*Psychophysiology, 43* (2006), 104–112. Blackwell Publishing Inc. Printed in the USA.

DOI: 10.1111/j.1469-8986.2006.00382.x

# Expressive suppression during an acoustic startle

TIM HAGEMANN[a], ROBERT W. LEVENSON[b], AND JAMES J. GROSS[c]
[a]Department of Organizational Psychology, University of Dortmund, 44227 Dortmund, Germany
[b]Department of Psychology, University of California, Berkeley Berkeley, California, USA
[c]Department of Psychology, Stanford University Stanford, California, USA

**Abstract**

Previous studies have shown that inhibiting negative or positive emotion-expressive behavior leads to increased sympathetic activation. Inhibiting facial behavior while in an affectively neutral state has no such physiological consequences. This suggests that there may be something special about inhibiting emotion-expressive behavior. To test the boundary conditions of the suppression effect, acoustic startles were delivered to 252 participants in three experimental groups. Participants in one group received unanticipated startles. Participants in the other two groups were told that after a 20-s countdown a loud noise would occur; participants in one of these groups were further told to inhibit their expressive behavior. Results indicated that startle suppression increased sympathetic activation. These findings extend prior work on emotion suppression, and suggest that inhibiting other biologically based responses also may be physiologically taxing.

**Descriptors:** Acoustic startle, Suppression, Emotion, Physiology, Inhibition

In many contexts, self-regulation takes the form of inhibiting powerful emotional responses that are deemed inappropriate. We thus work hard to refrain from laughing at a friend's embarrassing gaffe, avoid the temptation of ramming an impossibly slow and erratic driver, and bite our lip when angered by an unfair public criticism of our work. Our success in these efforts matters, and failures of self-regulation have been linked to a wide range of maladaptive outcomes (Baumeister & Vohs, 2004; Gross & Levenson, 1997).

Researchers interested in self-regulation have begun to investigate the behavioral, experiential, and physiological consequences of effortful self-regulation (e.g., Gross, 1998; Gross & Levenson, 1993, 1997; Harris, 2001). Many of these studies have focused on one type of emotion regulation, namely expressive suppression, which has been defined as the conscious inhibition of emotion-expressive behavior. Studies of emotion-expressive suppression[1] have shown that it leads to decreased behavior, decreased positive emotion experience (when participants are asked to suppress facial expression to a positive stimulus), and increased sympathetic activation. Findings such as these have encouraged speculation that there may be something special about emotion suppression. To date, however, there has been no direct test of whether inhibiting biologically prepared responses other than canonical emotions has comparable effects.

In the following sections, we first review the experimental literature on the suppression of emotion-expressive behavior. Next, we consider the literature on the startle response, which provides an intriguing context in which to study the boundary conditions of suppression. Finally, we consider the possibility that the effects of suppression vary by sex or ethnicity, and present a study that examines the suppression of an acoustic startle response in a large multi-ethnic sample.

### *Emotion Suppression*

To examine the effects of suppressing emotion-expressive behavior, Gross and Levenson (1993) used a short disgust-eliciting film that showed an arm amputation. Participants watched the film under one of two instructions. In the first, subjects simply watched the film (no suppression). In the second, subjects were asked to *hide* their emotional reactions (suppression). Results indicated that suppression led to a two-part physiological response. Prior to engaging in expressive suppression, participants showed increased somatic activity (assessed by using an electromagnetic device attached to the platform on which the subject's chair was placed), increased heart rate, and widespread increases in sympathetic responding. We interpreted these changes as reflecting the participants' efforts to "brace" themselves for their impending task. During the suppression period itself, participants showed decreased disgust-expressive behavior (assessed by coding facial behavior) and a mixed physiological state characterized by decreased somatic activity and decreased heart rate,

The authors thank members of the Stanford Psychophysiology Laboratory for their feedback on a previous draft of this article. The authors also thank Nicole Roberts and Jose Soto for their contributions to this research. This research was supported by NIMH grants MH58147 and MH50841 and NIA grant AG17766.

Address reprint requests to: Dr. Tim Hagemann, Department of Organizational Psychology, University of Dortmund, Emil-Figge-Str. 50, 44227 Dortmund, Germany. E-mail: hagemann@orgapsy.uni-dortmund.de.

[1]For brevity, we refer to "emotion suppression" throughout this article.

but increased sympathetic activation of the cardiovascular and electrodermal systems. Suppression had no effect on self-reported disgust experience.

Subsequent studies have examined the boundary conditions of the effects of suppression. For example, Gross and Levenson (1997) examined a second negative emotion—sadness—as well as a positive emotion, namely amusement. Consistent with expectations, suppressing sadness and amusement led to increased sympathetic activation of the cardiovascular system, as indexed by changes in finger pulse amplitude, finger temperature, and pulse transit times to the finger and ear. Similarly, Harris (2001) found that suppressing visible signs of embarrassment leads to enhanced blood pressure responses, but had no effect on emotion experience reports.

It is noteworthy that whereas suppressing negative emotion-expressive behavior has no discernible impact on negative emotion experience (e.g., disgust, sadness, embarrassment), suppressing positive emotion-expressive behavior *does* have an impact on positive emotion experience (e.g., amusement). Gross and Levenson (1997) found a suppression effect for amusement experience both in a context that predominantly elicited amusement (an amusement film) and in a context in which there were lower levels of amusement (a sadness film that evoked a bit of secondary amusement). This finding agrees with prior reports from the facial feedback tradition that inhibiting amusement (e.g., McCanne & Anderson, 1987; Strack, Martin, & Stepper, 1988) and pride (e.g., Stepper & Strack, 1993) expressive behavior leads to decreases in the self-reports of these positive emotions. It is not yet clear why the effects of suppression on emotion experience vary for positive and negative emotions.

If the experiential and physiological effects we have described really are the result of suppressing ongoing emotion-expressive behavior, suppressing *non*-emotion expressive behavior should have no such consequences. In one test of this critical boundary condition, we examined participants' responses during a neutral film (Gross & Levenson, 1997). This film produced low levels of self-reported emotion and essentially no emotional expressive behavior. As expected, suppression had no effect on any of the physiological or experiential variables.

This finding suggests that the physiological impact of emotional suppression grows out of the counterpoising of attempts to inhibit expression against strong impulses to express. Absent a stimulus that produces these expressive impulses, behavioral inhibition seems to have little impact on physiological responding. However, it is not yet clear whether the critical ingredient in the emotional suppression effect shown in previous studies is emotion per se, or whether efforts to inhibit other biologically based impulses would lead to similar patterns of physiological activation. To address this important question, what is needed is an examination of response inhibition in the context of other biologically prepared responses. The acoustic startle response provides just such a context (Ekman, Friesen & Simons, 1985).

### *The Acoustic Startle Response*

When confronted with a sudden, strong auditory stimulus (e.g., a gun shot), people react with sudden stereotypical movements (e.g., neck muscle activity, torso movement) and increased sympathetic responding (Ekman et al., 1985; Landis & Hunt, 1939). This startle reflex is elicited by transient stimuli with fast rise times and high intensity levels. It can be identified by its cardiac response (e.g., specific latency in heart rate acceleration) and relatively fast habituation (Graham, 1973, 1979; Turpin, 1986; Turpin & Siddle, 1978, 1983). It has been suggested that startle responses may serve a defensive function (see Turpin, 1986; Turpin & Siddle, 1978), a movement interruptive function (Graham, 1979; Overduin, 1993), and/or may help to prepare the organism either to flee or to fight (Turpin, 1986).

There remains debate concerning the functions startle responses serve, but what is clear is that stimulus quality and intensity powerfully shape the startle response (Böhmelt, Schell, & Dawson, 1999; Cook & Turpin, 1997; Turpin & Siddle, 1979, 1983; Vossel & Zimmer, 1992). The early literature featured relatively high-intensity startle probes (>100 dB), and emphasized the powerful, coordinated set of biologically prepared responses that were associated with these probes. More recently, greater emphasis has been placed on lower intensity startle probes (<100 dB), particularly in the context of emotion modulated startle (Lang, 1995). The focus in this newer literature has been the finding that unpleasant affective states potentiate startle responses (eyeblink), whereas pleasant affective states diminish the response (Bradley, Cuthburt, & Lang, 1993; Kaviani, Gray, Checkley, Kumari, & Wilson, 1999; Vrana, Spence, & Lang, 1988).

Although both literatures refer to the "startle response," it is important to note that the nature and magnitude of the associated psychophysiological response varies according to the magnitude of the stimulus. It is the dramatic whole-body response to the high-intensity startle that is our focus here. In the one prior report of explicit suppression of high-intensity acoustic startle probes, Ekman et al. (1985) found that people asked to suppress any visible response showed no significant differences within the first 500 ms, in either the frequency with which an action was shown or in the latency of facial actions, but the intensity was slightly weaker.

Based on these findings, Ekman and colleagues (1985) argued that the startle response differs from an emotional response in four ways: the startle response (a) is easier to elicit, (b) is shown reliably by every subject, (c) cannot be totally inhibited, and (d) cannot be well simulated. These considerations led Ekman to view the startle reflex rather as a biological prepared (defensive) response rather than a canonical emotion. We are sympathetic with Ekman's view, but find it very difficult to know where to draw the line between biologically prepared responses such as the startle, on the one hand, and emotion on the other. For present purposes, however, we wish to argue simply that the acoustic startle provides a very different context within which to examine expressive suppression than any other context that we or others have examined previously.

### *Group Differences in Expressive Suppression: Sex and Culture*

Thus far, we have focused on the generality of the effects of emotion suppression across other (nonemotional) contexts. It is also important to ask, however, whether the suppression effect—whatever the target of suppression—is comparable across respondents. In particular, in view of the high level of interest in sex and cultural variation in emotion processes, we thought it important to ask whether group differences were evident in the effects of suppression. Based on our view that suppression involves the regulation of powerful biologically based (and hence species-typical) response tendencies, our expectation was that group differences in the effects of suppression should be quite limited. This no-group-differences expectation has been borne out in research on suppression to date. To our knowledge, there have been no reports of sex or ethnic differences in the consequences of emotion suppression.

Although consistent with a universalist perspective on emotion, these null findings would be somewhat surprising from another vantage point. After all, men report using emotion suppression more than women (Gross & John, 2003), and Asians Americans, African Americans, and Latino Americans report using suppression more than European Americans (Gross & John, 2003). Given these differences, we might expect subtle differences in the impact of emotion suppression due to differences in prior experience and practice with suppression. In the present study, we pursue this possibility in a large, multi-ethnic sample under conditions that enhance the likelihood of observing sex or ethnic effects in suppression if they in fact exist.

***The Present Study***

To examine the generality of the suppression effect to (a) a high-intensity acoustic startle response, and (b) to both sexes and four ethnic groups, we assessed behavioral, experiential, and physiological consequences of suppressing an acoustic startle response in a large, diverse sample. Several features of our study warrant comment.

First, given how difficult it is to inhibit the startle response on demand, we framed our suppression instructions broadly, so as to maximize the chance that participants would be able to inhibit their startle. It should be noted that these instructions differ significantly from those used previously (see Gross & Levenson, 1993, 1997). The rationale for this modification was to capture the many changes associated with the startle probe. The present instructions are therefore similar to those used in ego-depletion research (see Muraven, Tice, & Baumeister, 1998).

Second, given the differences in time frame between the relatively brief startle response and the longer-lasting emotional responses to films used in our previous studies of emotion suppression, we adjusted the relevant observation windows accordingly, focusing on the 5 s before and the 6 s after the startle presentation.

Third, to match one group of the no-suppression participants as closely as we could to the suppression participants, we informed participants in an ''anticipation'' control group of the impending startle stimulus as well. Because this may have led some of our no-suppression participants to spontaneously inhibit their startle responses, our estimates of any observed effects of suppression are likely to be relatively conservative. We therefore also included a ''no anticipation'' control group of participants who were not warned about the impending startle.

Finally, we employed a sample that was homogeneous with respect to age in view of prior findings regarding age-related changes in startle responsivity (Ellwanger, Geyer, & Braff, 2003).

Because we view the effects of suppression as deriving from the effortful management of biologically based response tendencies, we expected the effects of startle suppression to parallel those observed previously in studies of emotion suppression. Specifically, we predicted that, relative to no-suppression participants, suppression participants would show decreases in behavior, no change in emotion experience, and increases in sympathetic activation. We did not expect these effects of startle suppression to vary as a function of participant sex or ethnicity.

## Method

***Participants***

Participants were 252 undergraduates (131 women) whose ages ranged from 18 to 29 ($M = 20.5$ years). The ethnic composition of this sample was 18% African American, 36% Asian American, 22% Caucasian, and 24% Hispanic (see Table 1). Participants were paid for their participation.

**Table 1.** *Participant Ethnicity and Sex for Each Instructional Group*

| | African American | | Asian American | | Caucasian | | Hispanic | |
|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female |
| Unanticipated | 7 | 9 | 16 | 16 | 8 | 11 | 7 | 10 |
| Anticipated | 7 | 6 | 14 | 14 | 7 | 9 | 12 | 10 |
| Suppression | 8 | 8 | 15 | 16 | 9 | 11 | 11 | 11 |
| Total | 22 | 23 | 45 | 46 | 24 | 31 | 30 | 31 |

***Procedure***

Participants were invited to the laboratory for individual experimental sessions. To maximize participant comfort and increase the likelihood of detecting any potential sex- or ethnicity-specific effects, participants only had contact with a research assistant of their own sex and ethnicity (Graham, 1992; Marin & Marin, 1991).

Participants were seated in a chair approximately 5 ft from a video monitor, which was used to present all instructions. Participants then completed a consent form, a brief health checklist, and a baseline measure of their current emotional state (see below). After completing these measures, the research assistant attached physiological sensors.

The experiment began with a 2-min period during which participants were asked to relax and watch an ''X'' on the video monitor. We gave this instruction for two reasons: (1) to keep the participants' eyes from wandering around the room, and (2) to keep the participants focused on the part of the screen that would provide the countdown information regarding the impending startle (for participants who would be receiving information regarding the impending startle).

Participants were randomly assigned to one of three conditions and were exposed to only one startle probe. Our decision to present a single startle probe was based on pilot findings that suggested that the presentation of repeated high-intensity (110 db) probes led participants to begin to spontaneously inhibit their response, and were uncomfortable for participants. It should be noted that to the extent that a single measure is a less reliable indicator, our present findings from this between-subjects design may represent a conservative estimate of true effect sizes.

In the no-suppression–unanticipated condition ($N = 84$), participants received no warning regarding the impending startle. All other participants either in the no-suppression–anticipated condition ($N = 79$) or in the suppression condition ($N = 89$) received the following instructions on the video monitor: ''In this part of the experiment, you will hear a loud noise. You will know exactly when the loud noise will occur. You will see a countdown from 10 to 1 on the video screen. When you see '1'—the loud noise will happen. Before beginning the countdown, I want you to relax.''

Participants assigned to the suppression condition received the following additional instructions: ''We want to see how well you can keep from showing any emotional response when you hear the noise. Try not to feel anything, and try not to have a physiological reaction. Also, see if you can act so that someone seeing the video with the sound off won't know that anything has happened. Try not to show any visible signs or feel anything before, during, or after the loud noise occurs. Try to look relaxed all the way through. See if you can fool the person who will be studying this video. Before beginning the countdown, I want you to relax."

The pre-startle countdown lasted for 20 s, with each number in the countdown (10 to 1) presented for 2 s. At the end of the countdown, an acoustic startle (110 dB white noise, 50 ms, with an instantaneous rise time) was delivered via loudspeakers positioned immediately behind the participant. After the startle, an "X" was presented on the screen for 2 min. Participants were then asked to rate their experience of a number of specific emotions (see below).

### *Measures*

*Behavioral.* A remotely controlled high-resolution color video camera placed behind darkened glass in a bookshelf was used to unobtrusively record the subject's upper body movement. After the session, trained research assistants used a variant of the Emotional Expressive Behavior coding system (Gross & Levenson, 1993) to code videotaped records made of participants during the pre- and poststartle periods. An initial review of the videotapes indicated that most of subjects' behavior took place during the first 5 s poststartle. Thus, for each second during the 5 s prestartle, the second of the startle, and the 5 s poststartle, coders rated the presence or absence of a number of specific behaviors (described below) known to be associated with responses to startle stimuli. The 5 s prior to the startle were defined as the *pre-startle period*, and the 6 s after the startle (the second of the startle and the 5 s poststartle) were defined as the *post-startle period*. To reduce the behavioral variables, we created one composite score representing the participant's behavioral response. This measure was a composite of various body movements associated with the acoustic startle, including neck stretches, head jerks, shoulder raises, shudders, forward lunges, torso raises, and utterances/cries.

*Self-reported emotion experience.* At the beginning of the experimental session (baseline) and again after the startle event, participants used a 9-point Likert type scale ranging from 0 *not at all* to 8 *very much* to rate how strongly they felt each of 11 specific emotions: amusement, anxiety, contempt, contentment, disgust, embarrassment, fear, anger, happiness, relief, and sadness. To reduce the number of dependent measures, two self-report composites were created: positive emotion experience (amusement, contentment, happiness, relief) and negative emotion (anger, anxiety, contempt, disgust, embarrassment, fear, sadness). Change scores were created by subtracting baseline values from post-startle values for each emotion.

*Physiological.* Continuous recordings were made using a 12-channel Grass Model 7 polygraph (Astro-Med, Inc., West Warwick, RI), which was connected to a microcomputer programmed to obtain second-by-second means for nine measures:

1. Heart rate. Beckman miniature electrodes with Beckman electrodes were placed in a bipolar configuration on opposite sides of the participant's chest. The interbeat interval was calculated as the time in milliseconds between successive R waves in the electrocardiogram (EKG).
2. Skin conductance level. A Med Associates device was used to pass a small constant voltage (0.5 V) between Beckman regular electrodes attached to the palmar surface of the middle phalanges of the first and third fingers of the nondominant hand. The electrolyte was sodium chloride in Unibase.
3. Finger temperature. A Yellow Springs Instruments thermistor taped to the palmar surface of the distal phalange of the fourth finger of the nondominant hand was connected to a Med Associates device that provided a measure of finger temperature in degrees Fahrenheit.
4. Pulse transmission time to the finger. A UFI photoplethysmograph was attached to the distal phalange of the second finger of the nondominant hand. The interval was timed between the R wave of the EKG and the upstroke of the pulse wave at the finger.
5. Finger pulse amplitude. The trough-to-peak amplitude of each finger pulse was measured to index the maximum volume of blood in the tip of the finger during each heart beat.
6. Pulse transmission time to the ear. A UFI photoplethysmograph was attached to the right ear. The interval was timed between the R wave of the EKG and the upstroke of the pulse wave at the ear.
7. General somatic activity. Activity was detected using an electromagnetic device attached to the platform on which the subject's chair was placed. The wooden platform was mounted on a metal crossbar that allows for a small amount of flex. A wire coil mounted to the metal crossbar moved in the center of a ring magnet mounted to the wooden platform, thus inducing a small current flow when the platform flexed.
8. Respiration period. A pneumatic bellows was stretched around the thoracic region, and the intercycle interval was measured as the time in milliseconds between successive inspirations.
9. Respiratory sinus arrhythmia (RSA). RSA was computed as the difference in milliseconds between the longest IBI that occurred during the expiratory phase of the respiratory cycle and the shortest IBI that occurred during the inspiratory phase (Grossman, van Beek, & Wientjes, 1990).

This set of physiological measures was selected to sample broadly from major organ systems known to be important to emotional responding (cardiac, vascular, electrodermal, respiratory, and somatic), to allow for continuous measurement, and to be as unobtrusive as possible.

We did not obtain electromyogram (EMG) responses, which are often obtained in the context of lower-intensity startle probes. Several considerations led us to choose not to measure EMG: (1) In general, in our work on emotion regulation, we have been quite reluctant to add facial EMG. This is because pilot testing has revealed that participants report feeling more self-conscious and aware of their facial responses when they have EMG sensors on. Because our interest has been in the effects of behavioral suppression, we have been reluctant to obtain measures that could induce suppression in all participants, as this would make it that much more difficult to detect differences between our "suppression" and "no suppression" participants. (2) Given that our prior work on emotional suppression has not employed facial EMG, we worried that using facial EMG in the context of this study would introduce an important confound. (3) As in previous studies, we knew we would be able to monitor and record global somatic activity assessed by an electromagnetic device attached to the platform on which the subject's chair was placed.

After the experimental session, physiological data were visually inspected to exclude artifacts. Second-by-second values for each of the physiological measures, except RSA, were then reduced to mean values representing nonoverlapping time slices: (1) 2-min pretrial baseline, (2) 5-s pre-startle period, and (3) 6-s post-startle period (including the startle). For RSA, we used 20-s pre-startle and 50-s post-startle periods. Physiological reactivity scores were calculated for each measure by subtracting the pretrial baseline from the pre- and post-startle periods.

To provide continuity with prior work on emotion suppression (Gross & Levenson, 1997), we created a composite measure of sympathetic activation of the cardiovascular system. This theoretically defined measure was derived using four unit-weighted standardized change scores (pulse transit time to the finger, pulse transit time to the ear, finger pulse amplitude, finger temperature) with signs all inverted so that larger Z scores indicated greater activation. Measures were standardized across all conditions and time periods to permit comparisons among experimental groups for both pre- and post-startle periods. Using this composite allowed us to take advantage of the principle of aggregation (Ossenkopp & Mazmanian, 1985; Rushton, Brainerd, & Pressley, 1983) and limited the impact of individual response stereotypy (Stern & Sison, 1990). With respect to the nature of the composite itself, our assumption was that in this context, sympathetic activation should lead to peripheral vasoconstriction, reflected by a decrease in pulse transit times, by a decrease in peripheral pulse volume, and by a decrease in finger temperature (Goldstein & Edelberg, 1997; Johnsen & Lutgendorf, 2001; Papillo & Sharpiro, 1990). Although skin conductance is also a sympathetic measure, there can be differential responding in the cardiovascular and electrodermal systems (see Lacey, Kagan, Lacey, & Moss, 1963; Levenson, 1988). For this reason, we did not include skin conductance in the cardiovascular composite.

### Data Analysis

Our multimethod approach has the advantage of broadly sampling response systems involved in emotion and self-regulation. However, this approach has the disadvantage of potentially increasing Type I error due to multiple significance tests. This problem is lessened considerably by our use of composite scores. In addition, we used the modified Bonferroni procedure (Keppel, 1982) to provide additional protection against Type I error, setting a familywise error rate of .02 for each class of dependent variables (behavior, experience, physiology) for our primary analyses, in which we examined the effects of suppressing startle responses.

Dependent measures were obtained from three domains. *Behavioral data* were collected for the pre- and post-startle periods only. To examine the effects of suppression, we conducted an overall $3 \times 4 \times 2 \times 2$ ANOVA (with condition, ethnicity, and sex as between-participants factors and time as a within-subject factor). *Emotion experience measures* were collected for the baseline and post-startle periods only. To examine the effects of suppression, we conducted an overall $3 \times 4 \times 2$ MANOVA (with condition, ethnicity, and sex as between-participants factors) using change from baseline. This was followed by a similarly structured univariate ANOVA for negative and positive emotion experience. *Physiological measures* were available for baseline, pre-startle, and post-startle periods. To examine the effects of suppression, we conducted an overall $3 \times 4 \times 2 \times 2$ MANOVA (with condition, ethnicity, and sex as between-participants factors and time as a within-subject factor) using change from baseline. This was followed by similarly structured univariate ANOVAs and *t* tests for each physiological measure to localize group differences.

## Results

Our manipulation had two parts—the startle probe and the suppression instructions. To assess the impact of our startle procedure, we first examined the participants in the no-suppression–unanticipated conditions only (to avoid confounding the effects of startle anticipation with the effects of the manipulation). Next, we examined the participants in all conditions in order to assess the behavioral, experiential, and physiological consequences of suppressing startle responses.

### Effects of Startle: Behavior, Experience, and Physiology

As shown in Table 2, the no-suppression–unanticipated participants showed an increase from pre-startle to post-startle periods in behavioral responding, $t(83) = -9.79$, $p < .001$. Compared to the baseline period, no-suppression–unanticipated participants had increased negative emotion experience, $t(83) = 8.99$, $p < .001$, and decreased positive emotion experience, $t(83) = -13.13$, $p < .001$, after the startle probe (Table 3). As shown in Table 4, there were increases from baseline during the 6-s post-startle period for the no-suppression–unanticipated group in heart rate, $t(83) = -8.37$, $p < .001$, skin conductance level, $t(83) = 8.93$, $p < .001$, somatic activity, $t(83) = 11.77$, $p < .001$, and finger temperature, $t(83) = 3.67$, $p < .001$. Finger pulse amplitude showed a significant decrease, $t(83) = -2.83$, $p = .006$. Finger pulse and ear pulse transit time, sympathetic activation of the cardiovascular system, and respiratory sinus arrhythmia showed no significant changes.

### Effects of Suppression: Behavior

The overall ANOVA for behavioral responding revealed main effects of condition, $F(2,216) = 12.15$, $p < .001$, $\eta^2 = .101$, time, $F(1,216) = 324.32$, $p < .001$, $\eta^2 = .60$, an interaction of Condition $\times$ Time, $F(2,216) = 6.43$, $p = .002$, $\eta^2 = .056$, and an interaction of Condition $\times$ Sex, $F(2,216) = 6.51$, $p = .002$, $\eta^2 = .057$. Follow-up tests revealed that the interaction of Condition $\times$ Time effect was due to the fact that during the pre-startle period no significant group differences occurred, but during the post-startle period suppression participants showed lesser behavior than no-suppression–unanticipated participants, $t(171) = 3.95$, $p < .001$, and no-suppression–anticipated participants, $t(166) = 2.99$, $p = .003$. The Condition $\times$ Sex interaction was due to the fact that in the no-suppression–anticipated group men showed lesser movement than women, $t(82) = 3.18$, $p = .002$. There were no effects involving ethnicity.

**Table 2.** *Means (Standard Deviations) for Behavioral Expression during Pre-Startle and Post-Startle Periods for Each Instructional Group*

| | Unanticipated | | Anticipated | | Suppression | |
|---|---|---|---|---|---|---|
| Pre-startle | $0.08^{a,1}$ | (0.28) | $0.11^{a,1}$ | (0.44) | $0.01^{a,1}$ | (0.08) |
| Post-startle | $1.13^{a,2}$ | (0.93) | $0.92^{a,2}$ | (0.55) | $0.70^{b,2}$ | (0.40) |

*Note:* Means that do not share a superscript are different from one another ($p < .02$). Letters indicate differences in condition. Numbers indicate differences in time.

**Table 3.** *Means (Standard Deviations) for Experience Ratings for Each Instructional Group (Change Scores)*

| | Unanticipated | | Anticipated | | Suppression | |
|---|---|---|---|---|---|---|
| Positive emotion | – 1.99[a] | (1.39) | – 1.24[b] | (1.81) | – 1.18[b] | (1.51) |
| Negative emotion | 1.10[a] | (1.13) | 0.82[a] | (1.07) | 0.78[a] | (0.97) |

*Note:* Means that do not share a superscript are different from one another ($p < .02$).

### *Effects of Suppression: Emotion Experience*

The overall MANOVA for the positive and negative emotion experience composites revealed no effect of sex or ethnicity. There was only an effect of condition, $F(4,456) = 4.13$, $p = .003$, $\eta^2 = .035$. As shown in Table 3, follow-up tests revealed that participants in the no-suppression–unanticipated group reported significantly greater decreases in positive emotion experience than participants in the no-suppression–anticipated group, $t(161) = 2.95$, $p = .004$ and than participants in the suppression group, $t(171) = 3.66$, $p < .001$. There were no group differences in negative emotion experience.

### *Effects of Suppression: Physiology*

The overall MANOVA showed effects for condition, $F(18,438) = 6.79$, $p < .001$, $\eta^2 = .218$, time, $F(9,219) = 70.59$, $p < .001$, $\eta^2 = .744$, and an interaction of Condition $\times$ Time, $F(18,438) = 4.29$, $p < .001$, $\eta^2 = .150$. There were no effects for sex or ethnicity. Similarly structured follow-up univariate tests were conducted for each of the physiological measures.

Significant Condition $\times$ Time interactions were evident for heart rate $F(2,251) = 10.39$, $p < .001$, somatic activation, $F(2,251) = 6.72$, $p = .001$, finger pulse transit time, $F(2,251) = 6.52$, $p = .002$, ear pulse transit time, $F(2,251) = 4.38$, $p = .014$, and sympathetic activation of the cardiovascular system, $F(2,251) = 10.18$, $p < .001$. Follow-up $t$ tests were conducted to decompose these effects.

*Pre-startle period.* As shown in Table 4, during the pre-startle period, participants in the suppression group showed greater decreases in interbeat interval than participants in the no-suppression–anticipated group, $t(166) = -4.73$, $p < .001$, and in the no-suppression–unanticipated group, $t(171) = -6.28$, $p < .001$. Similar results can be seen for sympathetic activation of the cardiovascular system: Participants in the suppression group showed an increase in activation whereas participants in the no-suppression–anticipated group, $t(166) = 5.54$, $p < .001$, and in the no-suppression–unanticipated group, $t(171) = 3.28$, $p = .001$, showed a decrease relative to baseline.

Participants in the suppression group also showed a smaller increase in finger pulse transit time than participants in the no-suppression–anticipated, $t(166) = -2.50$, $p = .014$. Unexpectedly, participants in the no-suppression–unanticipated condition showed a decrease in finger pulse transit time, a change that was significantly different from the increase observed in participants in the suppression condition, $t(171) = -2.39$, $p = .018$, and in the no-suppression–anticipated condition, $t(161) = 4.03$, $p < .001$. There were no effects for the other measures.

*Post-startle period.* As shown in Table 4, during the post-startle period, participants in the suppression group showed greater decreases in interbeat interval, $t(166) = -2.30$, $p = .003$, a smaller increase in somatic activation, $t(166) = -2.65$, $p = .009$, a decrease, rather than an increase, in finger pulse

**Table 4.** *Means (Standard Deviations) for Physiological Measures during Pre-Startle and Post-Startle Periods for Each Instructional Group (Change Scores)*

| | Unanticipated | | Anticipated | | Suppression | |
|---|---|---|---|---|---|---|
| Interbeat interval | | | | | | |
| Pre-startle | – 27.82[a,1] | (69.61) | – 45.10[a,1] | (64.63) | – 94.39[b,1] | (69.79) |
| Post-startle | – 84.79[a,b,2] | (92.83) | – 56.73[a,1] | (85.00) | – 95.53[b,1] | (82.51) |
| Skin conductance level | | | | | | |
| Pre-startle | – 0.29[a,1] | (0.36) | 0.16[a,1] | (0.61) | 0.68[a,1] | (1.33) |
| Post-startle | 0.70[a,2] | (0.71) | 1.03[a,2] | (1.3) | 1.31[a,2] | (1.72) |
| Somatic activity | | | | | | |
| Pre-startle | 0.05[a,1] | (0.37) | – 0.02[a,1] | (0.25) | – 0.01[a,1] | (0.20) |
| Post-startle | 1.31[a,b,2] | (1.02) | 1.76[a,2] | (1.44) | 1.26[b,2] | (0.94) |
| Finger pulse transit time | | | | | | |
| Pre-startle | – 5.8[a,1] | (22.17) | 6.30[b,1] | (15.31) | 0.80[c,1] | (13.3) |
| Post-startle | – 1.32[a,b,1] | (11.98) | 3.73[a,1] | (17.10) | – 2.87[b,2] | (15.42) |
| Finger pulse amplitude | | | | | | |
| Pre-startle | – 0.31[a,1] | (3.36) | – 1.68[a,1] | (1.90) | – 2.22[a,1] | (2.37) |
| Post-startle | – 0.54[a,1] | (1.76) | – 2.03[a,1] | (2.18) | – 2.33[a,1] | (2.74) |
| Ear pulse transit time | | | | | | |
| Pre-startle | – 3.57[a,1] | (22.40) | 2.73[a,1] | (14.23) | – 2.52[a,1] | (13.32) |
| Post-startle | 4.23[a,2] | (16.53) | 1.50[a,b,1] | (13.37) | – 3.40[b,1] | (21.42) |
| Finger temperature | | | | | | |
| Pre-startle | 0.03[a,1] | (1.64) | 0.09[a,1] | (0.58) | – 0.22[a,1] | (0.55) |
| Post-startle | 0.21[a,1] | (0.53) | 0.05[a,2] | (0.58) | – 0.27[a,2] | (0.55) |
| Sympathetic composite | | | | | | |
| Pre-startle | – 0.08[a,1] | (0.66) | – 0.16[a,1] | (0.43) | 0.19[b,1] | (0.39) |
| Post-startle | – 0.23[a,2] | (0.45) | – 0.05[b,2] | (0.48) | 0.29[c,2] | (0.58) |
| RSA | | | | | | |
| Pre-startle | 2.59[a,1] | (47.76) | 2.59[a,1] | (47.76) | – 13.15[a,1] | (44.15) |
| Post-startle | – 4.08[a,1] | (33.64) | – 4.65[a,1] | (39.73) | – 4.70[a,1] | (46.73) |

*Note:* Means that do not share a superscript are different from one another ($p < .02$). Letters indicate differences in condition. Numbers indicate differences in time.

transit time, $t(166) = -2.30$, $p = .003$, and an increase, rather than a decrease, in sympathetic activation of the cardiovascular system $t(166) = 4.10$, $p < .001$ in comparison with participants in the no-suppression–anticipated group. Compared to the no-suppression–unanticipated group, participants in the suppression group showed a decrease, rather than an increase, in ear pulse transit time, $t(171) = -2.61$, $p = .010$, and an increase, rather than a decrease, in sympathetic activation of the cardiovascular system $t(171) = 3.28$, $p = .001$. Finally, participants in the no-suppression–anticipated group showed a smaller decrease in sympathetic activation of the cardiovascular system, $t(161) = 2.52$, $p = .013$, than participants in the no-suppression–unanticipated group. There were no effects for the other measures.

The results indicate that participants trying to suppress their startle responses showed greater activation in sympathetically mediated physiological responding than the participants in the two control groups. This effect was similar for men and women and for participants of all ethnic groups. No suppression effects were found for finger pulse amplitude, finger temperature, skin conductance, and respiratory sinus arrhythmia.

## Discussion

Self-regulation often requires that we inhibit prepotent responses. A growing literature suggests that one common type of self-regulation—inhibiting emotion-expressive behavior—is associated with decreased behavior, decreased positive emotion experience (when participants are asked to suppress facial expressions elicited by a positive stimulus), and increased sympathetic activation of the cardiovascular system. The present study was designed to investigate the generality of these findings by considering the effects of inhibiting the response to an acoustic startle, a biologically prepared response that differs in important ways from the emotional responses studied to date. Using a high-intensity acoustic startle, we found that startle suppression led to (a) decreased behavior, (b) no consistent change in emotion experience, and (c) indications of increased sympathetic responding. These suppression effects were comparable for men and for women and for participants from differing ethnic backgrounds.

### *Relation to Prior Findings*

Similar to prior findings with emotion suppression, the present findings suggest that startle suppression consists of a two-part response. Initially, during the preparation (pre-startle) period, participants in the suppression group showed greater increases in heart rate and sympathetic activation of the cardiovascular system compared to the other two groups. During the suppression period itself, suppression participants showed lesser expressive behavior and greater increases in sympathetic activation of the cardiovascular system compared to the two other experimental groups, as well as smaller increases in somatic activity and greater increases in heart rates compared to participants in the no-suppression–anticipated group.

Despite the many differences between the present context and contexts used in previous studies to examine emotion suppression, results were remarkably consistent. Indeed, we observed only one point of divergence, namely the increases (as opposed to either no change or decreases) in heart rate found in startle suppression but not in emotion suppression in a context of a disgust-eliciting film (Gross & Levenson, 1993). However, changes in heart rate have been one of the least consistent aspects of the emotion suppression effect; thus, we believe it is important not to overinterpret this potential difference.

The present findings also show impressive generalizability across sex and ethnicity. As noted above, we are not aware of prior reports of sex or ethnic differences in the consequences of emotion suppression. Nonetheless, in light of accumulating evidence for group differences in the frequency of use of emotion suppression in everyday life (Gross & John, 1997; Gross, Richards, & John, in press), it is intriguing that even under favorable conditions (e.g., the use of a large number of carefully screened participants of various ethnicities in an experimental session with an experimenter matched on sex and ethnicity) we found no clear evidence of sex or ethnic differences. Like the cross-context generality of our findings, the cross-group generality of our findings suggests that the suppression effect is quite robust.

### *Implications for Self-Regulation*

Self-regulation refers to a person's ability to control emotional, cognitive, psychophysiological, or behavioral states. One of the fundamental questions in the literature on self-regulation is whether there are general principles that broadly cover the many forms of self-regulation, or whether different self-regulation domains are characterized by different, domain-specific mechanisms and processes.

A comparison of our previous findings regarding emotion suppression with the present findings regarding startle suppression suggests that suppressing these two types of biologically prepared responses has comparable consequences. As we have previously observed in studies of emotion suppression (Gross & Levenson, 1993, 1997), the present results indicate that suppression during a startle paradigm leads to increased sympathetic activation of the cardiovascular system. Even heart rate, which usually closely tracks somatic activity, was faster in participants who were inhibiting their behavioral response. Different acts of suppression (e.g., the inhibition of expressive behavior to startle in the present study and the inhibition of expressive behavior to emotion in previous studies) seem to produce a cost, namely greater autonomic physiological responding. Our interpretation of these findings is that the act of suppressing a biologically prepared response—whether emotion-related or startle-related—requires effort, which in turn increases the level of metabolic demand.

These commonalities across types of suppression are important, as they suggest that the effects of inhibiting one type of impulse may generalize to other types of impulses. Further evidence for common consequences of different forms of self-regulation is provided by Baumeister and colleagues' research on ego depletion (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Muraven & Baumeister, 2000). This research has shown that many different types of self-regulation (e.g., emotion suppression, restaining the impulse to eat delicious smelling cookies) lead to "ego depletion," as manifested by lesser persistence on later demanding tasks (e.g., anagrams).

Just how far does the evidence support a common-features view of self-regulation? In our own work, in addition to the commonalities across different types of suppression that we have emphasized here, we have also documented important differences among different families of specific emotion regulation strategies (Gross, 2002). For example, we have found that using an antecedent-focused emotion regulation strategy such as cognitive reappraisal (which involves thinking in such a way as to decrease emotional responding) has a different physiological and cognitive profile than the response-focused strategy of suppression. Like suppression, reappraisal decreased expressive behavior; however, unlike suppression, reappraisal had no observable consequences for sympathetic activation (Gross, 1998). Other studies also indicate that reappraisal has different cognitive consequences; emotion suppression reduces memory for emotional events but reappraisal does not (Richards & Gross, 2000). Findings such as these suggest that although there are common features of self-regulation, there are also crucial differences across different types of self-regulation. Clearly, one crucial challenge facing future research is to better understand the nature of commonalities (vs. differences) across different types of self-regulation.

### *Limitations and Future Directions*

We set out to create a context in which participants would inhibit biologically prepared responses other than canonical emotions. We found, however, that even in the context of the acoustic startle, participants reported experiencing emotion. Because the suppression instructions acted both on the startle-related behaviors and any emotion-expressive behavior generated in this context, we were unable to completely disentangle these effects. These findings highlight the difficulty of creating a context that involves the inhibition of a biologically prepared response that does not also involve emotional responding in one way or another. In future research, it will be important to search for contexts and/or experimental designs that allow for greater separation of the effects of inhibiting emotional and nonemotional responding.

A second limitation of the present study is that the only individual differences we examined were sex and ethnicity. There is growing evidence that other individual-difference approaches such as personality factors can shed important light on the antecedents and consequences of self-regulation (Gross & John, 2003). In future work, it will be important to assess individual differences in the strength of various types of response tendencies, as well as the frequency of different strategies used to modulate when and how they are enacted.

A third limitation is that we considered only one type of biologically prepared response—the acoustic startle, which differs in important ways from the canonical emotions we had previously studied. In future work, it will be important to extend this work to the inhibition of other biologically prepared responses (e.g., blink reflex, patellar reflex). In this way, it will be possible to delineate more clearly the types of responses that are physiologically costly to inhibit and those that are not. Such studies will add to our growing understanding of both commonalities and similarities across various forms of self-regulation in the context of different types of impulses.

## REFERENCES


Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego-depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology*, *74*, 1252–1265.

Baumeister, R. F., & Vohs, K. D. (2004). *Handbook of self-regulation: Research, theory, and applications*. New York: Guilford.

Böhmelt, A. H., Schell, A. M., & Dawson, M. E. (1999). Attentional modulation of short-and long-lead-interval modification of the acoustic startle eyeblink response: Comparing auditory and visual prestimuli. *International Journal of Psychophychology*, *32*, 239–250.

Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (1993). Pictures as prepulse: Attention and emotion in startle modification. *Psychophysiology*, *30*, 541–545.

Cook, E., & Turpin, G. (1997). Differentiating orienting, startle and defense responses: The role of affect and its implications for psychopathology. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 137–164). Hillsdale, NJ: Erlbaum.

Ekman, P., Friesen, W. V., & Simons, R. C. (1985). Is the startle reaction an emotion? *Journal of Personality and Social Psychology*, *49*, 1416–1426.

Ellwanger, J., Geyer, M. A., & Braff, D. L. (2003). The relationship of age to prepulse inhibition and habituation of the acoustic startle response. *Biological Psychology*, *62*, 175–195.

Goldstein, H. S., & Edelberg, R. (1997). A plethysmographic method for demonstrating the response specificity of the oral vascular bed. *Psychophysiology*, *34*, 124–128.

Graham, F. K. (1973). Habituation and dishabituation of responses innervated by the autonomic nervous system. In H. V. S. Peeke & M. J. Herz (Eds.), *Habituation: Vol. 1. Behavioral studies* (pp. 163–218). New York: Academic Press.

Graham, F. K. (1979). Distinguishing among orienting, defense, and startle reflexes. In H. D. Kimmel, E. H. van Olst, & J. F. Orlebeke (Eds.), *The orienting reflex in humans* (pp. 137–168). Hillsdale, NJ: Erlbaum.

Graham, S. (1992). Most of the subjects were white and middle class: Trends in published research on African Americans in selected APA journals, 1970–1989. *American Psychologist*, *47*, 629–639.

Gross, J. J. (1998). Antecedent-and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology*, *74*, 224–237.

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*, 281–291.

Gross, J. J., & John, O. P. (1997). Revealing feelings: Facets of emotional expressivity in self-reports, peer ratings, and behavior. *Journal of Personality and Social Psychology*, *72*, 435–448.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*, 348–362.

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: Physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology*, *64*, 970–986.

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting positive and negative emotions. *Journal of Abnormal Psychology*, *106*, 95–103.

Gross, J. J., Richards, J. M., & John, O. P. (in press). Emotion regulation in everyday life. In D. K. Snyder, J. A. Simpson, & J. N. Hughes (Eds.), *Emotion regulation in families: Pathways to dysfunction and health*. Washington, DC: American Psychological Association.

Grossman, P., van Beek, J., & Wientjes, C. (1990). A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology*, *27*, 702–714.

Harris, C. R. (2001). Cardiovascular responses of embarrassment and effects of emotional suppression in a social setting. *Journal of Personality and Social Psychology*, *81*, 886–897.

Johnsen, E. L., & Lutgendorf, S. K. (2001). Contributions of imagery ability to stress and relaxation. *Annals of Behavioral Medicine*, *23*, 273–281.

Keppel, G. (1982). *Design and analyses: A researcher's handbook*, 82nd ed. Englewood Cliffs, NJ: Prentice-Hall.

Kaviani, H., Gray, J. A., Checkley, S. A., Kumari, V., & Wilson, G. D. (1999). Modulation of the acoustic startle reflex by emotionally-toned film-clips. *International Journal of Psychophysiology*, *32*, 47–54.

Lacey, J. I., Kagan, J., Lacey, B. C., & Moss, H. A. (1963). The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In P. H. Knapp (Ed.), *Expression of the emotions in man* (pp. 161–196). New York: International Universities Press.

Landis, C., & Hunt, W. A. (1939). *The startle pattern*. New York: Farrar, Straus & Giroux.

Lang, P. J. (1995). The emotion probe. *American Psychologist*, *5*, 372–385.

Levenson, R. W. (1988). Emotion and the autonomic nervous system: A prospectus for research on autonomic specificity. In H. L. Wagner (Ed.), *Social psychophysiology and emotion: Theory and clinical applications* (pp. 17–42). Hoboken, NJ: John Wiley & Sons.

Marin, G., & Marin, B. A. (1991). *Research with Hispanic populations*. Newbury Park, CA: Sage.

McCanne, T. R., & Anderson, J. A. (1987). Emotional responding following experimental manipulation of facial electromyographic activity. *Journal of Personality and Social Psychology*, *52*, 759–768.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin*, *126*, 247–259.

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as a limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology*, *74*, 774–789.

Ossenkopp, K. P., & Mazmanian, D. S. (1985). The principle of aggregation in psychobiological correlational research: An example from the open-field test. *Animal Learning & Behavior*, *13*, 339–344.

Overduin, J. (1993). The advantage of the startle reaction: On the incomplete use of the reflex in studies of emotions. *Psycholoog*, *28*, 193–200.

Papillo, J. F., & Shapiro, D. (1990). The cardiovascular system. In J. T. Cacioppo & L. G. Tassinary (Eds.), *Principles of psychophysiology* (pp. 456–512). Cambridge, UK: Cambridge University Press.

Richards, J. M., & Gross, J. J. (2000). Emotion regulation and memory: The cognitive costs of keeping one's cool. *Journal of Personality and Social Psychology*, *79*, 410–424.

Rushton, J. P., Brainerd, C. J., & Pressley, M. (1983). Behavioral development and construct validity: The principle of aggregation. *Psychological Bulletin*, *94*, 18–38.

Stepper, S., & Strack, F. (1993). Proprioceptive determinants of emotional and nonemotional feelings. *Journal of Personality and Social Psychology*, *64*, 211–220.

Stern, R. M., & Sison, C. E. E. (1990). Response patterning. In J. T. Cacioppo & L. G. Tassinary (Eds.), *Principles of psychophysiology* (pp. 193–215). Cambridge, UK: Cambridge University Press.

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology*, *54*, 768–777.

Turpin, G. (1986). Effects of stimulus intensity on autonomic responding: The problem of differentiating orienting and defense reflexes. *Psychophysiology*, *23*, 1–15.

Turpin, G., & Siddle, D. A. T. (1978). Cardiac and forearm plethysmographic responses to high intensity auditory stimuli. *Biological Psychology*, *6*, 267–282.

Turpin, G., & Siddle, D. A. T. (1979). Effects of stimulus intensity on electrodermal activity. *Psychophysiology*, *16*, 582–591.

Turpin, G., & Siddle, D. A. T. (1983). Effects of stimulus intensity on cardiovascular activity. *Psychophysiology*, *20*, 611–624.

Vossel, G., & Zimmer, H. (1992). Stimulus rise time, intensity and the elicitation of unconditioned cardiac and electrodermal responses. *International Journal of Psychophysiology*, *12*, 41–51.

Vrana, S. R., Spence, E. L., & Lang, P. J. (1988). The startle probe response: A new measure of emotion? *Journal of Abnormal Psychology*, *97*, 487–491.

(Received December 16, 2004; Accepted December 23, 2005)