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# In the face of anger: Startle modulation to graded facial expressions

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**Abstract**

In the present study, the startle reflex was examined with respect to the degree of anger displayed in facial expressions. To this end, 52 participants viewed faces that were morphed to display 0, 20, 40, 60, 80, or 100% anger. As the percentage of anger in faces increased from 0 to 100%, faces were perceived as increasingly angry; however, relative to neutral facial expressions, startle amplitude was only potentiated to maximally angry faces. These data imply a non-linear relationship between the intensity of angry faces and defensive physiological activity. This pattern of startle modulation suggests a categorical distinction between threatening (100% anger) and other facial expressions presented. These results are further discussed in terms of existing data, and how this paradigm might be utilized in psychopathology research.

**Descriptors:** Emotion, Startle, Faces, Anger

The startle response is a primitive defensive reflex that is observed across species in response to abrupt and intense sensory stimuli (Davis, 1984; Grillon & Baas, 2003). In humans, the eyeblink reflex is one of the most reliable components of the startle response (Grillon & Baas, 2003; Landis & Hunt, 1939). According to the motivational priming hypothesis, a defensive reflex should be potentiated when the aversive motivational system is active, but should be attenuated when the appetitive motivational system is active (Lang, Bradley, & Cuthbert, 1997). Indeed, research has supported this notion by demonstrating that eyeblink responses to startle probes are enhanced while participants view unpleasant scenes and attenuated when they view pleasant scenes (Lang, 1995); this pattern holds across various probe (e.g., acoustic, visual, tactile; Bradley, Cuthbert, & Lang, 1990) and affective stimulus modalities (e.g., sounds, movies, odors; Bradley, Cuthbert, & Lang, 1999).

Extensive research in non-human animals suggests that potentiation of the startle reflex by fear-eliciting stimuli depends critically on the amygdala (Davis, Falls, Campeau, & Kim, 1993; Davis, Walker, & Lee, 1999; Lang, Davis, & Ohman, 2000). Studies that employ functional neuroimaging confirm that startle modulation in humans is likewise dependent upon the amygdala (Pissiota, Frans, Michelgard, Appel, Langstrom, et al., 2003). Despite ample evidence that the human startle reflex is potentiated by complex aversive pictures, fewer studies have assessed whether the startle response is similarly increased while participants view threatening emotional faces. This is particularly surprising in light of the rather large functional neuroimaging literature on the amygdala that has utilized threatening faces as emotional stimuli (Blair, Morris, Frith, Perrett, & Dolan, 1999; Breiter, Etcoff, Whalen, Kennedy, Rauch, et al., 1996; Vuilleumier, Armony, Driver, & Dolan, 2001; Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998; Whalen, Shin, McInerney, Fischer, Wright, & Rauch, 2001). In one developmental study, 5-month-old children had larger startle amplitudes when viewing angry compared to happy or neutral faces (Balaban, 1995; but see Spangler, Emlinger, Meinhardt, & Hamm, 2001). In adult samples, potentiated startle has also been found in the context of angry compared to happy and neutral faces (Hess, Sabourin, & Kleck, 2007; Springer, Rosas, McGetrick, & Bowers, 2007). Thus, angry expressions reflect viewer-directed threat and effectively engage withdrawal or escape motivation (Springer et al., 2007). However, one study only found this effect when expressers were male (Hess et al., 2007); and Hess and colleagues suggest that male compared to female faces may indicate more direct threat since men are more associated with social dominance and aggressive acts than women.

Activation of the amygdala depends on the affective strength of the eliciting stimuli, such that amygdala activation increases as ratings of emotional intensity/arousal also increase (Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Phan, Taylor, Welsh, Decker, Noll, et al., 2003; Phan, Taylor, Welsh, Ho, Britton, et al., 2004). Data suggests that this type of dose-response relationship may also exist between stimulus aversiveness and potentiation of the startle reflex. For example, Bradley, Codispoti, Cuthbert, and Lang (2001) found potentiated startle responses in the presence of a wide variety of aversive picture content, including contamination, mutilation, and scenes depicting human and animal attack.

The authors would like to thank Paul Ekman for providing permission to reproduce Figure 1.

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Interestingly, when the unpleasant content was ordered according to participant ratings of arousal, a linear relationship between startle amplitude and arousal was evident such that startle responses were larger with higher arousal ratings (Bradley et al., 2001).

Although pictures of both complex scenes and emotional faces activate the amygdala and potentiate the magnitude of the defensive startle reflex, it is unclear whether the degree of unpleasant emotion in facial displays would be related to increases in startle response, as was shown with pictures from the International Affective Picture System. Facial stimuli are ideal for investigating dose-response relationships because the same face can be easily manipulated to display gradations of emotional intensity. No studies to date have examined whether 'more anger' in faces relates to larger startle responses. Therefore, the present study sought to determine whether the startle reflex would linearly track increasing levels of anger in faces, or whether startle potentiation would be evident at some threshold in the anger continuum. To this end, participants viewed faces that displayed 0, 20, 40, 60, 80, or 100% anger while acoustic startle probes were presented and eyeblink electromyographic (EMG) activity was measured. Participants also completed self-report ratings of perceived anger.

## Methods

### *Participants*

Fifty-two undergraduate students (29 female) participated in the present study. All participants gave written informed consent and received course credit for their participation. This research was approved by the Stony Brook University Institutional Review Board.

### *Stimuli*

Twelve photographs were selected from a standardized (Ekman & Friesen, 1976) picture set. For each of six male actors (male expressors were selected based on the aforementioned findings of Hess et al. (2007)[1]), we chose their neutral and angry facial expression; within each actor, neutral and angry faces were morphed with digital morphing software (MorphMan 3.0, STOIK Imaging, Moscow, Russia) to create six different facial expressions that ranged from neutral to angry (0%–100%) in increments of 20% (see Figure 1). Each picture was 732 $\times$ 452 pixels and presented in black and white on a 19-inch monitor set with a resolution of 1024 $\times$ 768 pixels. At a viewing distance of 25 inches, each picture occupied approximately 33° of visual angle horizontally and 27° vertically.

The acoustic startle probe was a 50-ms burst of white noise that was set to a volume of 105 dB and was delivered through headphones using a tone generator (Contact Precision Instruments, Cambridge, MA). All stimuli and psychophysiological responses were presented and recorded using PSYLAB hardware and PSYLAB 8 software (Contact Precision Instruments).

### *Procedure*

After obtaining informed consent, participants were given detailed task instructions. The experiment began with a four-trial startle habituation phase used to elicit initial extreme startle responses. For the remainder of the experiment, participants were presented with three blocks of 12 trials; each block contained two faces displaying each level of anger (0, 20, 40, 60, 80, and 100%) distributed randomly. On each trial, faces were presented for 10 s; startle probes occurred randomly between 3 to 5 s following picture onset. In addition, each block contained one or two intertrial interval (ITI) startle probes that occurred randomly between 3 to 7 s following stimulus offset in order to reduce probe predictability.

Finally, all participants completed a self-report rating of perceived anger for each of the 36 faces. Every picture was rated using an 11-point Likert-type scale that ranged from "neutral" (0) on one end to "angry" (100) on the other end in increments of 10 units; the midpoint was unlabeled.

### *Data Recording, Reduction, and Analysis*

Startle responses were recorded from EMG activity using a PSYLAB Stand Alone Monitor Unit (SAM) and BioAmplifier (Contact Precision Instruments). Two 4 mm Ag-AgCl electrodes were positioned approximately 25 mm apart over the orbicularis oculi muscle beneath the left eye, and an isolated ground was positioned on the forehead. EMG activity was sampled at 500 Hz, and band-pass filtered between 30 and 500 Hz. Startle EMG was rectified in a 200-ms window beginning 50 ms before the startle probe and smoothed using a 6-point running average. Startle amplitude was quantified as the maximum response in a 100-ms post-probe window relative to the average activity in the 50-ms pre-probe baseline period. No trials were excluded due to artifact or movement, and all trials (including non-response trials) were included in the present analyses. Startle amplitude for each subject was converted to *t* scores to reduce between-subject variability unrelated to variables of interest. Comparable results, however, were obtained when raw scores were analyzed.

All measures were statistically analyzed using SPSS 15.0 through repeated-measures analysis of variance (ANOVA) with Greenhouse-Geisser correction applied. Startle response and self-reported ratings of perceived anger were each examined by conducting separate one-way (degree of anger: 0, 20, 40, 60, 80, & 100%) repeated-measures ANOVAs. To further examine significant omnibus effects for startle responses, post hoc paired-samples *t*-tests were performed between neutral (0%) and all other angry faces (20, 40, 60, 80, 100%). For self-reported anger, post hoc paired-samples *t*-tests were performed between each level of anger and the one before it in the continuum. Bonferroni's correction was used for multiple comparisons (0.05/5 = 0.01).

## Results

As evident in Figure 2, self-reported ratings of perceived anger in facial expressions significantly differed across stimuli ($F$(5,

[1]Given the findings of Hess and colleagues (2007), we explored whether the gender of our participants may have played a role in the effects of startle potentiation or ratings of perceived anger in faces by conducting separate 6 (degree of anger: 0, 20, 40, 60, 80, & 100%) $\times$ 2 (gender) mixed-model ANOVAs. Results of startle amplitude revealed no main effect of gender ($F(1,50) < 1$) and no interaction between gender and degree of anger ($F(5,250) < 1$). Results of perceived anger ratings in facial expressions revealed no main effect of gender ($F(1,50) = 1.72$, $p > .15$) but a significant interaction between gender and degree of anger ($F(5,250) = 4.10$, $p < .01$). Post-hoc comparisons revealed that females compared to males rated 40% ($t(50) = 2.23$, $p < .05$) and 60% ($t(50) = 2.22$, $p < .05$) angry faces as slightly more angry. In addition, within males, 20% and 40% angry faces were not rated differently ($t(22) = -2.06$, $p > .05$), but all other within-gender effects matched the present study's overall findings.

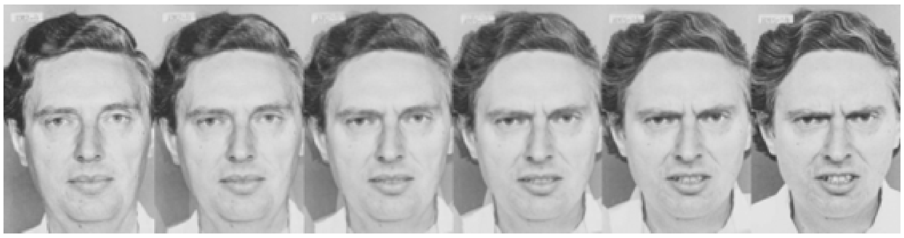

**Figure 1.** An example of one actor's morphed faces used in the present study. Starting from the left, faces demonstrate 0, 20, 40, 60, 80, and 100% anger.

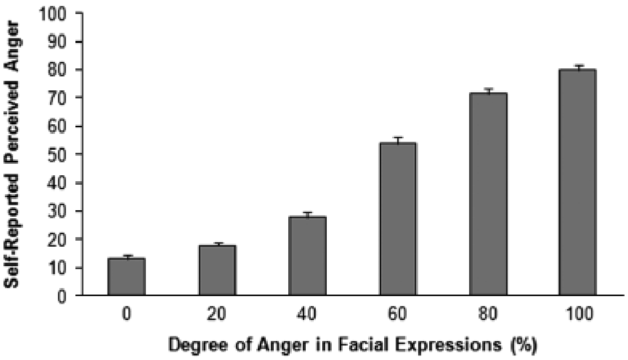


**Figure 2.** Average self-reported perceived anger present in each facial expression (0, 20, 40, 60, 80, and 100% anger). The scale ranged from 0 (neutral) to 100 (angry). Bars represent standard errors of the mean.

255) = 620.19, $p < .001$). Post-hoc comparisons revealed that each set of increasingly angry faces were rated as significantly more angry than the one before (20 > 0%, ($t(51) = -5.20$, $p < .001$); 40 > 20%, ($t(51) = -6.22$, $p < .001$); 60 > 40%, ($t(51) = -18.24$, $p < .001$); 80 > 60%, ($t(51) = -15.26$, $p < .001$); and 100 > 80%, ($t(51) = -7.34$, $p < .001$).

Consistent with the impression from Figure 3, startle amplitude differed as a function of the degree of anger in the facial stimuli ($F(5,255) = 2.70$, $p < .03$). Unlike the self-report findings, startle amplitude was significantly potentiated relative to neutral expressions (0%) only when faces were maximally angry (100%; $t(51) = -3.05$, $p < .005$). Relative to neutral expressions, there were no differences in startle amplitude at 20% ($t(51) = -.71$, $p > .45$), 40% ($t(51) = -.91$, $p > .35$), 60% ($t(51) = -.89$, $p > .35$), or 80% ($t(51) = .19$, $p > .80$) anger. Overall then, perceived anger increased linearly as a function of the percent of anger displayed in each facial expression. However, relative to neutral facial expressions, startle amplitude was significantly potentiated only by maximally angry faces.[2]

[2]To explore possible habituation effects over the course of the study, we compared startle amplitudes in the first and second halves of the task. In order to maintain an adequate number of trials per average in each half of the task, we collapsed levels of facial anger into the following 3 groups: 0–20%, 40–60%, and 80–100%. A 3 (degree of anger) × 2 (task half) repeated measures ANOVA revealed a main effect of task half ($F(1,51) = 114.82$, $p < .001$), such that larger startles were present in the first half of the task, and an interaction between task half and degree of facial anger ($F(2,102) = 9.26$, $p < .001$). Post-hoc comparisons revealed no differences in startle between levels of facial anger in the first half of the task (all $t$s < 2.20, $p$s > .03; did not meet family-wise alpha corrections). However, in the second half of the task, only 80–100% angry faces elicited larger startles than 0–20% angry faces ($t(51) = -3.42$, $p < .001$). Hence, the second half of the task exhibited results most similar to the original analyses in which only maximally angry faces elicited potentiated startle amplitudes.

## Discussion

The present study sought to determine whether the defensive startle reflex would be sensitive to the intensity of anger in facial expressions. Self-report ratings of perceived anger linearly tracked increasing levels of anger in faces, confirming that participants were aware of the relatively subtle differences of displayed anger. However, measures of defensive psychophysiology exhibited a different pattern of results: startle amplitude was potentiated only by maximally angry relative to neutral faces; startle amplitude did not differ between any of the less angry (20, 40, 60, 80%) compared to neutral facial expressions.

In regard to the maximally angry faces, the present findings are in line with recent studies demonstrating startle modulation to angry compared to neutral facial expressions (Hess et al., 2007; Springer et al., 2007). However, the threshold evident in our startle findings initially appear in contrast to that of Bradley et al. (2001), in which startle potentiation linearly increased with arousal ratings of unpleasant pictures. Such a comparison, although, may be between non-equivalent stimuli; Bradley et al. (2001) used unpleasant, complex pictorial scenes while our study focused on finer gradations of emotion in *facial* stimuli. A recent study found that, although viewing IAPS and facial expressions activates similar brain regions (e.g., amygdala, ventromedial prefrontal cortex, and visual cortex), participants rated expressive faces lower on dimensions of arousal and valence compared to IAPS (Britton, Taylor, Sudheimer, & Liberzon, 2006). Hence, one possibility is that there may exist more of a dose-response relationship between aversiveness and startle potentiation at the upper end of the arousal spectrum, whereas this relationship is binary/categorical for stimuli that are relatively low in arousal. Consistent with this possibility, Hess et al. (2007) only found startle potentiation to angry male, but not female, faces; these data are consistent with the possibility that only the most threat-

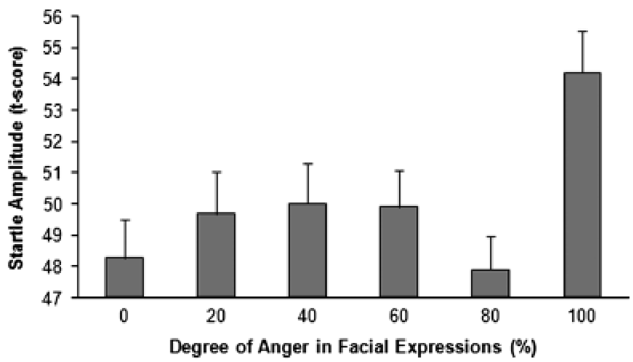


**Figure 3.** Standardized EMG activity elicited by startle probes as a function of degree of anger present in the facial expressions (0, 20, 40, 60, 80, and 100% anger). Bars represent standard errors of the mean.

ening faces in a given context are sufficient to activate the defensive motivational system.

When examining startle amplitudes between each half of the task, we found evidence of overall habituation, such that larger startles were present in the first compared to second half of the task. Interestingly, startle potentiation to angry faces was not present in the first half of the task; however, in the second half results were similar to the overall findings such that startle was potentiated only by the most angry faces. These data imply that modulation of startle by maximally angry faces may depend on experience with the full-range of stimuli, such that the categorization of anger with respect to other stimuli develops over time.

Our results do imply a disconnect between the perceived intensity of an aversive facial expression and modulation of the startle reflex. In this study, individuals were able to accurately perceive increasing increments of anger in faces via self-report ratings, but the startle response was potentiated in a binary manner, and only in response to maximally angry faces. In this way, the startle reflex was relatively insensitive to small gradations of anger in the present study.

It would be interesting to evaluate whether physiological or self-report measures better predict behavioral responses and individual differences in future studies. Along the same lines, the present paradigm may also have utility for investigating the role that individual differences play in patterns of startle modulation. By examining certain individual differences that might be linked to susceptibility to psychopathology (e.g., personality traits such as neuroticism, and individual differences in anxiety and depression), it is possible that group differences may emerge in patterns of startle modulation. For instance, social phobia and high levels of social anxiety have been associated with interpretation biases—the tendency to interpret ambiguous social information as negative (Franklin, Huppert, Langner, Leiberg, & Foa, 2005; Hirsch & Clark, 2004; Stopa & Clark, 2000). It is possible that social anxiety may be associated with a lower threshold for startle potentiation when viewing morphed faces. If this were the case, patterns of startle reflex attenuation/potentiation in paradigms that use graded facial expressions of emotion might be useful in psychopathology studies.

Startle potentiation to maximally angry faces in the present study would also suggest modulation of the amygdala (Blair et al., 1999; Breiter et al., 1996; Pissiota et al., 2003; Vuilleumier et al., 2001; Whalen et al., 1998, 2001). Given this notion, it would be interesting for future studies to determine if the amygdala similarly demonstrates a binary response to faces that vary in expressed anger. A final possible future direction would be to determine if the present findings generalize to different emotions such as fear or even happiness. Given that startle inhibition typically occurs in the presence of pleasant scenes (Bradley et al., 2001; Lang et al., 1997), future studies could determine if startle attenuation, as opposed to potentiation, similarly requires intense emotional stimuli or whether a dose-response relationship between startle inhibition and emotional intensity would be evident when viewing graded facial expressions of happiness.

Overall, our study demonstrated that, in the context of angry facial expressions, the defensive startle reflex was only potentiated by maximally angry expressions. Interestingly, self-reported perceived anger did not follow this pattern, but instead linearly tracked increasing levels of anger. Results indicate that aversive facial expressions differentially engage the startle reflex and conscious emotional perception. Future studies should determine if this effect generalizes to different emotions, and determine whether or not different patterns of startle modulation would be evident among those more sensitive to social signals of rejection and threat.

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