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Suppression and enhancement of emotional responses to unpleasant pictures

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Abstract

Despite the prominence of emotional dysfunction in psychopathology, relatively few experiments have explicitly studied emotion regulation in adults. The present study examined one type of emotion regulation: voluntary regulation of short-term emotional responses to unpleasant visual stimuli. In a sample of 48 college students, both eyeblink startle magnitude and corrugator activity were sensitive to experimental manipulation. Instructions to suppress negative emotion led to both smaller startle eyeblinks and decreased corrugator activity. Instructions to enhance negative emotion led to larger startle eyeblinks and increased corrugator activity. Several advantages of this experimental manipulation are discussed, including the use of both a suppress and an enhance emotion condition, independent measurement of initial emotion elicitation and subsequent regulation of that emotion, the use of a completely within-subjects design, and the use of naturalistic emotion regulation strategies.

Descriptors: Emotion regulation, Eyeblink startle magnitude, Corrugator

Emotion regulation has been defined by Thompson (1994) as "the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals" (pp. 27–28). Disruptions in normal emotion regulation undoubtedly play a pivotal role in the onset and maintenance of depression and anxiety, both of which may involve a chronic inability to suppress negative affect. In addition, several of the Axis II disorders described in the *DSM-IV* (American Psychiatric Association, 1994) list an inability to regulate negative affect as a criterion for diagnosis. Although there have been many studies that have examined relations between self-report measures of coping that putatively reflect aspects of emotion regulation and indices of emotional reactivity (e.g., Notarius & Levenson, 1979; Weinberger, Schwartz, & Davidson, 1979), few experimental studies have explicitly examined the regulation of negative affect in either patient or nonpatient samples.

Experimenters examining the effects of long-term suppression of emotional arousal typically find that individuals who characteristically suppress emotional arousal (as indexed by self-report) show heightened physiological responses to emotionally arousing stimuli (e.g., Weinberger et al., 1979). Wegner has amassed considerable evidence showing that attempts to suppress "exciting thoughts" result in increased skin conductance levels (SCL) both during the suppression task and when subjects experience subsequent re-intrusions of the suppressed thought (Wegner, Shortt, Blake, & Page, 1990; Wegner & Zanakos, 1994). These results suggest that self-reported emotional suppression may be inversely correlated with suppression as measured physiologically.

Conversely, studies in which emotional expressivity has been manipulated experimentally suggest the opposite: subjects who are asked to inhibit emotional expression are likely to show decreases in emotional arousal commensurate with the degree of inhibition of expression (for a review, see Gross & Levenson, 1993). For example, Colby, Lanzetta, and Kleck (1977) reported a monotonic and positive relation between intensity of posed facial pain expression and SCL during painful electrical shock of varying intensities. In several recent studies, Gross attempted to more closely examine the autonomic and somatic nervous system effects of emotion regulation (Gross, 1998; Gross & Levenson, 1993, 1997). In general, instructions to inhibit facial expressiveness while watching disgusting film clips have led to increases in SCL and finger pulse amplitude, suggesting that suppression of negative emotion leads

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to increased arousal. However, suppression also led to decreases in heart rate and somatic activity, suggesting a more complex pattern of suppression effects. Gross (1998) also studied the effects of "reappraisal"—asking subjects to remain detached from the emotional material—and reported that reappraisal led to decreases in emotional expressiveness but *not* to increased sympathetic arousal. Gross argued, therefore, that reappraisal may be more effective and less costly in terms of long-term physical health than merely suppressing emotional expression.

The studies of emotion regulation cited above reveal the difficulties encountered by the researcher interested in studying emotion regulation. The largely correlational studies of characteristic expressive styles suggest that suppression of negative affect is associated with increased physiological activity, whereas experimental studies of the suppression of emotion expression present a mixed pattern of increased and decreased activation. An important distinction between the two basic types of studies described above is that between voluntary and automatic regulation of negative affect. Studies of characteristic expressive styles typically examine the correlations between particular styles of coping with, and awareness of, negative emotions that occur in largely automatic fashion. In contrast to the correlational studies of the effects of automatic emotion regulation, the data presented here were acquired using a simple laboratory paradigm to elicit affect and its subsequent regulation. Given the ubiquity with which problems in the regulation of negative emotions are present in various forms of psychopathology, the focus of the current study was on the voluntary regulation of negative emotional responses. In addition, the focus of the current study was on the conscious *experience* of negative affect rather than on the *expression* of that affect. The effects of regulation of negative affect on two physiological measures that are heavily used in emotion research, but previously unused in emotion regulation tasks, were examined: startle eyeblink response and corrugator electromyogram (EMG) activity.

The present study examined a small subset of possible emotion regulation techniques: voluntary regulation of short-term responses to unpleasant pictures. Both the initial and persistent effects of emotion suppression and enhancement on the startle response and corrugator EMG activity were examined. The startle eyeblink response, comprised of a pattern of behaviors that are typically elicited by an abrupt stimulus, such as electric shock or a fast rise-time white noise burst, provides a reliable, well-validated measure of bivalent (i.e., positive/negative) responses to emotional stimuli (e.g., Bradley, Cuthbert, & Lang, 1990). Behaviors associated with the startle response include forward head and trunk movement, flexion of the fingers, widening of the mouth, and contraction of the abdomen (Davis, 1984). In human research, the startle response is often conveniently indexed by measurements of the contraction of the *orbicularis oculi* muscle in response to auditory startle probes (white noise bursts). Measures of startle blink magnitude are sensitive to changes in attentional demands (Bradley, Cuthbert, & Lang, 1993) and to psychophysical stimulus properties (Blumenthal & Berg, 1986).

Extensive research by Lang and his colleagues (e.g., Lang, Bradley, & Cuthbert, 1990, 1992; Lang, Greenwald, Bradley, & Hamm, 1993) has shown that the startle blink displays affect modulation: the magnitude of startle blinks elicited by a background auditory startle probe varies as a function of foreground stimulus valence. The startle blink is typically larger when the probe is presented in the presence of a negative foreground stimulus (relative to a neutral stimulus), and smaller when the probe is presented in the presence of a positive foreground stimulus. Lang (Lang, 1995; Lang et al., 1990, 1992) has interpreted this finding in terms of motivational state: an unpleasant foreground stimulus activates the aversive motivational system, thus potentiating the startle response. Conversely, a pleasant foreground stimulus activates the appetitive motivational system, which in turn inhibits the startle response. Affect modulation of startle blink magnitude has been demonstrated using visual (Bradley et al., 1993; Jansen & Frijda, 1994), olfactory (Miltner, Matjak, Braun, Diekmann, & Brody, 1994), and narrative (Cook, Hawk, Davis, & Stevenson, 1991) stimuli. The startle response is particularly useful as a tool for affective chronometry (Davidson, 1998): the measurement of waxing and waning emotional states over short time epochs. By presenting probes at various points in different experimental trials, the startle eyeblink may be used to characterize both the timing and intensity of an emotional response. In addition to examining startle eyeblink data, in the current study EMG was also collected from the facial muscle *corrugator supercilii*, activity of which typically increases in response to unpleasant stimuli and decreases in response to pleasant stimuli (Bradley et al., 1990; Lang et al., 1993). The choice of these psychophysiological measures reflects the belief that the physiological effects of emotion regulation are best indexed by measures that have been shown to reflect brief changes in emotional state. Given that increases in startle eyeblink magnitude and corrugator activity have been consistently associated with increases in negative affect, the effectiveness of instructions to suppress or enhance negative affect should be reliably indexed by these measures. Two features of the startle eyeblink and corrugator activity particularly recommend these measures for use in experimental studies of emotion regulation. First, they are relatively unobtrusive and place few or no demand characteristics on the subject. Second, they are capable of tracking extremely short-term changes in emotional state—a clear advantage over the use of self-report measures.

It was hypothesized that successful suppression and enhancement of negative emotion would mirror the oft-reported affect-modulation effects in both startle eyeblink magnitude and corrugator activity. Simply put, if the presence of negative affect is indexed by increased startle blink magnitude and increased corrugator activity, successful enhancement of that negative affect should produce even greater increases in the activity of these psychophysiological variables. Likewise, successful suppression of negative affect should result in smaller eyeblinks and decreased corrugator activity.

In the current study, subjects were presented with highly unpleasant, highly arousing visual stimuli, interspersed with neutral visual stimuli. After stimulus onset subjects were asked to suppress, enhance, or simply maintain their emotional response to the stimulus. An important feature of the current study was the ability to differentiate between the initial emotion and the subsequent regulation of that emotion. By collecting startle eyeblink and corrugator data both before and after the instruction to suppress, enhance, or maintain the negative affect induced by the picture, it is possible to assess the degree to which the pictures are successful at eliciting negative affect, independently of emotion regulation instruction. A second feature of this study was the inclusion of an enhance condition in addition to a suppress condition. In addition, a maintain instruction was included as a control condition. By including these three conditions in a within-subject design, separate (and opposite) predictions concerning the effects of different emotion regulation instructions on startle eyeblink magnitude and corrugator activity could be made, rather than more vague predictions about emotion regulation in general. This predictive ability is particularly important in separating the effects of the general effort (e.g., cognitive, attentional) involved in regulating negative emotion from the patterns of physiological activity that may accompany specific emotion regulation operations. In pilot work, suppress and enhance instructions were paired with neutral as well as unpleasant pictures; however, subjects reported confusion when asked to suppress a neutral emotional response. An analysis strategy was therefore adopted in which the suppression and enhancement of negative affect was compared with the maintain condition in a within-valence, within-subjects fashion. Finally, subjects were allowed to choose emotion regulation strategies that they felt would be most effective at suppressing or enhancing negative emotion. Gross (1998) successfully differentiated between the effectiveness of different experimenter-taught emotion regulation strategies (i.e., antecedent-focused vs. response-focused strategies of suppression of emotion expression). By giving subjects the freedom to use whatever strategies they saw as most effective, it was hoped that their choices would help elucidate the ways in which people choose to suppress and enhance negative emotion in their everyday lives.

It was predicted that startle eyeblinks would be larger for probes presented during unpleasant pictures, relative to neutral pictures, and that there would be more corrugator activity during the unpleasant pictures. Confirmation of these predictions would provide validation of our stimuli and psychophysiological measures, based on previous work with these pictures (e.g., Bradley et al., 1990; Lang et al., 1990, 1993; Sutton, Davidson, Donzella, Irwin, & Dottl, 1997). The main predictions for this study, however, involved the emotion regulation instructions: it was hypothesized that instructions to suppress negative affect would lead to startle eyeblinks of lesser magnitude (relative to the maintain instruction), and that the instructions to enhance negative emotion would lead to startle eyeblinks of greater magnitude. It was also hypothesized that more corrugator activity would be measured following instructions to enhance negative emotion, and less corrugator activity following instructions to suppress negative emotion. These predictions follow directly from the affect-modulation work cited above: successful suppression of negative affect should lead to less intense negative affect (and thus smaller startle eyeblinks and decreased corrugator activity), and successful enhancement of negative affect should lead to more intense negative affect (and thus larger startle eyeblinks and increased corrugator activity).

Method

Subjects

A total of 33 female and 15 male subjects were tested. Subjects were recruited from the Introductory Psychology pool of the University of Wisconsin–Madison and received $20 for their participation in a 2-hr laboratory session. Subjects ranged in age from 18 to 52 years ($M = 20.50$ years, $SD = 5.00$). All subjects were right handed as assessed by the Chapman Handedness Inventory (Chapman & Chapman, 1987). Subjects were screened for psychiatric and neurological disorders during the initial phone contact. One subject voluntarily discontinued the experiment after becoming distressed by the unpleasant pictures. The startle blink data of four subjects were excluded, as they displayed an insufficient number of eyeblink responses; these subjects were retained in the analyses of corrugator activity.

Procedure

Each subject participated in one laboratory session, which lasted approximately 2 hr. In an effort to increase the motivation of subjects to perform well, subjects were told that $50 would be paid to the top 10% of suppressors and enhancers, as determined by their "physiological responses" to the stimuli. EMG sensors were then applied.

Subjects were asked to watch digitized color images from the International Affective Picture Set (IAPS; Center for the Study of Emotion and Attention [CSEA-NIMH], 1995). Each picture was presented for 8 s with 12 s between pictures. A total of 120 pictures were presented in 6 blocks of 20 pictures each. At 4 s poststimulus onset, a digitized human voice instructed the subject to attempt to regulate the emotion they were feeling in response to the picture. Subjects heard a one-word emotion regulation instruction: for unpleasant pictures, subjects were asked to either suppress, enhance, or maintain their emotional response, whereas for neutral pictures, subjects were always asked to maintain their emotional response. Subjects were asked only to maintain their emotional response to neutral pictures to avoid ambiguous instructions to suppress or enhance a presumably nonexisting emotional response. Subjects were instructed to continue suppressing, enhancing, or maintaining their emotional response even after the picture disappeared. Four seconds before the onset of the next stimulus the word "RELAX" appeared on the screen. This word was the cue for the subjects to stop suppressing, enhancing, or maintaining their emotional response to the previous picture. During and/or after each picture presentation, an acoustic startle probe (a 95-dB, 50-ms burst of white noise generated by a Coulbourn S81-02 noise generator) was presented at either 3 s (probe A), 7 s (probe B), 12 s (probe C), or 15 s (probe D) poststimulus onset. Each of the 16 possible trial types (e.g., unpleasant picture/enhance instruction/Probe A; neutral picture/maintain instruction/Probe D) occurred exactly seven times during the course of the experiment. For eight of the trials no probe was presented. After the second and fourth picture blocks subjects completed a "strategy questionnaire" in which they described the strategies they used to suppress and enhance negative emotions. After the sixth and final picture block the physiological sensors were removed and the subject received an oral debriefing.

Stimuli

The emotion-eliciting stimuli were selected from the IAPS based on the female and male valence and arousal ratings published by Lang, Bradley, and Cuthbert (1995). Valence and arousal ratings within the entire IAPS were standardized separately before picture selection; valence and arousal ratings given below are thus in *z*-units. Pictures were selected to produce two distinct picture sets: unpleasant (low valence, high arousal), and neutral (medium valence, low arousal).[1] Ninety unpleasant (standardized valence $M = -1.25$, $SD = .44$, standardized arousal $M = 1.04$, $SD = .48$) and 30 neutral pictures (standardized valence $M = -.06$, $SD = .20$, standardized arousal $M = -1.59$, $SD = .36$) were included in the final picture set. (Fewer neutral pictures were needed because they were paired only with the instruction to maintain the currently felt emotion.) This provided 7 pictures in each of the 16 picture set/instruction/probe time conditions.

Three quasirandom orders were created in which pictures were counterbalanced for order of presentation, instruction type, and

[1] For a complete list of IAPS pictures used in this study, or for information concerning statistical comparisons between valence and arousal ratings for the unpleasant and neutral picture sets, contact the authors.

time of startle probe. No more than five pictures from a particular picture set appeared consecutively, and no more than three identical instruction types or startle probe times occurred consecutively.

Emotion Regulation Instructions

Subjects were free to choose the emotion regulation strategies they felt were most effective. However, based on the notion that suppression of an emotion is not equivalent to replacing that emotion with a different one, subjects were instructed not to generate thoughts and images that were completely unrelated to the presented stimulus in order to produce a different emotion to compete with or replace their initial emotional response to the picture. For example, if the subject was asked to suppress the fear they felt in response to a picture of a poisonous snake, they were instructed not to think of something unrelated that generated a positive emotion (e.g., the end of finals week and beginning of winter holiday). However, subjects were free to focus on a positive aspect of the picture or on a possible positive outcome of the situation in the picture. For example, one subject reported imagining that the poisonous snake mentioned above was about to be killed, which helped to decrease the fear he was feeling in response to the picture. Subjects were able to understand these instructions, as evidenced during an intensive practice session in which subjects gave detailed verbal descriptions of the strategies they were using to regulate emotion. Subjects who had a difficult time understanding the task or generating effective strategies were given additional coaching until the experimenter felt they were able to implement and articulate their emotion regulation strategies. The experimenter continued to monitor the chosen emotion regulation strategies via the strategy questionnaires administered after the second and fourth picture blocks. (For a verbatim account of the emotion regulation instructions given to each subject, see Appendix I.)

EMG Data Collection and Reduction

Raw EMG from the *orbicularis oculi* was collected using two Sensormedics mini-electrodes placed directly below the left or right eye (counterbalanced across subjects). Eyeblink startle and corrugator EMG data were amplified with SAI Bioelectric amplifiers (SA Instrumentation Co., Encinitas, CA) using a gain of 10,000, and highpass filter setting of 1 Hz. Startle eyeblink data were lowpass filtered at 800 Hz; corrugator data were lowpass filtered at 400 Hz. Startle eyeblink data were integrated and rectified using a Coulbourn S76-01 contour-following integrator with a time constant of 20 ms. Data were collected using a personal computer equipped with a 12-bit analog-to-digital board (Analogic Corp., Wakefield, MA) with SnapStream software (HEM Data Corp., Southfield, MI). The eyeblink startle signal was sampled at 1000 Hz, beginning 50 ms before the onset of the startle probe; sampling continued for 250 ms following probe onset. The corrugator signal was recorded continuously throughout the trial. Recording equipment was calibrated both before and after each recording session.

Integrated and rectified EMG signals were computer-scored and reviewed. Trials were excluded if they contained excessive noise during the 50-ms prestartle baseline epoch, or if the onset of the eyeblink reflex began less than 15 ms after the startle probe. Startle blink magnitudes (in microvolts) were calculated by subtracting the amount of integrated EMG at reflex onset from the maximum peak of integrated EMG between 20 and 120 ms following probe onset. Noise-free trials with no perceptible eyeblink reflex were given a magnitude of zero. Blink magnitudes were z-transformed within-subjects to control for large individual differences in response amplitude and baseline EMG levels. Finally, startle blink magnitudes were averaged across subjects to obtain grand-average blink magnitudes for each cell (e.g., unpleasant picture/maintain instruction/Probe B). Data from individual subjects were not included in these grand averages if they contained fewer than three scorable responses in any particular cell.

Raw EMG from the *corrugator supercilii* was recorded in identical fashion as the *orbicularis* EMG. All data were scored for artifact. A fast Hartley transform (FHT; Bracewell, 1984) was performed on all artifact-free 1.024-s chunks of data (extracted through overlapping Hamming windows) to derive estimates of spectral power density (μV^2) in the 45–200-Hz frequency band. These values were log-transformed to normalize the data. Corrugator activity was divided into three distinct epochs for analysis: preinstruction epoch (0–4 s poststimulus onset), postinstruction epoch (4–8 s poststimulus onset), and postpicture epoch (0–7 s poststimulus offset).

Data Analysis

There were two main classes of predictions for these data: those involving affect modulation and those involving emotion regulation. Data collected *before* the occurrence of the emotion regulation instruction (i.e., Probe A eyeblink magnitude and preinstruction epoch corrugator activity) were used to assess the modulation of startle eyeblink magnitude and corrugator activity by the viewing of unpleasant pictures (relative to neutral pictures). This important comparison thus examines responses to unpleasant and neutral pictures in the absence of emotion regulation effects. Emotion regulation effects on the startle blink data collected during and following the unpleasant pictures were assessed using a 3 (Instruction: enhance, maintain, suppress) $\times$ 3 (Probe Time: 7, 12, 15 s poststimulus onset) multivariate analysis of variance (MANOVA). Emotion regulation effects on corrugator activity were similarly examined with a 3 (Instruction) $\times$ 2 (Epoch: postinstruction and postpicture) MANOVA. All factors were treated as repeated measures. Effects were evaluated using a multivariate test statistic (Wilks' lambda); a significance level of .05 was used in all analyses. Emotion regulation strategies generated by subjects are reported descriptively. To assess the effectiveness of different emotion regulation strategies in terms of changes in startle eyeblink magnitude and corrugator activity, t tests were used. Finally, correlations between the ability to suppress negative emotion and the ability to enhance negative emotion were computed using change scores (enhance $-$ maintain and maintain $-$ suppress) for both startle eyeblink and corrugator data.

Results

Affect-Modulation Effects

Eyeblink startles elicited by Probe A were significantly larger during unpleasant ($M = .21$, $SD = .24$) pictures than during neutral ($M = -.12$, $SD = .32$) pictures, $t(42) = 5.41$, $p < .001$. There was also significantly greater corrugator activity during the unpleasant ($M = 4.88$, $SD = 1.35$) pictures than during neutral ($M = 4.22$, $SD = 1.32$) pictures, $t(47) = 6.53$, $p < .001$.

Emotion Regulation Effects on Startle Magnitude

Table 1 lists the means and standard deviations for eyeblink startle magnitude and corrugator activity in each of the emotion regulation conditions.

Table 1. *Means (SDs) for Eyeblink Startle Magnitude and Corrugator Activity in Each Emotion Regulation Condition*

	Unpleasant			All instructions	Neutral
	Enhance	Maintain	Suppress		Maintain
Eyeblink magnitude					
Probe B	.19 (.50)	−.36 (.39)	−.56 (.30)	−.22 (.30)	−.50 (.34)
Probe C	.34 (.47)	.23 (.50)	−.09 (.35)	.15 (.21)	−.15 (.33)
Probe D	.38 (.43)	.17 (.41)	.01 (.34)	.18 (.23)	.07 (.49)
All probes	.29 (.30)	.02 (.23)	−.20 (.19)	.04 (.12)	−.18 (.27)
Corrugator power density (45–200 Hz)					
Postinstruction	5.02 (1.34)	4.92 (1.36)	4.49 (1.34)	4.81 (1.31)	4.21 (1.29)
Postpicture	4.89 (1.31)	4.76 (1.33)	4.33 (1.30)	4.66 (1.27)	4.14 (1.27)
All epochs	4.95 (1.32)	4.84 (1.34)	4.41 (1.31)	4.73 (1.29)	4.17 (1.28)

A 3 (Instruction: enhance, maintain, and suppress) × 3 (Probe Time: Probes B, C, D) MANOVA[2] using startle blink magnitude during and following the viewing of unpleasant pictures as the dependent variable revealed a main effect for instruction, $F(2,34) = 34.77$, $p < .001$. Startle blinks following the enhance ($M = .29$, $SD = .30$) instruction were significantly larger than those following the maintain ($M = .02$, $SD = .23$) instruction, $t(43) = 4.09$, $p < .001$, and suppress ($M = -.20$, $SD = .19$) instruction, $t(43) = 7.90$, $p < .001$. Startle blinks following the suppress instruction were significantly smaller than those following the maintain instruction, $t(43) = 5.48$, $p < .001$. There was also a main effect for probe time, $F(2,34) = 28.16$, $p < .001$. Startle blinks at Probe B ($M = -.22$, $SD = .30$) were significantly smaller than startle blinks at Probe C ($M = .15$, $SD = .21$), $t(43) = 6.30$, $p < .001$ and Probe D ($M = .18$, $SD = .23$), $t(43) = 6.62$, $p < .001$. Startle blinks at Probe D and Probe C did not differ. The Instruction × Probe Time interaction was also significant, $F(4,32) = 5.05$, $p = .003$, accounted for by the fact that at Probe C there was no significant difference between eyeblinks following the enhance and maintain instructions (see Table 1).

Emotion Regulation Effects on Corrugator Activity

Using corrugator activity during and following unpleasant pictures as the dependent variable, a 3 (Instruction: enhance, maintain, and suppress) × 2 (Epoch: postinstruction and postpicture) MANOVA revealed main effects for instruction, $F(2,46) = 17.80$, $p < .001$ and epoch, $F(1,47) = 20.87$, $p < .001$. Follow-up analyses revealed that there was less corrugator activity following the suppress ($M = 4.41$, $SD = 1.31$) instruction than following the maintain ($M = 4.84$, $SD = 1.34$) instruction, $t(47) = 5.45$, $p < .001$ and the enhance ($M = 4.95$, $SD = 1.32$) instruction, $t(47) = 5.96$, $p < .001$. There was also greater corrugator activity following the enhance instruction than following the maintain instruction, $t(47) = 2.20$, $p = .033$. In addition, there was greater corrugator activity during the postinstruction ($M = 4.81$, $SD = 1.31$) epoch than during the postpicture ($M = 4.66$, $SD = 1.27$) epoch, $t(47) = 4.57$, $p < .001$. There was no Instruction × Epoch interaction.

Self-Reported Emotion Regulation Strategies

The strategy questionnaires completed by subjects after the second and fourth picture blocks revealed that few emotion regulation strategies were used. When subjects used more than one strategy to suppress or enhance negative emotion, they were asked to indicate the approximate percentage of time they used each strategy. The totals presented below reflect the strategy each subject used most frequently. To suppress negative emotions, 19 subjects (40%) reported attempting to focus on positive aspects or possible outcomes of the situation depicted. For instance, following the presentation of a depiction of a wounded soldier, one subject reported imagining that the battle was over and that the soldier was returning to his family. Twenty-seven subjects (56%) reported attempting to rationalize or objectify the situation in the picture, for example, imagining that the picture was fake or part of a dream, or imagining that the characters in the scene had "gotten what they deserved." Finally, 2 subjects (4%) reported using idiosyncratic strategies to suppress negative emotion. To enhance negative emotion, 22 subjects (46%) reported simply imagining themselves or a loved one in the situation depicted (e.g., imagining themselves or a family member as the victim of a vicious assault). Twenty-two subjects (46%) reported attempting to focus on the extremely negative aspects (e.g., focusing on the blood in a picture of an auto accident) or possible outcomes (e.g., imagining the funeral of the victims of the accident) of the situation in the picture. Four subjects (8%) reported using idiosyncratic strategies to enhance negative emotion.

To assess the relative effectiveness of the different emotion regulation strategies (effectiveness being defined here in terms of predicted effects on startle eyeblink magnitude and corrugator activity), enhance minus maintain and maintain minus suppress difference scores were computed for eyeblink startle magnitude

[2] In the following analyses examining the effects of emotion regulation instructions, data acquired before the regulation instruction (i.e., startle blink magnitudes to Probe A, and corrugator activity during the preinstruction epoch) are not included. To detect the possibility that the counterbalancing of stimuli had inadvertently favored one condition over others (e.g., if more negatively valenced pictures had been randomly assigned to the enhance negative condition), we conducted MANOVAs using only preinstruction data. A one-way MANOVA using startle blink magnitudes during the unpleasant pictures as the dependent variable confirmed that there was no main effect for instruction at startle Probe A. An identical MANOVA using corrugator activity did reveal a main effect for instruction during the preinstruction epoch, $F(2,46) = 3.50$, $p = .038$. However, follow-up comparisons showed that this effect was due to the presence of slightly greater corrugator activity preceding the suppress ($M = 4.93$, $SD = 1.35$) instruction than preceding the maintain ($M = 4.85$, $SD = 1.36$) instruction, $t(47) = 2.65$, $p = .012$. The direction of this difference works against our hypothesized effects.

and corrugator activity. High numbers indicate effective enhancement (enhance − maintain) or effective suppression (maintain − suppression) of negative emotion; t tests were performed using these difference scores as the dependent variables and strategy as the independent variable. For the enhance − maintain difference scores, eyeblink startle magnitude was greater for those subjects who reported enhancing negative emotion by imagining themselves or a loved one in the situation depicted (M = .41, SD = .44) than for those subjects who reported focusing on the extremely negative aspects of the situation in the picture (M = .14, SD = .43) epoch, $t(39) = 1.99$, $p = .05$. There were no differences in effectiveness at enhancing negative emotion as indexed by enhance − maintain differences in corrugator activity. Likewise, there were no differences in effectiveness between the two common suppression strategies (focusing on positive aspects or outcomes of the situation and rationalizing or objectifying the situation) on either eyeblink startle magnitude or corrugator activity.

Relation Between Suppressing and Enhancing

Finally, the relation between ability to suppress negative emotion and ability to enhance negative emotion was examined by computing correlations between maintain minus suppress and enhance minus maintain difference scores for both eyeblink startle magnitude and corrugator activity. Startle eyeblink magnitudes in the maintain minus suppress and enhance minus maintain conditions were significantly inversely correlated, $r = -.40$, $p = .006$ (see Figure 1). Corrugator activity in the two subtraction conditions was not correlated.

Discussion

Affect-Modulation Effects

An important feature of the current study was the ability to assess the initial elicitation of a negative emotional response *prior* to any attempt to regulate that response. The placement of a startle probe after picture onset but before the instruction to suppress, maintain, or enhance the emotional response, and the collection of corrugator data during this preinstruction period, allowed examination of "unregulated" emotional responses. Both startle eyeblink magnitude and corrugator activity were increased during the viewing of unpleasant pictures, relative to neutral pictures, thus verifying that these stimuli produced the intended emotional consequences. These affect-modulation effects ensured that the to-be-regulated negative affect was indeed present before the instruction to suppress, maintain, or enhance.

Time Effects

We found that Probe B (7 s poststimulus onset) elicited smaller startle blinks than did any other probe during or following unpleasant pictures. This effect may reflect the increased attentional demands caused by concurrent processing of the emotion regulation instruction and picture viewing. Probe B occurred a full 2,100 ms after the emotion regulation instructions, considerably later than those probes used by Bradley et al. (1993) who reported prepulse inhibitory effects of a visual stimulus occurring up to 800 ms before the startle probe. It is thus unclear whether prepulse inhibition, described by Graham as an attentional mechanism that protects processing from disruption by a competing stimulus (Graham, 1980; Hackley & Graham, 1987),

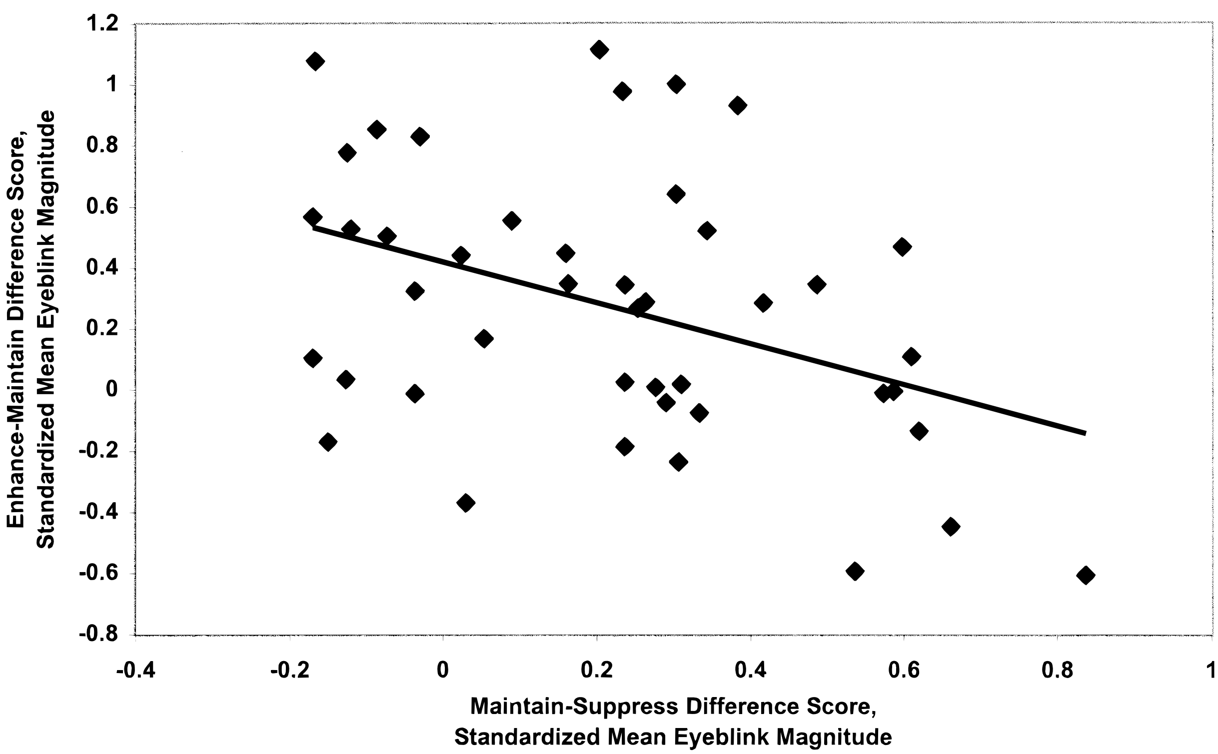

Figure 1. Relationship between standardized mean eyeblink magnitude enhance − maintain and maintain − suppress difference scores ($r = -.40$, $p = .006$).

is a viable explanation for our Probe B effect. This effect may reflect a more general attentional attenuation of startle magnitude. It is important to note that our emotion regulation effects were as large or larger at Probe B than at other times (see Table 1), suggesting that this attenuation does not disrupt changes in startle magnitude associated with emotion regulation. We also found greater corrugator activity in the postinstruction epoch, relative to the postpicture epoch. We attribute these effects to the natural decay of the emotional response following stimulus offset. It may be that more discrete divisions of corrugator activity (e.g., examining 1-s data bins) will be a fruitful future strategy for characterizing this decay function.

Emotion Regulation Effects

The main predictions for the current study involved changes in startle blink magnitude and corrugator activity as a result of instructions to suppress, maintain, or enhance emotion. It was reasoned that successful suppression and enhancement of negative emotion, as measured physiologically, would mirror the basic affect-modulation effects described in the literature. These predictions concerning regulation of negative emotion were confirmed. Attempts to suppress a negative emotional response led to decreased startle magnitude and decreased corrugator activity, whereas attempts to enhance a negative emotional response led to increased startle magnitude and increased corrugator activity, relative to the maintain condition. These findings suggest that this experimental paradigm (utilizing visual stimuli and simple instructions to suppress, enhance, or maintain the experiential effects of those stimuli) may be used successfully in experimental studies of the regulation of negative emotion.

Most subjects relied on few strategies to suppress and enhance negative emotion. As measured by the startle eyeblink response, one strategy was particularly effective in enhancing negative emotion: imagining oneself or a loved one experiencing whatever was depicted in the visual stimuli. In contrast, there was no difference in effectiveness (as measured by startle eyeblink response or corrugator activity) between the two common suppression strategies. In future studies, it may be fruitful to explicitly manipulate subject strategies for suppressing and enhancing negative affect. Such a manipulation has been used successfully by Gross (1998) to explore the differential effectiveness of antecedent-focused versus response-focused strategies for suppressing affect. Future studies could examine the effectiveness of teaching subjects to use different strategies for suppressing and enhancing the experiential component of negative emotion. In particular, it will be important to study the effectiveness of strategies involving reappraisal and focused cognition, which were reported by most of our subjects, with other types of strategies (e.g., attempting to control facial expression or autonomic activity).

Our findings of decreased eyeblink startle magnitude and decreased corrugator activity following emotion suppression are similar to those of other experimenters who have examined facial expression (Bush, Barr, McHugo, & Lanzetta, 1989) and SCL (Colby et al., 1977) to measure the effects of emotion regulation. Gross and Levenson (1993, 1997) reported a complex pattern of increases and decreases in different measures of autonomic activation during the suppression of emotion expression. Using dependent measures that have been shown to index affective valence, we found linear changes in startle eyeblink magnitude and corrugator activity following instructions to either suppress, enhance, or maintain the currently felt emotional response. Together with the findings of Gross and Levenson, our findings suggest that the autonomic concomitants of suppression may be complex and reflect “effort” as well as any changes in affect produced by the manipulation, whereas startle eyeblink magnitude and corrugator activity may reflect changes in affect alone. Future studies of the effects of emotion regulation on autonomic nervous system activity should use an enhance condition to more closely examine the parsing of effort from changes in affect. In addition, studies that examine autonomic activation, startle eyeblink, and corrugator activity should prove useful in teasing apart these emotion regulation effects.

Interestingly, ability to suppress negative emotion was inversely correlated with ability to enhance negative emotion, as measured by modulation of startle eyeblink magnitude. It will be important in future research to characterize the nomological network surrounding this individual difference in ability to voluntarily suppress and enhance negative emotion. In what ways are the subjects who show facility in suppressing negative emotion (and correspondingly show less aptitude for enhancing negative emotion) different from their counterparts who are better able to enhance negative emotion and less adept at suppressing negative emotion? Do these groups differ in other biological indices that reflect trait negative affect such as amygdala activation (e.g., Abercrombie et al., 1998)? It will also be of interest to ascertain whether individual differences in ability to voluntarily regulate emotion are associated with differences in automatic, involuntary emotion regulation such as those reflected in the recovery from a negative emotional challenge (Davidson, 1998).

Caveats

Perhaps the greatest limitation of the present study was the exclusive focus on the regulation of negative emotion. In a pilot study that utilized a similar emotion regulation paradigm, we found no evidence for inhibition of the startle eyeblink when probes were presented during and following pleasant pictures, despite analyzing the data collected before the emotion regulation instruction. This pattern of results is not uncommon. Jansen and Frijda (1994) found negative-neutral but not neutral-positive differences in startle blink magnitudes using film clips as the foreground affective stimulus. Bradley et al. (1990) and Cook et al. (1991) also reported a similar lack of neutral-positive differences in magnitude of startle blinks. In the absence of clear evidence that our pleasant pictures were indeed eliciting positive emotion, it was impossible to assess the effects of instructions to regulate that emotion. We attribute the difficulties other investigators and we have encountered in demonstrating startle suppression in response to positive stimuli to the general problem of eliciting positive affect in the context of a laboratory psychophysiology experiment. Our laboratory is currently working to develop ideographic stimuli that may be more reliable elicitors of positive emotion; meanwhile, we have chosen to continue our focus on the regulation of negative emotion.

It is important to note that although we did not examine the regulation of positive emotion in this study, our inclusion of both an enhance and a maintain condition allowed us to make (and confirm) strong predictions concerning the effects of suppressing negative emotion. Previously reported findings from experimental studies of the physiological correlates of emotion suppression may in part be reflecting increased effort, rather than the effects of emotional suppression per se. By including an enhance condition in the current study, we may be reasonably certain that our effects are due to specific emotion regulation instructions rather than to nonspecific effort.

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APPENDIX I

Emotion Regulation Instructions

While watching each picture, you will be instructed to either suppress, enhance, or maintain the emotion you are currently feeling in response to the picture. Suppose the emotion you are feeling in response to a picture is fear. Whatever fear you might experience in response to the picture, if you are instructed to ENHANCE, we would like you to increase the intensity of fear you feel. If you are instructed to SUPPRESS, we would like you to decrease the intensity of fear you feel. Similarly, if the emotion you experience in response to a picture is disgust and you are instructed to ENHANCE, we would like you to increase the intensity of disgust you feel. If you are instructed to SUPPRESS, we would like you to decrease the intensity of disgust you feel.

The other type of instruction you may receive is to MAINTAIN the emotion you are feeling in response to a picture. For example, if you are feeling a certain kind of fear in response to a picture, and you are instructed to MAINTAIN, we would like you to keep your fear at about that level. Similarly, if the emotion you are feeling in response to a picture is disgust, and you are instructed to MAINTAIN this emotion, we would like you to keep your disgust at about the same level.

When suppressing, enhancing, or maintaining emotion you should stay focused on the picture and on the emotion you are feeling in response to the picture. For example, if you are feeling disgust in response to a picture and you are told to suppress your emotion, you should not accomplish this by generating a different emotion. Also, you should *not* just think of something unrelated to the picture.

Try to concentrate on suppressing, enhancing, or maintaining your emotional reaction to each picture even after the picture disappears from the screen. A few seconds after the picture has disappeared, you will see a picture telling you to "RELAX." This is your cue to stop suppressing, enhancing, or maintaining your emotional response to the previous picture, and to get ready for the next picture.