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A startling absence of emotion effects: Active attention to the startle probe as a motor task cue appears to eliminate modulation of the startle reflex by valence and arousal

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ABSTRACT

Research has shown that during emotional imagery, valence and arousal each modulate the startle reflex. Here, two imagery-startle experiments required participants to attend to the startle probe as a simple reaction time cue. In Experiment 1, four emotional conditions differing in valence and arousal were examined. Experiment 2, to accentuate potential valence effects, included two negative high arousal, a positive high arousal and a negative low arousal condition. Imagery effectively manipulated emotional valence and arousal, as indicated by heart rate and subjective ratings. Compared to baseline, imagery facilitated startle responses. However, valence and arousal failed to significantly affect startle magnitude in both experiments and startle latency in Experiment 1. Results suggest that emotional startle modulation is eclipsed when the probe is significant for task completion and/or cues a motor response. Findings suggest that an active, rather than defensive, response set may interfere with affective startle modulation, warranting further investigation.

1. Introduction

The startle reflex, the involuntary response to a sudden onset stimulus, has received much research interest among psychophysiologists because it can serve as a probe into both affective and cognitive processes (Dawson et al., 1999). The magnitude and latency of the startle response are modulated by factors including affective valence (Vrana et al., 1988) and arousal (Witvliet and Vrana, 1995, 2000), presence of a non-startling prepulse (Blumenthal, 1999; Robinson and Vrana, 2000), direction of attention toward the startle probe modality (Anthony and Graham, 1985), or engagement in an effortful mental task (Panayiotou and Vrana, 1998). The valence effect on startle (potentiated startle during negative emotion) is extremely robust. It has been replicated dozens if not hundreds of times and has been obtained with a range of different affective manipulations such as picture viewing (e.g., Bradley et al., 1996a; Sloan and Sandt, 2010; Vrana et al., 1988), imagery (e.g., McTeague et al., 2010; Witvliet and Vrana, 1995, 2000), and olfactory stimuli (Miltner et al., 1994). Within the imagery paradigm valence and arousal appear to modulate startle independently: negative emotions, such as fear and sadness, result in larger startle blink responses than positive emotions such as joy or pleasant relaxation, and high arousal emotions, such as joy or fear, result in larger startle blink responses compared to less arousing emotions such as pleasant relaxation or sadness (Cook et al., 1991; Robinson and Vrana, 2000; Witvliet and Vrana, 1995, 2000).

Attention also modulates the startle response independently of affect. The effect of attention on the startle has been demonstrated in studies that show that when attention is directed to the sensory modality that contains the startle evoking stimulus the reflex is potentiated (Anthony and Graham, 1985). Performing a reaction time (RT) response to an imperative stimulus that occurs simultaneously with the startle probe enhances the startle reflex (Valls-Solé et al., 1995; Lipp et al., 2006) and reduces startle habituation (Valls-Solé et al., 1997), an effect known as the StartReact effect (Valls-Solé et al., 2005). An explanation for this effect has been the summation of the startle reflex and a pre-programmed movement to the imperative task requiring the RT motor response (Siegmund et al., 2001). Conversely, startle is attenuated if attention is directed to a different modality than the startle probe (Schicatano and Blumenthal, 1997), particularly when the task to be completed in this modality is complex (Neumann, 2002). However, this reduction in startle response during cross-modal monitoring has not been consistently found, as Lipp (2002) reported that attending

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to a significant task-relevant stimulus, even if it is in a different modality than the startle probe, enhances the startle response compared to a task-irrelevant condition (Lipp and Hardwick, 2003). Such cross-modal facilitation is not unequivocal either, however, as it was not obtained for startle magnitude, while it was present for startle latency in some studies (e.g., Lipp et al., 2000).

In addition to being modulated by task-relevant stimuli, the startle reflex is enhanced during effortful mental tasks. For instance, startle responses are larger during active imagery, a task that requires cognitive effort, compared to periods when participants engage in a less effortful cognitive task (Robinson and Vrana, 2000), and responses are larger when participants rehearse digits compared to passively listening to digit presentation, especially when the digit rehearsal is more effortful (Panayiotou and Vrana, 1998).

Although attentional and emotional processes often interact, usually research on the affective modulation of the startle response does not simultaneously examine sensory and cognitive variables that may be influencing the response "except as alternative explanations of the emotion effects" (Hawk and Cook, 2000, p. 5). In fact, the experimental paradigm within which affective startle modulation has typically been studied entails instructions to participants to focus attention on the emotion induction task and ignore the startle probe (e.g., Codispoti et al., 2001). In the prepulse paradigm, the interaction of affective and attentional processes is most clearly seen. When the prepulse stimulus, which precedes and overlaps with the startle probe, is an emotional picture or imagery, studies show that the attention-engaging properties of the prepulse interact with its emotional aspects (e.g., Filion et al., 1993). However, when the prepulse stimulus is not the emotional stimulus, the prepulse and emotion modulate the startle response independently (Hawk and Cook, 2000; Robinson and Vrana, 2000).

Few studies have examined the effects of attending to the startle probe itself on affective modulation, but most find that manipulating the task-relevance of the startle probe does not impair affective startle modulation. Extant studies relied on the affective picture paradigm. For example, Cuthbert et al. (1998) found that startle modulation by affective pictures did not vary as a function of whether the startle probe was attended to. From this they concluded that emotional responding is automatic and obligatory, and is independent of the attentional aspects of the probe and its signal value. Haerich (1994) found that, regardless of whether or not participants attended to the startle probe to judge its duration, negative emotion primarily modulated startle. Negative emotion was triggered by instructions that made the startle probe an aversive stimulus, and no active response to the probe was required. Bradley et al. (1996b) found that making a startle probe significant by requiring a simple RT in response to its occurrence did not affect modulation of the startle by concurrent viewing of affective pictures. Thus, so far, in all cases affective modulation of the startle is found even when the startle probe is task-relevant. No data exist, however, on startle modulation during affective imagery when the probe is task-relevant.

Lang's explanation for startle enhancement by negative valence is that affective "matching" occurs between the defensive reaction evoked by the startle probe and the negative affective foreground (Lang, 1995). Thus, both the startle probe and a negative affective context call for the participant to withdraw or take a defensive, stance enhancing the startle response. In the studies described above, where the startle probe was task-relevant, and particularly when one had to perform an RT response to it, it can be argued that the startle stimulus acquires an "approach" rather than "avoidance" meaning. Apparently, within the picture paradigm this did not over-ride the robust effect of the emotional foreground on startle, but this effect has not been studied in the imagery paradigm. Picture viewing, a situation that directs attention to interesting visual stimuli that may more easily sustain attention, is very different from imagery, where mental processing rather than sensory attention is required, and where it may be harder to sustain attention.

The primary aim of this research was to examine emotional valence and arousal modulation of the acoustic startle response during affective imagery while participants attend to the acoustic startle probe stimulus for the purposes of a reaction time (RT) task to the stimulus itself. The question we sought to answer is whether changing the meaning of the startle stimulus from avoidance to approach (task relevance) would counter its match with the negative affective context produced by the imagery task and consequently reduce affective startle modulation. To examine whether affective modulation of the task-relevant probe differs from the typical affect modulation study, we conducted meta-analytic comparisons with a similar study (Witvliet and Vrana, 1995) that used the same affective materials but in which the startle probe was task irrelevant. It is hypothesized that the standard affective startle modulation effects will be found in the current study; that is, affective valence and arousal will both modulate startle magnitude, and that meta-analytic comparisons between effects in this study and Witvliet and Vrana (1995) will verify the similarity of the results. Further, the startle response should be enhanced during the effortful imagery task compared to a non-effortful baseline task. Heart rate, which increases during arousing imagery (Witvliet and Vrana, 1995, 2000), and emotional ratings were collected to provide additional measures of emotional processing during imagery.

2. Experiment 1

2.1. Method

2.1.1. Participants

Participants were 27 male and 26 female undergraduate students at a U.S. university who took part in this experiment in return for course credit.

2.1.2. Procedure

Participants completed six blocks of an emotional imagery task, using the same procedure and standardized imagery scripts as Witvliet and Vrana (1995, 2000). At the beginning of each block the participant was given two index cards, each with a sentence-long script describing a scenario representing one of the four emotions. The participant was instructed to read the sentences and create a vivid personal image of participating in the events described. The participant was then instructed to sit with eyes closed and listen to a series of tones, one every 8 s. The medium tone was heard most often, and instructed the participant to "count one" and relax until the next tone. The high or low tone was the signal to imagine the specified sentence content and to continue this until the next (medium) tone. The tones were presented in a quasi-random order, so that there were six high tones and six low tones signaling imagery in a block with 3–5 medium tones (24–40 s) separating each imagery period.

Within each block, the startle-provoking/RT stimulus was presented during two "high tone" and two "low tone" imagery periods, and during four medium tone "count one" periods. Probes occurred either at 2, 3.5, or 5 s after tone onset. Participants were instructed to press a button held in their dominant hand as quickly as possible each time they heard a "loud click" (i.e. the startle probe).[1]

Following each block participants completed ratings using the Self-Assessment Manikin (Hodes et al., 1985) to rate the valence, arousal, dominance and vividness for each of the two imagery scripts. These ratings were converted to a 0–20 scale. Following the ratings, the experimenter returned with a new pair of sentences. By the end of the six blocks, the participant had imagined three different sentences in each of the four emotion categories described below, such that 2 sentences were allocated to each block, each of a different emotional content. Allocation of sentences to blocks was semi-random so that all emotions were paired with all others (see below).

2.1.3. Apparatus and materials

Timing of stimulus presentation and digital data collection were monitored by a PC and on-line physiological data collection software (Cook et al., 1987). Auditory stimuli were presented binaurally through headphones. The acoustic startle stimulus was a 50-ms burst of 95-dB(A) white noise with near instantaneous rise time. Imagery signals were 500 ms long [70 dB(A)], high (1200 Hz), medium (1000 Hz), and low (800 Hz) frequency tones that were generated by a Coulbourn Voltage Con-

[1] Because of an error in collecting reaction time, RT data will not be reported.

Table 1
Means and standard deviations (in parentheses) of startle magnitude, startle latency, and HR for Experiments 1 and 2.

	Fear	Sadness	Joy	Pleasant relaxation	"Count One"
Experiment 1					
Startle magnitude	10.64	10.32	10.75	10.27	10.00
	(5.08)	(5.33)	(4.85)	(5.13)	(5.11)
Startle latency	39.78	39.92	39.49	41.03	41.77
	(8.04)	(8.61)	(8.22)	(8.81)	(7.80)
Heart rate	1.72	.77	1.07	.71	.93
	(1.90)	(1.65)	(1.79)	(1.52)	(1.41)
	Fear	Sadness	Joy	Disgust	"Count One"
Experiment 2					
Startle magnitude	9.60	9.16	9.18	9.29	8.88
	(7.98)	(7.81)	(8.62)	(7.84)	(8.06)
Startle latency	35.47	36.67	37.71	35.51	37.86
	(10.22)	(10.89)	(10.46)	(10.71)	(12.74)
Heart rate	1.47	.60	1.57	1.75	1.10
	(2.31)	(2.10)	(2.20)	(2.06)	(1.33)

Note: Startle magnitude data are in μV, latency is in ms, and HR is in change in beats/minute.

trolled Oscillator with a selectable Envelope Rise/Fall Gate set for a 25-ms rise/fall time.

Heart rate was collected via Lead I EKG by two Ag/AgCl electrodes filled with electrode gel and placed on each inner forearm. The signal was filtered by a Coulbourn S75-01 Hi Gain Bioamplifier and fed into a digital input on the computer, which recorded inter-beat intervals with millisecond resolution. To measure the startle reflex, electromyographic activity at the orbicularis oculi muscle was recorded with 4-mm Ag/AgCl electrodes placed under the left eye, according to the placement suggested by Fridlund and Cacioppo (1986). Signals were amplified (60,000×) by a Hi Gain Bioamplifier using 90-Hz high-pass and 250 Hz low-pass filters. The signals were rectified and integrated by a Coulbourn Contour Following Integrator (measured time constant = 80 ms). The reflexes were sampled at 1000 Hz for 250 ms after the onset of the startle probe.

Materials were 12 sentences previously used by Witvliet and Vrana (1995, 2000), with three representing each of the emotions in the 2 Valence × 2 Arousal quadrant. Fear served as the negative, high-arousal imagery content, sadness was the negative, low-arousal imagery content, joy was the positive, high-arousal imagery content, and pleasant relaxation served as the positive, low-arousal imagery content. Each emotion type was represented in three different scripts. Scripts were counterbalanced across participants such that all possible pairings of emotions were made, all emotions were imagined at the high and low tones equally often, and all materials appeared equally often in different blocks of the experiment. See Witvliet and Vrana (1995) for information about stimulus creation and validation, and for the specific sentences.

2.1.4. Data reduction and analysis

Each startle eyeblink response was scored off line for peak magnitude in analog-to-digital units (converted later to μV) and blink onset latency (in ms). Cardiac interbeat intervals were converted to heart rate in beats per minute, and heart rate from the 2 s prior to the tone signaling imagery initiation was subtracted from the mean heart rate during the 8-s imagery period to create a change score. For each individual, data were averaged across all presentations within the same emotion and across the three different startle stimulus presentation times.

Each of the dependent measures (startle magnitude and latency, heart rate and emotion ratings) was analyzed in a 2 Valence (negative, positive) × 2 Arousal (high, low) repeated measures analyses of variance. A second analysis of physiological variables averaged across all imagery periods and statistically compared these data with response during the "count one" period. Significant interactions were followed by a modified Bonferroni procedure that kept $p \leq .05$ for multiple comparisons (Simes, 1986). Effect sizes (partial eta squared) are presented for significant effects. Meta-analytic techniques were used to compare startle effects in this study with those of Witvliet and Vrana (1995), which used the same design, methods, and materials.

2.2. Results

2.2.1. Startle reflex

Startle magnitude and latency means and standard deviations are shown in Table 1. Contrary to hypotheses, there were no significant effects of valence, $F(1, 51) = 0.01$, $p \geq .9$, or arousal, $F(1, 51) = 2.19$, $p \geq .2$, on startle magnitude. Startle magnitude during emotional imagery was significantly greater than during the "count one" baseline, $F(1, 52) = 4.89$, $p < .04$ ($\eta^2 = .09$). Startle latency was also unaffected by valence, $F(1, 52) = 0.48$, $p \geq .5$, or arousal, $F(1, 52) = 2.30$, $p \geq .1$, and there was a significant latency effect of imagery vs. "count one," with shorter latencies during imagery, $F(1, 52) = 16.11$, $p < .0001$ ($\eta^2 = .24$).

2.2.2. Affective startle modulation with and without the RT task

In order to determine whether the instruction to respond to the startle stimulus produced significantly different affective modulation compared to having no RT task, we compared startle effects with previous results where no RT response was required. The present study and Witvliet and Vrana (1995) were similar in design, procedure, materials, participant population sampled, timing and intensity of the startle stimulus, and measurement of the startle response. The two studies differed substantially only in that subjects were instructed to ignore the startling stimulus in the earlier study and to press a button as quickly as possible upon hearing the stimulus in the present study.[2] The data from the two studies were compared using meta-analytic statistics (Rosenthal, 1993) in order to assess whether affective modulation of the startle differed significantly in the two studies. The effect sizes for startle magnitude modulation by valence and arousal in the present study were .01 and .20, respectively, whereas the effect sizes for valence and arousal modulation of startle response magnitude in Witvliet and Vrana (1995) were .43 and .53, respectively. These effect sizes differed significantly between the two studies ($Z = 2.28$ for valence and $Z = 1.87$ for arousal, both $p < .05$), indicating that affective startle modulation was significantly greater when subjects were instructed to ignore the startling stimulus. A similar result was found when comparing the effect sizes for valence mod-

[2] A second methodological difference had to do with the number of startle probes presented, in that the present study included startle probes during one third of the imagery trials only, whereas in Witvliet and Vrana (1995) startle stimuli occurred in two-thirds of the imagery trials. Thus mean startle measures in the current study are based on fewer datapoints per condition (affecting measurement reliability) and fewer total startle stimuli (affecting response habituation). Prior evidence indicates that startle habituation is independent of affective startle modulation, so that the same affective effects on startle are present at different levels of habituation and show no diminution over trials (Bradley et al., 1993b, 1996a); further, the affective startle modulation found in Witvliet and Vrana (1995) are consistent with effects found in countless studies employing widely varying numbers of startle probes. The meta-analyses described here were repeated with the effect sizes based on analysis of the first four of six blocks of data from Witvliet and Vrana. This nearly equated the number of startle responses per condition between the studies, and exactly equated the total number of startle stimuli presented in the experiments. The meta-analytic results from this comparison were the same as those reported in this section.

Table 2
Means and standard deviations (in parentheses) of ratings of valence, arousal, dominance and vividness provided by participants during Experiments 1 and 2.

	Fear	Sadness	Joy	Pl. relaxation
Experiment 1				
Valence	5.62	5.98	16.96	14.94
	(2.91)	(2.61)	(2.84)	(2.20)
Arousal	14.87	8.17	13.47	6.23
	(4.62)	(3.59)	(4.58)	(3.78)
Dominance	5.64	7.93	13.62	14.02
	(3.69)	(4.24)	(3.07)	(2.77)
Vividness	14.51	12.80	16.08	15.60
	(3.44)	(3.97)	(2.82)	(3.12)

	Fear	Sadness	Joy	Disgust
Experiment 2				
Valence	5.62	6.38	16.31	5.47
	(2.90)	(3.16)	(3.57)	(3.40)
Arousal	14.24	9.07	13.80	13.69
	(4.48)	(4.23)	(4.69)	(5.09)
Dominance	6.42	8.42	13.18	6.98
	(3.77)	(3.82)	(4.18)	(3.76)
Vividness	14.04	12.69	16.09	14.31
	(3.60)	(3.84)	(3.23)	(3.57)

ulation of startle latency (.45 in Witvliet and Vrana and .00 for the present study)—the effect size in the earlier study was significantly greater, $Z = 2.32$, $p < .05$. The effect sizes for arousal modulation of startle latency were in the same direction (.53 in Witvliet and Vrana; .20 for the present study) but not significantly different from each other, $Z = 0.53$, $p > .25$.

Although making the startle probe the imperative stimulus for a reaction time task essentially eliminated affective modulation of the startle response, it was still expected that the startle response would be enhanced by directing attention to the startle stimulus, based on previous findings of enhanced startle response when attention is directed to the sensory channel containing the probe (e.g., Lipp and Hardwick, 2003). To test this hypothesis, the magnitude and latency of startle during "count one" periods for the current study, in which the startle stimulus was an RT probe, were compared with startle magnitude and latency during "count one" periods in Witvliet and Vrana (1995), in which participants were instructed to ignore the startle stimulus. Startle magnitude from the current study (see Table 1) was significantly greater than that found during the earlier study (mean = 4.659 μV; SD = 2.11), $t(99) = 7.68$, $p < .00001$. Similarly, startle latency from the current study was marginally shorter than that found during the earlier study (mean = 44.7 ms; SD = 8.81), $t(99) = 1.75$, $p < .10$.

2.2.3. Heart rate (HR)

As can be seen in Table 1, imagining high arousal emotions resulted in greater mean HR than imagining low arousal emotions, $F(1, 52) = 8.72$, $p < .01$ ($\eta^2 = .14$). There was also a significant main effect of valence, $F(1, 52) = 4.30$, $p < .05$ ($\eta^2 = .08$), where negative emotions showed a greater increase in HR than positive emotions. HR during emotional imagery was not significantly different than HR during the "count one" period.

2.2.4. Emotion ratings

The pattern of emotion ratings, presented in Table 2, replicated those found in Witvliet and Vrana (1995). With regard to valence ratings, there was a significant main effect of valence, $F(1, 52) = 350.90$, $p < .0001$ ($\eta^2 = .87$), a main effect of arousal, $F(1, 52) = 12.10$, $p < .001$ ($\eta^2 = .19$), and a Valence × Arousal interaction, $F(1, 52) = 18.06$, $p < .0001$ ($\eta^2 = .26$). Positively valent emotions resulted in higher ratings of positive valence. The Valence × Arousal interaction indicated that joy produced significantly higher valence ratings than all other emotions, relaxation was rated higher than the two negative emotions, and the two negative emotions did not differ significantly. For arousal ratings, there were significant main effects of arousal, $F(1, 52) = 146.69$, $p < .0001$ ($\eta^2 = .74$), and valence, $F(1, 52) = 19.14$ ($\eta^2 = .27$), $p < .0001$: high arousal imagery and negative imagery were rated as more arousing than low arousal imagery and positive imagery, respectively.

For dominance ratings, positive emotions resulted in higher ratings of dominance than negative emotions $F(1, 52) = 158.83$, $p < .0001$ ($\eta^2 = .75$), and low arousal emotions resulted in higher ratings than high arousal emotions $F(1, 52) = 17.96$, $p < .0001$ ($\eta^2 = .26$). Whereas the two positive emotions did not significantly differ in dominance ratings, sadness resulted in significantly higher ratings of dominance than did fear, Valence × Arousal, $F(1, 52) = 12.49$, $p < .001$ ($\eta^2 = .19$). For imagery vividness positive imagery was rated as more vivid than negative imagery, $F(1, 52) = 67.15$, $p < .0001$ ($\eta^2 = .56$), and highly arousing imagery was more vivid than low arousal imagery, $F(1, 52) = 17.17$, $p < .0001$ ($\eta^2 = .25$).

2.3. Discussion

Experiment 1 found that requiring attention and a behavioral response to the startle probe was associated with a failure to observe the valence and arousal potentiation of the startle response typically found during emotional imagery (Robinson and Vrana, 2000; Witvliet and Vrana, 1995, 2000). Making the startle probe an imperative stimulus for a reaction time task did not disrupt affective imagery processing: heart rate and affective ratings indicated participants experienced emotions during imagery as predicted, and replicated the effects found by Witvliet and Vrana (1995), demonstrating that affective imagery was effective. The startle response was also larger and had faster onset during the "count one" periods in this study compared to Witvliet and Vrana (1995), consistent with previous findings that directing attention to the startle probe (Anthony and Graham, 1985) and requiring an RT to an imperative stimulus concurrent with the probe (Lipp et al., 2006) enhances the response to it.

3. Experiment 2

Because it is highly unusual *not* to find affective modulation of the startle, the present results require replication. Thus a second experiment was conducted with the same procedure but a different set of affective stimuli to further investigate startle modulation when the probe is attended to and significant for an RT task. Experiment 2 added a second emotional content to the negatively valent, high-arousal quadrant, which is the most potent facilitator of the startle reflex (Lang, 1995). Based on prior research finding that disgust imagery robustly potentiates the startle reflex (Vrana, 1994; Yartz and Hawk, 2002), disgust imagery and fear imagery were used in Experiment 2. The joy and sadness conditions were the same as Experiment 1, and pleasant relaxation, the low arousal positive emotional condition, was removed from the design.

3.1. Method

3.1.1. Participants

Participants were 45 psychology undergraduate students (24 males, 21 females) who took part in the experiment in return for course credit.

3.1.2. Apparatus and materials

The apparatus was the same as Experiment 1. Materials were the same except that disgust sentence materials replaced the pleasant relaxation sentences. The disgust sentences, like the fear sentences, were chosen for their negative valence, high arousal properties. See Vrana (1994) for details on these sentences.

3.1.3. Procedure

The same procedure was used as in Experiment 1.

3.1.4. Data reduction and statistical analysis

Data reduction followed that described in Experiment 1. Repeated measures analyses of variance were conducted on each of the dependent measures (startle magnitude and latency, heart rate and emotion ratings) with emotion (with four levels representing the four emotional contents) as the within-subjects variable. In addition, planned comparisons of negative vs. positive valence at high levels of arousal (fear and disgust vs. joy) and high vs. low arousal with negative valence (fear and disgust vs. sadness) were conducted. Effect sizes (partial eta squared) are presented for significant effects. As in the first experiment, physiological variables were averaged across all imagery periods and statistically compared with response during the "count one" period. Greenhouse–Geisser corrections for violations of the sphericity assumption were made for all analyses for which the within-subjects variable had more than one level, and corrected *p* values and epsilon are reported.

3.2. Results

3.2.1. Startle reflex

Startle magnitude and latency means and standard deviations for the four emotions are shown in Table 1. There were no significant effects of emotion on startle magnitude, $F(3, 126) = .95$, $p > .4$, $\varepsilon = .88$. Planned tests revealed no effect of valence, $F(1, 43) = .02$, $p = .89$ or arousal, $F(1, 44) = .68$, $p = .42$ on startle magnitude. Startle magnitude was not significantly different during emotional imagery compared to during the "count one" baseline, $F(1, 44) = 1.10$, $p > .25$.

Emotion did not significantly affect latency of startle response, $F(3, 117) = 2.77$, $p > .05$, $\varepsilon = .83$. However, the planned valence comparison (fear and disgust vs. joy) found that startle latency was shorter during negative compared to positive valence imagery, $F(1, 41) = 7.69$, $p < .002$ ($\eta^2 = .16$); see Table 1. There was no significant effect of imagery arousal on startle latency, $F(1, 41) = 1.94$, $p > .1$. Additionally, startle latency during imagery was not significantly different from those during the "count one" period, $F(1, 43) = 2.67$, $p > .10$. One should note that, although neither magnitude nor latency were significantly different during imagery compared to "count one," the pattern of means are indicative of startle enhancement during imagery, as found in Experiment 1, and meta-analytic comparisons found no significant differences in the size of this effect for the two experiments, magnitude $Z = 0.66$, latency $Z = 1.36$, both $p > .05$.

3.2.2. Affective startle modulation with and without the RT task

In order to determine whether the affective modulation effect sizes of the startle response in the current study were significantly different from the study in which no RT task was required, we compared the current startle effects with those found in Witvliet and Vrana (1995).[3] Once again the effect sizes for valence and arousal modulation of startle magnitude were significantly smaller when an RT was required in response to the startle probe ($Z = 2.05$ for valence and $Z = 2.19$ for arousal, both $p < .05$). The effect sizes for valence and arousal modulation of startle latency were both in the same direction (smaller when an RT was required in response to the startle probe), but neither was significant ($Z = 0.32$ for valence and $Z = 0.69$ for arousal, both $p > .4$). As in the first experiment, the startle response during "count one" baseline periods was both larger in magnitude, $t(92) = 3.40$, $p < .001$, and faster in latency, $t(89) = 2.91$, $p < .005$, when the probe required an RT response than when it did not.

3.2.3. Heart rate

The emotional content of the image significantly affected heart rate, $F(3, 129) = 5.98$, $p < .001$, $\varepsilon = .95$ ($\eta^2 = .12$). Post hoc comparisons indicated that high arousal (fear, joy and disgust) imagery resulted in significantly greater heart rate increase compared to low arousal (sad) imagery. A planned comparison of fear and disgust to sadness indicated that high arousal negative emotions resulted in faster heart rate than low arousal negative emotion, $F(1, 43) = 12.42$, $p < .001$ ($\eta^2 = .22$). When negatively valent high arousal emotions (fear, disgust) were compared to positively valent high arousal joy, no significant difference was observed. Heart rate during imagery was significantly higher than HR during the "count one" period, $F(1, 43) = 37.78$, $p < .0001$ ($\eta^2 = .47$).

3.2.4. Emotion ratings

Table 2 shows the means and standard deviations of ratings for each emotion. There were significant valence differences between emotions, $F(3, 132) = 112.97$, $p < .0001$, $\varepsilon = .67$ ($\eta^2 = .72$), with joy rated as significantly more positive than the other three emotions. Sadness was rated as significantly less arousing than the other three emotions, $F(3, 132) = 20.69$, $p < .0001$, $\varepsilon = .82$ ($\eta^2 = .32$). Dominance was rated higher for positively valent joy compared to the three negatively valent emotions, and for low arousal sadness compared to fear and disgust, $F(3, 132) = 35.87$, $p < .0001$, $\varepsilon = .76$ ($\eta^2 = .45$). Vividness was higher for joy imagery compared to all other emotions, and fear and disgust were experienced as more vivid than sadness, $F(3, 132) = 13.83$, $p < .0001$, $\varepsilon = .96$ ($\eta^2 = .24$).

3.3. Discussion

The results of Experiment 2 added to the initial evidence from Experiment 1 that when the startle-eliciting probe is attended as the signal for a secondary reaction time task, the expected emotion effects on startle magnitude and latency are for the most part eclipsed. Neither valence nor arousal exerted the predicted effects on startle magnitude. Latency was speeded by negative compared to positive imagery at high levels of arousal; however, this result occurred as a planned comparison and in the absence of an overall effect of emotional modulation on startle latency. As in the first experiment, heart rate and rating results indicate that, other than for startle response, the emotional imagery contents produced the expected results.

4. General discussion

Two experiments examined the effects of attending and responding to the startle probe on affective modulation of the startle reflex. The two current experiments found no valence or arousal

[3] It should be noted that though the studies had similar methods, the arousal and valence comparisons were made using different emotion contents in the two experiments.

effect on modulation of the startle reflex response. This is contrary to at least 14 published studies of emotional imagery modulation of the startle response (Cook et al., 1991; Cuthbert et al., 2003; Gautier and Cook, 1997; Hawk et al., 1992; McTeague et al., 2009, 2010; Miller et al., 2002; Vrana, 1994; Vrana, 1995; Vrana et al., 1992; Vrana and Lang, 1990; Witvliet and Vrana, 1995, 2000), as well as hundreds of studies finding modulation of startle response by emotional pictures, smells, and aversive conditioning (see Bradley et al., 1999, and Lang, 1995, for early reviews). In contrast to the large literature finding affective modulation of the startle reflex, in the current studies the startle probe was attended to and was a signal for a speeded motor response.

Although the finding of no valence or arousal modulation of the startle reflex was replicated across two studies totaling nearly 100 participants, considerable caution must be taken when interpreting the results: construing a null statistical effect as a "real" no difference can be premature, especially when no condition was included to demonstrate emotional modulation of the startle response in these studies. To address this concern, and given that the operative variable (ignore vs. attend to the startle probe) was not manipulated in the present study, we compared the startle modulation effect sizes of Experiment 1 with the effect sizes from a nearly identical experiment-run in the same laboratory, sampling from the same participant population, and using the same equipment, startling stimuli, emotion stimuli, participant instructions, data collection and reduction software, etc. – differing mainly in whether the startle probe signaled a reaction time task. Effect sizes for valence and arousal modulation of startle magnitude, and for valence modulation of startle latency, were significantly smaller in the study requiring an RT to the startle probe. Disgust, another negative valence/high arousal emotion (the category that produces the greatest startle modulation) was added as an emotional content in Experiment 2. Once again, there was no valence or arousal modulation of startle magnitude, and once again these effect sizes were significantly smaller in the study requiring an RT to the startle probe. Experiment 2 found significant valence modulation of startle latency, though its effect size was still (nonsignificantly) smaller than the effect size in the study that did not require an RT to the startle probe. In sum, both experiments produced significantly smaller effect sizes for valence and arousal modulation of startle magnitude; all four valence and arousal modulation effect size comparisons for startle latency (an infrequently-reported dependent variable compared to magnitude) were smaller when an RT was required, though only one was significantly smaller. Thus, the null effects demonstrated in this manuscript appear to be substantially and reliably different from the often-found affective modulation of the startle response.

It must be first considered that the affective modulation of the startle response was eliminated because the reaction time task disrupted emotional image processing. However, this possibility can be discounted. Ratings of valence, arousal, dominance, and vividness of imagery replicated previous studies and showed that participants experienced the imagery as vivid and the emotional contents as intended. Similarly, heart rate accelerated during arousing and negative imagery, replicating earlier studies. Further, like previous studies (Vrana and Lang, 1990), startle responses were augmented during imagery compared to during the "count one" periods, suggesting that cognitive effort was being allocated to the imagery task (Panayiotou and Vrana, 1998).

Another possible explanation is that attention to the probe augmented the startle magnitude to the extent that a ceiling effect precluded affective modulation. In fact, startle response during the "count one" periods was larger in this study, when the probe signaled an RT response, than in an earlier study in which it did not. However, it is unlikely that this resulted in a ceiling effect, because a significant increase in startle was found in Experiment 1 during imagery compared to responses during "count one" periods, and a similar non-significant trend was found in Experiment 2; also, other studies have found both emotional and attentional modulation within the same procedure, and the emotion effects generally are larger (e.g., Haerich, 1994).

If affective modulation of the startle response was not eliminated by disrupted emotional processing or by a ceiling effect, possibly it was accomplished by the change in meaning of the startle probe caused by the RT task. It may be that when the startle probe is a significant stimulus that needs to be attended and/or responded to, the probe loses its negative affective tone, and participants may instead take an "approach" disposition to it because it is required for task completion. This may counteract the synergistic affective matching typically found between the aversive emotion and the aversive startle stimulus that is hypothesized to lie behind affective modulation of the startle reflex (Lang, 1995). Note that this does not mean that startle responses should be enhanced during positive emotion compared to negative, given that such an effect has not been found within the imagery paradigm previously, and that the enhanced startles found during intense positive emotions in previous studies (e.g., Witvliet and Vrana, 1995) are believed to be due to the independent effect of arousal and not of positive valence. Haerich (1994) made the startle probe more or less aversive through instruction (by describing an airpuff startle probe as "near the eye" or "toward the ear," respectively), and had participants either attend to the probe for a duration discrimination task or attend away from the probe. When the probe was more aversive, the expected attentional effect (startle response augmentation when the probe was attended) was disrupted, perhaps because the instructed aversiveness of the probe created an affective/behavioral mismatch with the attentional task, which required an approach orientation to the probe stimulus.

Future research is needed to determine whether this effect is due to the increased attention to the startle probe, the required motor task, or both, and whether the answer differs depending on the primary emotion manipulation. In the current imagery procedure, the emotion manipulation hinged on the participants' ability to do a demanding mental processing task. By contrast, when a simple RT response to the startle probe similar to the present study was employed during affective picture viewing, affective startle modulation was found (Bradley et al., 1996a,b). Thus, the same simple RT task eliminated affective modulation of startle by emotional imagery but not by affective picture viewing. This may be because picture viewing draws participants' attention more powerfully and is a simpler task with lower mental processing requirements.

Two recent studies (King and Schaefer, 2011; Wangelin et al., 2011), employing more cognitively effortful tasks than a simple RT concurrent with picture viewing, reduced or eliminated startle modulation by affective pictures even while other indicators of affective processing (affective ratings, heart rate, skin conductance) were not affected by the concurrent task. In a third study (Adam et al., 2009), when a discrimination task and aversive conditioning were combined in a complex task environment, only attention, and not aversive conditioning, modulated magnitude of response to the acoustic probe. It is not clear how relevant these three findings are in helping to explain the current results, as they involved neither emotional imagery nor a change in the meaning of the startle probe. However, these studies do show that a concurrent attention-engaging task can reduce or eliminate the otherwise-robust affective startle modulation effect without interfering completely with affective processing.

The startle response has been described as a defensive reflex (Lang, 1995) that is potentiated by affective contexts that match this defensive orientation. However, enhancement of a defensive response set may have proved unproductive in the context of this study, because a competing set for participants was to become activated and prepare for a motor response, rather than to withdraw and prepare for danger. Hence, affective modulation of the startle response may have been inhibited because it was counterproductive for the RT task, which required an active rather than a passive/defensive attentional response. Indeed, it may be that passive attention is needed for affective modulation of startle during picture viewing (Lipp et al., 2001); active defensive responses interfere with startle potentiation in animals (Lang, 1995). Patrick and Berthot (1995) have proposed that while in an aversive anticipatory set the startle response may be attenuated if the subject can perform an active coping response. Their study did not find evidence of startle attenuation, but in their case it was not the startle probe that was the signal for the active response set.

However, an explanation based on competing response tendencies is not fully satisfactory as Bradley et al. (1996a,b) found that requiring an RT to the startle probe during passive picture viewing did not interfere with affective modulation of startle response. In addition, Haerich (1994) found that, when instructions described visual or airpuff probes as aversive vs. not (as described above), startle responses were facilitated under the aversive conditions regardless of attention to the probes. These two earlier studies used sensory stimuli for the emotion prompt, whereas we used emotional imagery, which requires participants to be cognitively active and generate the emotion conditions. Perhaps the active set engaged by the RT instruction must be combined with the active imagery set to interfere with the usually robust affective modulation of the startle reflex. It remains to be seen in future studies whether similar results would be obtained had the startle probe been significant but did not entail a motor reaction, a control condition that was missing from the current experiments.

Although affective modulation of startle response was not found, attentional and cognitive effort did modulate the reflex: responses were facilitated when probes were attended compared to when they were ignored (e.g., Witvliet and Vrana, 1995), and during imagery compared to "count one" baseline. As Lipp et al. (2001, p. 181) suggest, "attentional and emotional startle modulation effects will emerge depending on the relative salience of the two components in a given situation." In the present case, it appears that attention to the startle probe, in order to perform adequately the RT task, proved to be more salient than emotional imagery. A weakness of this study was that a task-irrelevant startle probe was not included. Had a task-irrelevant startle probe been included, similar results to those of Lipp et al. might have been found, with emotional modulation obtained only when startle probes were not salient for task completion, as is the case in the majority of studies finding affective modulation of the startle response.

In sum, these studies found that emotional modulation of the startle response is inhibited when the startle probe is an imperative stimulus for an active reaction time response. Further work is needed to verify these results using conditions that manipulate the relative significance, effortfulness, and sensory modality of the emotional and attentional manipulations, to examine for instance if motivationally salient affective stimuli would override the attention effect (Gard et al., 2007). Future research should additionally include a control condition in which the startle probe is attended to but does not require a response. In spite of these limitations, this study demonstrates that even effects as robust as valence and arousal modulation of startle during imagery can reliably be blocked when emotional processing competes with other cognitive tasks.

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