuli. One account of this finding holds that a startling noise elicits a protective (defensive) reaction that is either augmented during an ongoing aversive motivational state, or dampened during the processing of a positive stimulus that evokes an ongoing approach state (e.g., Lang, 1995; Lang et al., 1998).

Recent studies have indicated that at later probe times during picture viewing (i.e., for probes occurring 3 s and later after picture onset), pleasant and aversive scenes with strong motivational significance (i.e., erotic and direct threat scenes) produce the most robust modulatory effects on startle (Balaban and Taussig, 1994; Bernat et al., in press; Bradley et al., 2001a; Hawk et al., 2004; Levenston et al., 2000; Stanley and Knight, 2004). One explanation for these findings has been that the high motivational salience of threatening stimuli reliably activates an avoidance disposition, producing facilitation of the startle response (e.g., Stanley and Knight, 2004), whereas content that is most directly tied to reproduction or sex (and thus species survival) elicits the greatest blink inhibition because of its activation of appetitive or approach systems (Bradley et al., 2001a).

Studies that have examined modulation of startle responses to probes delivered at very early stages of affective picture processing (i.e.,<1 s after picture onset) have produced more variable results. Some studies have found blink inhibition as early as 300 ms after the onset of a picture foreground for both positive and negative stimuli relative to neutral (e.g., Bradley et al., 1993; Levenston et al., 2000). These findings have been interpreted as indicating greater early processing

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0167-8760/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.ijpsycho.2007.05.005

protection for pictures that are interesting or visually engaging (cf. Anthony and Graham, 1985), irrespective of the valence of the picture stimuli. Bradley et al. argued that these interesting or engaging stimuli might need "longer periods of 'processing protection' relative to simpler stimuli" (Bradley et al., 1993, p. 73). In contrast, other studies have found blink facilitation at 300 ms for threatening content (e.g., Globisch et al., 1999; Stanley and Knight, 2004; Volz et al., 2003). Stanley and Knight (2004) maintained that their finding of blink potentiation for threatening scenes at this early lead interval was due to the motivational salience of the pictures, specifically that direct threat-related scenes were more easily processed due to their motivational significance, thereby overriding any inhibitory effect of heightened attention on startle. Globisch et al. (1999) reported a similar finding of blink facilitation at 300 ms for spider and snake fearful subjects while viewing their feared stimuli. They similarly argue that when fear relevant cues were clear to the viewer, activation of the fear network could be triggered quickly (e.g., Öhman, 1993). This argument may explain the difference in findings from the earlier mentioned studies. In both the Levenston et al. and Bradley et al. studies the motivational salience of the scenes (positive or negative) was not separated or compared at the short lead intervals. The negative content in these studies contained threatening scenes, "victim" scenes (mutilated bodies), assault scenes (of an individual being attacked), and other negative content (e.g., contamination scenes). By including negative stimuli that do not have clear motivational significance (e.g., victim stimuli may elicit succorance in some participants) the defensive eliciting effects of the threatening stimuli may have been diminished.

The current study was thus conducted in order to: (a) further examine startle modulation effects for noise probes presented early in the picture viewing interval, and (b) systematically evaluate the hypothesis that affective contents with direct survival significance contribute most to affective startle modulation. These aims were addressed by systematically varying both affective content and probe time, providing for an evaluation of the impact of motivational significance of picture stimuli on startle modulation at early and late probe times. Specifically, we contrasted 'threat' scenes (pictures of direct threat towards the viewer) with similarly rated 'victim' scenes (pictures of injury), and 'erotic' scenes (pictures of male, female, or couple nudes) with similarly rated 'action' scenes (pictures of sports and adventure) — all in relation to neutral. Modulatory effects for these picture contents were examined at early (300 and 800 ms) and late (3500 ms) probe times following previous investigations into the time course of affective startle (e.g., Bradley et al., 1993).

On the basis of prior work, we predicted – for probes presented 3500 ms after picture onset – that erotic and threat scenes that unambiguously depict motivationally salient (survival-relevant) scenes would produce more robust inhibition and potentiation of the startle response, respectively, than victim or action scenes, which are more ambiguous in terms of their motivational salience. Further, based on previous research (e.g., Stanley and Knight, 2004; Volz et al., 2003) we predicted that motivationally-relevant scenes may be easily resolvable from a processing standpoint, resulting in similarly enhanced modulatory effects on startle even at early probe times (300, 800 ms).

1. Method

1.1. Participants

Participants were 64 undergraduate students (40 female; mean age = 20.1 years) of diverse ethnicity (*n*: African American = 3, Asian American = 34, Caucasian = 21, Latino = 5, Native American = 1) with normal or corrected vision and no history of hearing problems who earned $10 for their participation.

1.2. Materials and design

Seventy-two pictures from five categories – 12 erotic, 12 action, 24 neutral, 12 victim, and 12 threat – were selected from the *International Affective Picture System* (IAPS; Lang et al., 1999). These pictures were selected based on published self-report rating norms (Lang et al., 1999). Based on these ratings, pictures were initially selected such that overall positive (i.e., erotic and action) and negative (i.e., threat and victim) categories were similar in terms of rated valence, and then selected from this larger group of pictures such that all positive and negative categories were not significantly different in terms of rated arousal. Neutral pictures (e.g., household objects, mushrooms, etc.) were chosen as scenes that were rated low in arousal and equidistant (i.e., in the middle) on valence between the erotic and action and victim and threat scenes based on published norm ratings. As in prior studies (e.g., Bradley et al., 2001b), separate picture sets meeting these criteria were selected for male and female participants, using the normative picture ratings available for each gender.[1]

Stimulus presentation and data acquisition were controlled by a PC running VPM software (Cook et al., 1987), which determined the presentation of the digitized pictures by digitally pulsing a yoked laptop (36 cm LCD display). After providing informed consent, participants were seated approximately .5 meters from the LCD screen, at a visual angle subtending 15.9°. Acoustic startle probes were digitally generated white noise bursts of 50 ms in duration, with instantaneous rise and fall times, amplified by a Radio Shack SA-155 Integrated Stereo

[1] IAPS picture numbers used in this study were: ACTION: 5621w, 5623, 5626w, 5629w, 8030m, 8040, 8080m, 8161w, 8170m, 8180, 8185, 8186m, 8200m, 8210w, 8300w, 8370m, 8400, 8490; EROTIC: 4180m, 4210m, 4220m, 4290m, 4310m, 4538w, 4572w, 4652, 4656w, 4658, 4660, 4670w, 4677w, 4680, 4681w, 4687w, 4690m, 4770m, 4800; NEUTRAL: 2190w, 2200m, 2440w, 2480w, 2570w, 2840, 5120w, 5500m, 5510m, 6150m, 7000m, 7004, 7009, 7010m, 7020m, 7025w, 7030, 7031w, 7034, 7050, 7060w, 7080m, 7090, 7095m, 7100m, 7110w, 7150, 7170, 7224w, 7233, 7234w, 7235w, 7490m, 7500m, 7700w, 7710m, 9070m, 9360w; THREAT: 1113, 1525, 6200, 6230m, 6242w, 6243, 6244, 6250, 6260, 6300, 6370, 6510; VICTIM: 3000m, 3010m, 3030, 3051w, 3060m, 3061w, 3080w, 3120, 3400m, 3530, 3550, 6540m, 6550, 6561w, 6570w, 6571, 9250 (m = picture used exclusively for men, w = picture used exclusively for women).

Mini-Amplifier to 105 dB and presented binaurally through Sennheiser HD 490 headphones. Startle probes were presented either at 300, 800 or 3500 ms following picture onset. To minimize predictability, nine trials were left unprobed and nine trials had probes during the intertrial intervals (ITIs) only. Following the offset of each picture stimulus, participants rated their emotional reaction to it on dimensions of valence and arousal using a modified version of the Self-Assessment Manikin (SAM; Levenston et al., 2000). The rating display depicts a cartoon figure in several states with a rating from 1–9 corresponding in one version to pleasantness and to another in arousal.

Half of the participants received a 2-s central fixation cross prior to each 6-s picture presentation and each SAM rating display, and half of the participants did not receive any fixation cross.[2] After the SAM ratings were completed, a random length (6 to 10 s) ITI was presented. Six serial orders were used in order to minimize any order or habituation effects, with participants randomly assigned to a given order. Each serial order was counterbalanced in blocks of 24 pictures such that all content by probe time cells occurred at some point in that block, and no more than two probe times or picture contents were presented consecutively.

1.3. Startle EMG recording and quantification

Electrode placement and skin preparation for blink startle measurement followed published guidelines (Blumenthal et al., 2005). Raw electromyographic (EMG) activity was recorded using two Med-Associates Ag/AgCl mini (4.2 mm sensor) Beckman-style electrodes, filled with electrolyte gel and placed over the orbicularis oculi region of the left eye, with one sensor directly under the pupil and the other lateral to this. A third electrode placed in the middle of the forehead served as a ground. Impedances were kept below 10 kΩ.

The EMG signal was filtered using a 13–1000 Hz passband and amplified using a Coulbourn V75-04 Isolated Bioamplifier with Bandpass Filter. EMG was sampled at 1000 Hz for 300 ms, starting 50 ms prior to probe onset (providing a pre-probe baseline) and ending 250 ms after probe onset. The signal was digitally refiltered offline with a 28–500 Hz passband (Van Boxtel et al., 1998) and digitally rectified and integrated using a 30 ms time constant.

Trained research assistants visually confirmed and scored the integrated EMG data segments using a modification of the Balaban algorithm (Balaban et al., 1986) that incorporated recent startle scoring guidelines (Blumenthal et al., 2005). Approximately 5.9% of eyeblink responses were discarded because the response occurred outside the post-probe 20–100 ms window or because the pre-probe baseline was unstable. Prior to analysis, A/D values were converted to microvolts.[3]

1.4. Data analysis

One-way repeated measures analyses of variance (ANOVAs) were computed separately for valence and arousal ratings, with picture content (erotic, action, neutral, victim, threat) as the within subjects factor. For the eyeblink response, a 3×5 repeated measures ANOVA was conducted with probe time (300, 800, & 3500) and content as the within subjects factors.[4] A Greenhouse–Geisser correction was used when appropriate, indicated in the corrected degrees of freedom. Follow-up pairwise comparisons included a Bonferroni correction for multiple comparisons. Effect sizes are reported as eta squared.

2. Results

2.1. Self-report

Analysis of picture valence ratings revealed a main effect of content, $F(2.44,153.91)=308.37$, $p<.001$, $\eta^2=.83$, with follow-up analyses indicating that erotic ($M=6.13$ SD$=1.23$) and action ($M=6.19$ SD$=.80$) scenes were experienced as more pleasant than neutral ($M=4.71$ SD$=.48$), $ps<.001$, η^2s$=.60$ & .75, and victim ($M=2.30$ SD$=.72$) and threat ($M=2.94$ SD$=.92$) scenes as more unpleasant than neutral, $ps<.001$, η^2s$=.91$ & .81. Erotic and action scenes did not differ from each other, $F(1,63)=.15$, $p=.70$), but victim scenes were experienced as more unpleasant than threat, $F(1,63)=58.96$, $p<.001$, $\eta^2=.48$. Analyses of arousal ratings revealed a main effect of content, $F(3.18,200.20)=139.35$, $p<.001$, $\eta^2=.69$, with follow-up analyses indicating that erotic ($M=5.52$ SD$=1.62$), action ($M=5.05$ SD$=1.77$), victim ($M=5.90$ SD$=1.65$) and threat ($M=5.80$ SD$=1.72$) scenes were all experienced as more arousing than neutral ($M=2.71$ SD$=1.18$), $ps<.001$, η^2s$=.81$, .74, .83, & .82. Erotic scenes were experienced as more arousing than action $F(1,63)=7.70$, $p<.01$, $\eta^2=.11$, although this effect appeared to be driven by male participants (see Footnote 4). There was no difference in reported arousal between victim and threat scenes, $F(1,63)=1.41$, $p=.24$.

2.2. Blink magnitude

Analyses of eyeblink responses revealed a main effect of probe time, $F(1.44,86.57)=7.67$, $p<.01$, $\eta^2=.27$. In line with expected findings of pre-pulse inhibition, follow-up analyses revealed that responses at the 300 ms probe time were significantly inhibited compared to the 800 ms $F(1,63)=15.78$, $p<.001$, $\eta^2=.20$ and 3500 ms $F(1,63)=8.26$, $p<.01$, $\eta^2=.12$ probe times. There was no significant difference between 800 ms and 3500 s $F(1,63)=.21$, $p=.65$. There was a significant main effect of content, $F(2.12,128.68)=22.33$, $p<.001$, $\eta^2=.27$, and a significant Probe Time×Content interaction, $F(4.43,265.58)=3.54$, $p<.01$,

[2] An initial hypothesis was that a warning cue might have accounted for the inconsistencies in findings at early probe times in previous studies. However, no differences were found and so these results are omitted for brevity's sake.

[3] Analyses were also conducted using *T*-scores to account for individual differences in overall blink magnitude. There were no differences in the pattern of results for either *T*-scores or raw microvolt scores.

[4] Sex was also computed as a between subjects factor for self-report and blink magnitude but is not reported here as differences were minimal. Specifically, in line with other studies the only sex difference was that men reported erotic pictures as more arousing than action pictures while women did not (Bradley et al., 2001b).

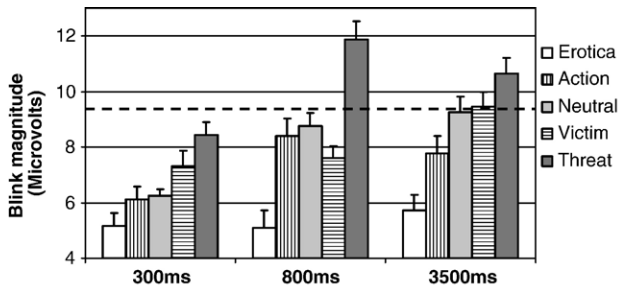

Fig. 1. Blink magnitude to startle responses during picture presentation of motivationally salient (erotic and threat), motivationally ambiguous (action and victim), and neutral picture contents at 300, 800 and 3500 ms. Error bars indicate one standard error. Dotted line indicates mean level of ITI responses.

η^2 = .06. In line with our hypotheses and shown in Fig. 1, follow-up analyses for the 300 ms probe time revealed significantly inhibited blink responses during erotic scenes compared to neutral $F(1,63)=6.79$, $p<.05$, $\eta^2=.10$, and significantly potentiated responses during threat compared to neutral scenes, $F(1,63)=18.01$, $p<.001$, $\eta^2=.23$. However, blink responses during action scenes did not differ from neutral $F(1,63)=.104$, $p=.75$, and responses during victim scenes only tended to differ from neutral, $F(1,63)=3.87$, $p=.054$, $\eta^2=.06$. Also consistent with the motivational salience hypothesis, blink responses were significantly inhibited during erotic compared to action scenes, $F(1,63)=6.79$, $p<.05$, $\eta^2=.10$, and blink responses were significantly potentiated during threat compared to victim scenes, $F(1,63)=5.00$, $p<.05$, $\eta^2=.08$.

A similar impact of motivational salience was evident at the 800 ms probe time, with blinks inhibited during erotic scenes compared to neutral, $F(1,63)=20.52$, $p<.001$, $\eta^2=.25$, and potentiated during threat scenes compared to neutral, $F(1,63)=11.46$, $p<.01$, $\eta^2=.16$, but no significant difference between action and neutral $F(1,63)=.21$, $p=.65$ or victim and neutral $F(1,63)=2.29$, $p=.14$. Blink magnitude was also inhibited during erotic compared to action scenes, $F(1,63)=9.82$, $p<.01$, $\eta^2=.14$, and potentiated during threat compared to victim, $F(1,63)=27.22$, $p<.001$, $\eta^2=.31$.

Finally, at the 3500 ms probe time, blink responses during erotic and action scenes were both inhibited compared to neutral, $Fs(1,63)=16.64$ & 4.14, $p<.001$ & .05, η^2s = .21 & .06, and blink responses during threat scenes were potentiated compared to neutral $F(1,63)=4.53$, $p<.05$, $\eta^2=.07$, but not during victim compared to neutral $F(1,63)=.06$, $p=.81$. In line with other time points, blink responses were inhibited during erotic compared to action, $F(1,63)=8.95$, $p<.01$, $\eta^2=.13$; and responses during threat were potentiated compared to victim although this difference only approached significance, $F(1,63)=2.81$, $p=.10$, $\eta^2=.04$.

3. Discussion

This study systematically varied both the content of affective pictures and the timing of noise probes to further examine whether scenes with strong motivational salience (i.e., sexual and directly-threatening scenes) produce maximal modulatory effects on the acoustic startle reflex. At both early and late probe times and compared to neutral, blink responses were inhibited during the viewing of erotic scenes, whereas blinks were potentiated during the viewing of threat scenes. This was not consistently the case for action and victim scenes of similarly rated affective potency. Moreover, direct comparisons of pleasant and aversive contents at most probe times revealed significantly inhibited blinks for erotic compared with action scenes, and significantly potentiated blinks for threat compared with victim scenes.

Our hypothesis is that the erotic and threatening scenes activated appetitive and defensive drive systems more directly than scenes of adventure or victimization — leading to greater antagonistic attenuation and synergistic enhancement, respectively, of the defensive startle reflex. With regard to early modulatory effects, the findings of the present study – in accordance with other recent findings (e.g., Globisch et al., 1999; Stanley and Knight, 2004; Volz et al., 2003) – provide evidence that when the motivational relevance of an aversive scene is clear and direct (i.e., as with the threat scenes examined here), initial pre-pulse inhibition effects on startle can be overridden, even as early as 300 ms, by defensive potentiation effects. As described by Globisch et al. (1999) and Stanley and Knight (2004), when the motivational relevance is clear and arousal is high there is an activation of the blink circuit that surpasses the effects of pre-pulse inhibition. In the present study, only scenes that were directly threatening to the viewer showed a facilitation of the startle response relative to neutral at 300 ms. Scenes of victimization showed a similar pattern as that of disgust scenes in the Stanley and Knight (2004) study — i.e., not significantly different from neutral. They concluded that this finding indicates that such content elicits either 1) aversive activation that is not enough to override attentional inhibition or 2) the scenes fail to produce an emotional processing that differs from neutral. Either could be the case for our victim scenes as well, but in both cases of victim and disgust, the processing of fear cues are much more ambiguous, thereby potentially limiting the speed and intensity of the activation of the fear network (Öhman, 1993) and decreasing the overall startle response.

Our findings differ from Bradley et al. (1993) who reported significant blink inhibition for both pleasant and aversive scenes at the earliest (300 ms) probe time. That study included a more diverse array of contents within the aversive category, including less potent pest and contamination scenes, which could account for the differential modulatory effects at 300 ms. However, in a study involving prison inmates, Levenston et al. (2000) reported overall inhibition at 300 ms in the prisoner control group for aversive scenes comprising the same contents used in the current study (threat, victim). However, these contents were combined in the Levenston et al. study for the 300 ms comparison, and thus a direct comparison of motivational salience was not possible. Some additional explanations for the difference in early probe results in the current study and the Levenston et al. study include: (1) gender representation (i.e., all participants in Levenston et al. were men; the current sample comprised 37.5% men and 62.5% women); (2) age (mean age of control prisoners in Levenston et al. was 31.6, versus 20.1 in the current study); (3) half the participants in the current study received a “ready” signal (fixation cross) prior to picture onset, whereas pictures occurred without warning for all participants in Levenston et al.; (4) the specific selection of aversive (threat, victim) pictures differed somewhat across the two studies in the Levenston et al. study and (5) The Levenston et al. and Bradley et al. studies used a large projected images for stimuli while the present study (and the Volz et al. and Stanley and Knight studies) used a smaller computer screen, perhaps altering the time it takes to scan and process the images (Volz et al., 2003). Further research is needed to evaluate the impact of these and other parameters affective modulation at this early (300) ms probe time.

One potential limitation of the current study pertains to the affective properties of the stimuli. Although picture stimuli were pre-selected on the basis of published rating norms (IAPS; Lang et al., 1999) such that the pictures did not significantly differ in terms of valence and arousal within positive and negative categories, the ratings data we collected indicated some differences within the current study sample. Specifically, our sample reported experiencing victim scenes as more unpleasant than threat scenes, and erotic scenes as more arousing than action scenes. Thus, concerns might be raised as to whether differences in the affective potency of these contents contributed to differences in startle effects. However, the pattern of ratings differences does not fit with differences for the startle measure. Victim scenes were rated as more unpleasant than threat scenes, but threat scenes produced greater startle potentiation than the victim scenes. With regard to the erotic scenes being higher in rated arousal than the action scenes, this effect was seen only among male participants. When the startle response data were analyzed for men and women separately, there were no differences in the pattern of results over any time point for men or women, indicating that differential startle effects for erotic versus action scenes were not attributable to differences in rated arousal.

In summary, the current study sheds light on the impact of motivational salience on affective startle modulation by demonstrating that affect-modulated startle is a particularly sensitive measure of the activation of appetitive and defensive motivational systems at both early and late time points. Future studies might do well to include other measures, such as skin conductance, additional probe times, and systematic manipulations of variables such as foreground stimulus complexity, in order to assess the impact of these variables on startle modulation effects. Further research is also needed to examine other picture contents and moderating effects of participant characteristics such as criminal deviancy in order to reconcile inconsistencies in findings across existing published studies. Finally, expanding beyond pictures to imagery and film clips will further elucidate the factors influencing affect startle modulation.

Acknowledgements

This study was supported by the Grant MH072850 from the National Institute of Mental Health.

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