Emotional Responding Following Experimental Manipulation of Facial Electromyographic Activity

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Increases in zygomatic electromyographic (EMG) responding have been reported during the imagination of positive affective scenes, and increases in corrugator EMG have been reported during negative affective scenes. Thirty female subjects were instructed to imagine three positive affective scenes and three negative affective scenes. During the initial imagination of each scene, the subject was told simply to imagine the situation. The subject then imagined the situation again and was instructed to enhance the muscle tension in one of two muscle groups (the zygomatic muscles for positive scenes and the corrugator muscle for negative scenes). The subject then imagined the scene a third time and was instructed to suppress the muscle tension in the same muscle group. The order of administration of enhancement and suppression trials was randomized for each scene. Subjects were given several trials to practice controlling both zygomatic and corrugator EMG. Feedback was available during the practice trials and during the enhancement and suppression trials of the experiment. Continuous monitoring of both zygomatic and corrugator EMG during the study indicated that subjects were successful in altering muscle tension in accord with the experimental instructions, and videotapes of subjects' faces indicated no overt changes in facial responding during imagination of the scenes. Subjects' ratings of emotional responding during each scene indicated that subjects experienced less enjoyment and more distress during positive affective trials in which they suppressed zygomatic EMG activity. The results are discussed in terms of the facial feedback hypothesis.

In recent years, numerous investigators have attempted to determine the role that facial expression plays in the experience of emotion (cf. Buck, 1980; Ekman & Friesen, 1975; Izard, 1972, 1977; Laird, 1984; Tomkins, 1962; Zajonc, 1985). Some of these authors have speculated that changes in facial muscle activity may affect brain functioning through afferent feedback loops (Izard, 1972, 1977; Tomkins, 1962) or by altering the flow of blood to the brain (Zajonc, 1985). Others, using self-perception theory (Bem, 1967, 1972), have argued that certain types of subjects use facial muscle cues in forming attributions about themselves (cf. Laird, 1984). The potential interactions among the self-attributive process initiated by facial muscle activity, the alteration of brain activity as a consequence of changes in facial muscle responding, and emotional experience have also been acknowledged by theorists in this area.

Laird (1984) has recently reviewed the studies concerned with the effects of facial alterations on emotions and has concluded that the evidence overwhelmingly supports the importance of facial feedback in determining emotions. As part of this support, Laird has pointed to a number of experiments in which subjects have been instructed to alter, exaggerate, or conceal facial activity with or without the presence of emotional stimuli (e.g., Colby, Lanzetta, & Kleck, 1977; Duncan & Laird, 1977; Kleck et al., 1976; Kopel & Arkowitz, 1974; Kraut, 1982; Laird, 1974; Lanzetta, Cartwright-Smith, & Kleck, 1976; Zuckerman, Klorman, Larrance, & Spiegel, 1981). The vast majority of these studies have yielded data that are consistent with the hypothesis that facial muscle activity contributes to the experience of emotions.

Despite the experimental interest in the role of facial muscle activity in the experience of emotion, little attention has been focused on the role of two particular groups of facial muscles that appear to be promising indicators of positive and negative affect: the zygomatic and corrugator muscles. Schwartz and his associates (Brown & Schwartz, 1980; Schwartz, Brown, & Ahern, 1980; Schwartz et al., 1978; Schwartz, Fair, Salt, Mandel, & Klerman, 1976a, 1976b; Schwartz & Weinberger, 1980), using paradigms in which subjects are required to imagine certain scenes, have consistently reported increases in zygomatic electromyographic (EMG) activity (the muscles associated with smiling) during the imagination of happy and pleasant scenes, and have reported increases in corrugator EMG (the muscles associated with frowning) during sad and unpleasant scenes.

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Schwartz et al. (1976b) reported that the changes in EMG activity during these imaginal scenes are so minute or so quick that they can be detected by sophisticated psychophysiological instruments but not by individuals simply observing a videotape of a subject's face.

In a recent study, Ekman, Levenson, and Friesen (1983) attempted to manipulate facial muscle activity systematically by training subjects to alter several discrete muscle groups that Ekman and his associates have found to be related to specific emotions (Ekman & Friesen, 1975). The innovative procedures for teaching subjects facial poses that were used by Ekman et al. (1983) resulted in differential patterns of autonomic responding during several of the poses. These results suggest that differential patterns of autonomic responding occur during the alteration of facial muscle activity associated with specific emotional states. However, Ekman et al. did not examine self-reported alterations in emotion associated with facial poses.

In this experiment, we used and adapted the paradigm used by Schwartz and his colleagues. In one condition, subjects were instructed to imagine several standard scenes. In two other conditions, subjects were instructed to imagine the standard scenes and were also told either to enhance or to suppress the muscle tension in the group of muscles that normally changes during those scenes. In addition, subjects were told that they were to enhance or suppress muscular activity without producing visible changes in facial responding. To be able to implement these instructions, subjects were given several practice trials during which they were provided with visual feedback of the integrated EMG levels from the target facial muscle groups, and they were given continuous visual feedback of integrated EMG responding during enhancement and suppression trials. Videotapes were made of subjects' faces during the trials and were rated by observers to ensure that observable changes in facial responding did not occur during the trials.

The methodology of the experiment thus constitutes a fairly rigorous test of the effects of altering two discrete muscle groups on subjects' reported affect during several imaginal scenes. The main purposes of the study were to determine the effects of minute, visually undetectable (but psychophysiologically measurable) alterations in facial muscle tension on reported emotions and to determine the contributions of two discrete facial muscle groups to the experience of emotions.

Method

Subjects

Thirty-five female undergraduate college students served as subjects. Subjects ranged from 18 to 24 years of age. Data for 5 subjects were not analyzed because of failure to comply with experimental procedures (to be discussed). Women were used as subjects because Schwartz et al. (1980) reported that women display more emotional expressiveness than men do during imaginal stimuli.

Apparatus

The experiment was conducted in two adjoining sound-attenuated and electronically shielded chambers connected by a two-way intercom system, a one-way video monitor, and a one-way mirror. Physiological recording was performed with a Grass model 7D polygraph equipped with two Grass 7P3 wideband AC amplifiers and integrators to process the EMG signals. A Digital Equipment Corporation PDP-11 computer monitored the output of the EMG channels and digitized the integrated analog signals.

Overview of Experimental Procedures

Subjects were required to imagine six standardized situations investigated by Brown and Schwartz (1980). Subjects in the Brown and Schwartz experiment judged three of these situations to be high-intensity happy images ("You inherit a million dollars," "You get a 4.0 grade point average," and "You meet the man of your dreams"). The other three situations were judged to be high-intensity sad images ("Your mother dies," "You lose a really close friendship," and "You lose a limb in an accident"). In this experiment, for each subject the order of presentation of the three happy images was randomized within a single positive-affect block, and the order of the three sad images was randomized within a single negative-affect block. The order of presentation of each affective block was also randomized for each subject.

For each of the six images, there were three trials: neutral, enhancement, and suppression. The first trial for each image was a neutral trial, during which the subject imagined the situation, with no additional instructions being provided. This trial was followed by two additional trials: an enhancement trial, during which the subject was instructed to keep the muscle tension in the target muscle relatively high while imagining the same situation, and a suppression trial, during which the subject was instructed to keep the muscle tension in the target muscle relatively low while imagining the same situation.[1] The order of presentation of the enhancement and suppression trials was randomized for each image for each subject. The target muscle for happy scenes was the zygomatic muscle and the target muscle for sad scenes was the corrugator muscle.

Each subject received 18 experimental trials (three instructions for each of the six imagery situations). Each trial included a 20-s pretrial period, reading of the imagery situation and instructions by the experimenter concerning the target muscle, and then a 40-s period during which the subject was to imagine the situation. After the 40-s imagery period, the subject was instructed to rate her emotional experiences during the imaginal period on a rating sheet (to be described). The rating period varied because of individual differences in speed of rating, but averaged approximately 40 s. When the subject indicated that she had completed the rating for that trial, she was instructed to turn to the next page in the ratings booklet and to wait for the next trial. A variable 30-s to 50-s intertrial interval then ensued before the presentation of the next imagery situation.

Zygomatic and corrugator EMG were both monitored continuously throughout the experiment. The raw EMG signals were continuously displayed on two channels of the polygraph and were inspected by the experimenter to ensure that the signals were free of artifact. The raw EMG signals were also integrated continuously with a time constant of approximately 2 s. Each integrated EMG signal was sampled once per second by the laboratory computer during the 20-s pretrial and during the 40-s imaginal period associated with each trial.

Procedure

Each subject was seated in a reclining chair in the experimental chamber. She was given the cover story that the purpose of the experi-

[1] The term *suppression* is used to describe experimental trials because increases in zygomatic EMG occur during the imagination of positive affective scenes and increases in corrugator EMG occur during the imagination of negative affective scenes (Schwartz et al., 1978; Schwartz & Weinberger, 1980). Thus, subjects had to suppress the naturally occurring increases in these muscle groups associated with imagining the positive and negative scenes.

ment was to examine the relations among several physiological variables during imagination. The subject was then told that electrodes purportedly measuring heart rate and skin resistance would be attached, as well as electrodes for measuring facial muscle tension, and was informed that heart rate and skin potential were the variables of major interest in the experiment. Electrodes were then attached. Skin resistance at the electrode sites was reduced to less than 3000 ohms by cleansing the skin with acetone and rubbing in a small amount of Grass electrode paste. Pairs of miniature Beckman silver/silver chloride skin electrodes with interelectrode distances of 12.5 mm were used for bipolar EMG recording. Electrodes were filled with Grass electrode paste and attached with adhesive collars. The zygomatic electrode placement was approximately 2 cm below the outer corner of the right eye near the cheekbone. The corrugator electrode placement was 1 cm above the right eyebrow and approximately 2 cm to the right of the nasal midline (cf. Schwartz et al., 1976a). In addition, to distract the subject's attention from the facial electrodes, additional electrodes were attached to the subject's arms and legs, supposedly to measure heart rate and skin responding.

The experimental procedures were then explained to the subject (see following paragraphs). She was given a ratings booklet containing the rating scales to be completed during the experiment. Each page of the ratings booklet contained 14 items to be rated. Two of the items assessed the subject's reported ability to imagine the scene. The remaining items were 12 adjectives from the Differential Emotions Scale (DES; Izard, 1972). The three items that load on the enjoyment factor of the DES (happy, delighted, and joyful) were included in each rating, as were the three items that load on the distress factor (sad, downhearted, and discouraged). The order of presentation of the 12 DES adjectives was randomized for each trial. The subject rated how she felt for each item on a 99 mm line (0 = *not at all;* 99 = *very much*).

The subject was asked to remain quiet and still throughout the experiment. During the imagery periods, the subject was told to imagine herself in the situation described by the experimenter, making it as real as possible. She was told to allow herself to experience whatever she would feel in the actual situation. When signaled that the imagery period was over, she was instructed to answer the rating questions quickly and honestly, indicating how she really felt, not how she thought she should feel. After completing the ratings for that trial, she was asked to turn to the next sheet in the ratings booklet and to sit back and use the time to relax before the next trial.

The additional task of changing the muscle tension for the "forehead" (corrugator) or "cheek" (zygomatic) muscle using the feedback meter was then explained to the subject. The subject was told that she would be asked during some trials to keep either her forehead or cheek muscle tension high or low while imagining a scene, and was also informed that there would be some trials during which she was simply to imagine the scene. The subject was further instructed that she was not to alter physically her facial expressions in any way during trials and was informed that the experimenter would be observing and videotaping her facial expression continuously via a video monitor and recorder in the adjoining chamber. If the experimenter noticed significant distortion in the subject's face, the experimenter reminded the subject not to alter physically her face in any way following that trial. The experimenter noted that although this task might seem difficult to the subject, the polygraph was capable of measuring very slight alterations in muscle tension and that the subject would be provided with continuous visual feedback by means of a meter during trials in which she was told to keep her muscle tension either high or low. The feedback meter was 5 in. × 7 in. (12.7 cm × 17.8 cm) and was located approximately 18 in. (45.7 cm) to the subject's left. Full-scale meter deflection to the left constituted an integrated EMG level of 1 microvolt/s; full-scale deflection to the right corresponded to an integrated EMG level of 80 microvolts/s. On the basis of previous pilot experimentation, the subject was told that during enhancement trials the reading on the meter should be somewhere in the middle of the scale. There was a brief introductory period to provide an opportunity for the subject to practice this task and to be sure the subject understood the instructions. A 10-min adaptation period then ensued.

Every subject was then given at least one nonimagery practice trial for each of four conditions: keeping zygomatic muscle tension relatively high and low and keeping corrugator muscle tension relatively high and low. Continuous visual feedback was provided during these practice trials, and the subject was told to keep her eyes open to make optimal use of the feedback. The order of presentation of the four practice conditions was randomized for each subject. Additional practice trials were included if the subject was unable to make the necessary changes. This was necessary for only 4 subjects, 2 of whom needed additional practice keeping zygomatic muscle tension high and 2 of whom required additional practice keeping corrugator muscle tension high. All subjects were able to produce reliable changes in corrugator and zygomatic EMG without visible facial alterations in eight trials or fewer. During supression trials for both practice and stimulus trials, subjects generally did not produce actual decreases in muscle tension but rather kept muscle tension low. Because subjects at rest were already exhibiting relatively low levels of zygomatic and corrugator EMG, it was probably impossible for them to lower muscle tension any further without extensive practice and feedback.

After the practice trials, the subject was administered the 18 stimulus trials in the manner described. The visual feedback was available continuously during the enhancement and suppression trials but not during neutral trials. Subjects were told that they need not watch the feedback meter constantly, but might choose to glance at it occasionally to monitor their muscle changes.

At the end of the 18 trials, the electrodes were removed and the subject was debriefed. Virtually all subjects reported no awareness of any overt alterations in facial expression during the trials, and the experimenter had to intervene with only 5 subjects to remind them not to distort their facial expressions. The experiment was discontinued before completion for 2 of these 5 subjects, who failed to comply with the instructions. Data from the other 3 subjects were not included in the analyses because of subsequent assessment by condition-blind raters that these subjects had overtly altered facial muscle activity during some trials. No subject volunteered awareness of the expected effects.

Results

Two independent raters, who were blind to the experimental conditions and hypotheses of the study, viewed the videotapes of all 33 subjects for whom complete data were available. The raters made a judgment as to whether there had been any visible change in zygomatic or corrugator muscle tension from the pretrial period to the imagery period for each trial. The data for 3 subjects were excluded from the analyses because of rated visible changes in facial muscle tension. The ratings for the remaining 30 subjects indicated no visible changes in the two muscle groups during the stimulus trials.

EMG Data

Data points for both zygomatic and corrugator EMG were averaged into three 20-s measurement periods: the 20-s pretrial, the initial 20 s of the imagery period, and the final 20 s of the imagery period. Separate 2 × 3 × 3 × 3 (Positive vs. Negative Affect × Three Different Images × Neutral vs. Enhancement vs. Suppression Trials × Measurement Periods for Each Trial) repeated measures analyses of variance (ANOVAs) were computed for each muscle group. Mean integrated EMG levels for

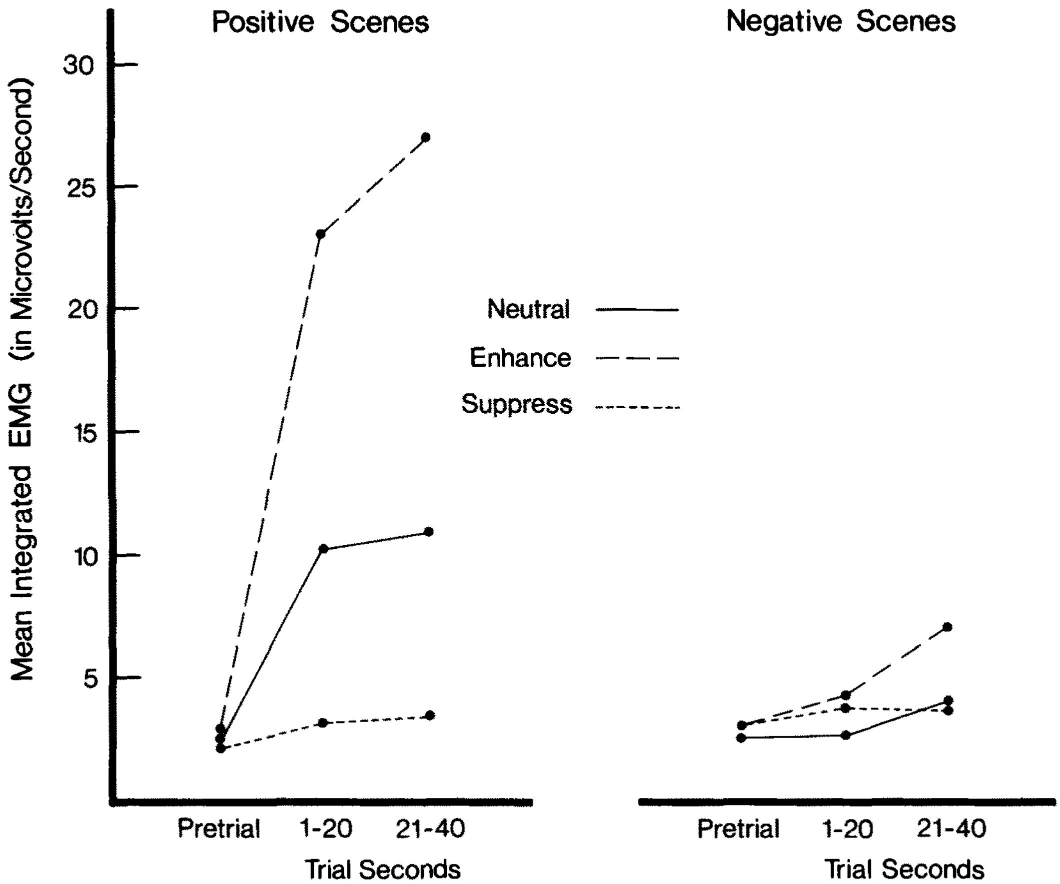

Figure 1. Mean integrated EMG levels for zygomatic muscle activity during positive and negative affective scenes.

zygomatic activity are presented in Figure 1, and mean integrated EMG levels for corrugator activity are illustrated in Figure 2.

ANOVAs yielded significant Affect × Type of Trials × Measurement Period interactions for both zygomatic and corrugator muscle activity, $F(4, 116) = 44.72$, $p < .001$, for zygomatic EMG and $F(4, 116) = 62.26$, $p < .001$, for corrugator EMG (see Figure 1). One-way F tests followed by the Newman–Keuls procedure were conducted to elucidate the meanings of the triple interactions.

As illustrated in Figure 1, there were significant increases in zygomatic EMG activity during positive affective imagery periods relative to the pretrial for both the neutral trials, $F(2, 58) = 88.70$, $p < .001$, and the enhancement trials, $F(2, 58) = 97.83$, $p < .001$, but not for the suppression trials, $F(2, 58) = 1.22$. During each of the measurement periods associated with imagining the neutral stimuli, mean zygomatic EMG activity differed significantly from that noted during the pretrial. During enhancement trials, mean zygomatic EMG activity during each of the three measurement periods differed significantly from the activity during the other two periods ($p < .01$ for all Newman–Keuls tests for the preceding differences).

In addition, there were no significant differences in zygomatic EMG activity among types of trials during the pretrial preceding positive affective images, $F(2, 58) = .62$, but there were significant differences among the types of trials during the first 20 s of the trial, $F(2, 58) = 60.52$, $p < .001$, and during the second 20 s of the trial, $F(2, 58) = 75.58$, $p < .001$. In both of the latter cases, zygomatic EMG activity during each type of trial differed significantly from that noted during the other two types of trials ($p < .01$ for all Newman–Keuls tests). Thus, as illustrated in Figure 1, during positive affective trials subjects exhibited increases in zygomatic EMG during the imagery periods of neutral and enhancement trials, and they did not exhibit increases in zygomatic activity during the suppression trials. In addition, zygomatic EMG levels during positive affective trials were highest during enhancement trials, intermediate during neutral trials, and lowest during suppression trials. These differential changes in zygomatic responding were consistent with the experimental manipulations.

During negative affective trials, the target muscle was the corrugator group, not the zygomatic group. The only follow-up F test that was significant for zygomatic EMG during negative affective trials was a measurement periods effect during the enhancement trials, $F(2, 58) = 8.89$, $p < .01$. Zygomatic EMG during all three measurement periods differed significantly from that noted during the other two periods for the negative affective trials with enhancement instructions ($p < .01$ for all

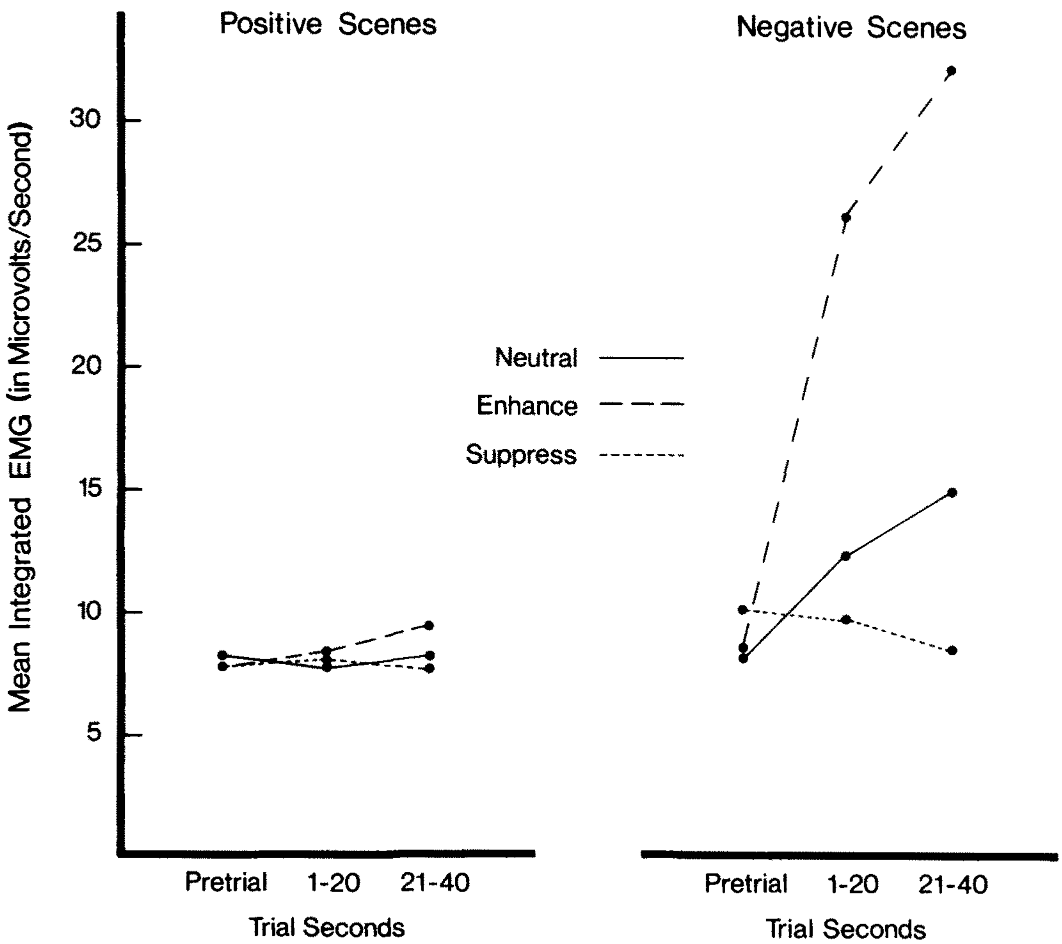

Figure 2. Mean integrated EMG levels for corrugator muscle activity during positive and negative affective scenes.

Newman–Keuls tests). Thus, there was a relatively small increase in zygomatic EMG activity in sympathy with the larger changes in corrugator activity noted during negative affective trials with enhancement instructions (see Figure 1).

The follow-up analyses for corrugator EMG indicated that during negative affective trials there was a significant increase in activity during neutral trials, $F(2, 58) = 18.15$, $p < .01$, and during enhancement trials, $F(2, 58) = 130.35$, $p < .001$, but not during suppression trials, $F(2, 58) = 1.13$ (see Figure 2). For both neutral and enhancement trials with negative images, corrugator activity during each measurement period differed significantly from that noted during the other periods ($p < .01$ for all Newman–Keuls tests). Additionally, significant differences were noted between the three types of trials during the first 20 s of the imagery period, $F(2, 58) = 57.46$, $p < .001$, and during the final 20 s of the imagery period, $F(2, 58) = 76.66$, $p < .001$, but not during the pretrial period, $F(2, 58) = 1.55$. During the initial and final 20-s imagery periods for negative affective stimuli, corrugator EMG during each type of instruction differed significantly from that during the other two instructions ($p < .01$ for all Newman–Keuls tests).

During positive affective stimuli, the zygomatic muscle was the target, rather than the corrugator group. Follow-up *F* tests for corrugator EMG during positive affective stimuli indicated no significant differences among the means presented in Figure 2. Thus, the changes in corrugator EMG activity during positive and negative affective trials were consistent with the experimental manipulations.

Self-Report Data

Four identical 2 × 3 × 3 (Affect × Images × Trials) repeated measures ANOVAs were computed for the following self-report variables: ratings of ability to imagine the situation, ratings of ability to experience the feelings associated with the situation, the sum of the ratings for the three adjectives from the enjoyment factor of the DES (happy, delighted, and joyful), and the sum of the ratings for the three adjectives from the distress factor of the DES (sad, downhearted, and discouraged).

Ratings of imagery. The only significant effects detected in the analyses of subjects' ratings of imaginal ability were trials main effects, $F(2, 58) = 9.17$, $p < .01$, for ability to imagine the scene and $F(2, 58) = 10.06$, $p < .01$, for ability to experience the feelings during the scene. Means and standard deviations

Table 1
Means and Standard Deviations for Self-Report of Ability to Imagine the Scenes and Ability to Experience the Feelings of the Scenes

	Neutral trials	Enhancement trials	Suppression trials
Ability to imagine positive scenes			
M	77.3	76.9	63.0
SD	11.4	10.6	9.1
Ability to imagine negative scenes			
M	71.9	73.7	60.5
SD	9.9	11.3	10.5
Ability to experience positive scenes			
M	69.2	70.7	56.0
SD	9.0	13.3	8.4
Ability to experience negative scenes			
M	71.4	72.1	59.6
SD	10.7	11.8	9.3

Note. For both variables, the rating scale ranged from 0 (*not at all*) to 99 (*very much*).

pertinent to these findings are presented in Table 1. Ratings during suppression trials were significantly different from those during neutral and enhancement trials for both ability to imagine and ability to experience the feelings ($p < .01$ for all Newman–Keuls tests). Thus, when subjects were suppressing the muscular expression of emotion, they reported that they were less able to imagine and experience a scene than when they were enhancing the muscular expression of the emotion or simply imagining the scene without any instructions to alter facial muscle activity.

Ratings of enjoyment and distress. The relevant mean ratings for the enjoyment and distress factors of the DES are presented in Figure 3. Significant Affect × Trials interactions were detected for the enjoyment factor, $F(2, 58) = 21.69$, $p < .001$, and for the distress factor, $F(2, 58) = 6.85$, $p < .01$.

A follow-up F test for enjoyment ratings during the positive affective trials indicated a significant difference among the three types of trials, $F(2, 58) = 23.38$, $p < .001$, with the mean enjoyment rating during suppression trials being significantly lower than the mean enjoyment rating during neutral and enhancement trials ($p < .01$ for Newman–Keuls tests). A follow-up F test for enjoyment ratings during the negative affective trials indicated no significant differences among the three types of trials, $F(2, 58) = 1.02$.

For the distress ratings during the positive affective trials, a follow-up F test indicated a significant difference among the three types of trials, $F(2, 58) = 8.20$, $p < .01$, with the mean score during the suppression trials being significantly higher than those noted during the neutral and enhancement trials ($p < .01$ for Newman–Keuls tests). For the distress ratings during the negative affective trials, a follow-up F test indicated differences among the three types of trials that were marginally significant, $F(2, 58) = 2.24$, $p < .10$.

Self-report data for the first trial block. In an attempt to minimize the potential demand characteristics inherent in the use of a repeated measures design, ratings of enjoyment and distress from the first block of three trials presented to each subject were analyzed. The rationale for the use of data from the first trial block was that during these three trials subjects would have had the least amount of opportunity to formulate a hypothesis about the nature of the experiment.

Ratings for both the enjoyment and distress factors of the DES were subjected to separate 2 × 3 (Affect × Trials) ANOVAS, with the first factor being a between-subjects factor and the second factor being a repeated measure. The effects of the three different positive and negative images were not analyzed, and means were computed by averaging the scores of each subject across each of the three images for each type of affect. There were 14 subjects who received a positive trial block first and 16 subjects who received a negative trial block first. Major results of these analyses are presented in Table 2.

Significant Affect × Trials interactions were detected for both the enjoyment ratings, $F(2, 56) = 5.14$, $p < .01$, and the distress ratings, $F(2, 56) = 6.17$, $p < .01$. A follow-up F test for the enjoyment ratings during positive affective scenes indicated significant differences among the three types of trials, $F(2, 26) = 4.07$, $p < .05$, with the mean rating during suppression trials being significantly lower than that noted during neutral trials or enhancement trials ($p < .05$ for Newman–Keuls test). No significant differences in enjoyment ratings were noted during negative affective scenes, $F(2, 30) = 1.07$.

A follow-up F test for the distress ratings during positive affective scenes indicated differences among the three types of

Table 2
Means and Standard Deviations for Self-Report of Enjoyment and Distress Factors During the First Trial Block

Factor	Neutral trials	Enhancement trials	Suppression trials
Enjoyment			
Negative affect			
M	20.3	40.4	39.0
SD	7.7	9.0	9.3
Positive affect			
M	255.2_a	217.3_b	$175.4_{a,b}$
SD	19.0	15.6	13.2
Distress			
Negative affect			
M	205.0	170.2	174.6
SD	17.5	16.0	18.8
Positive affect			
M	23.9_a	36.5_b	$66.3_{a,b}$
SD	6.5	7.9	10.5

Note. For each of the three adjectives comprising each factor, the rating scale ranged from 0 (*not at all*) to 99 (*very much*). The minimum rating for each factor was 0; the maximum rating for each factor was 297. Across rows, means sharing a common subscript differ significantly from one another at the .05 level (Newman–Keuls procedure).

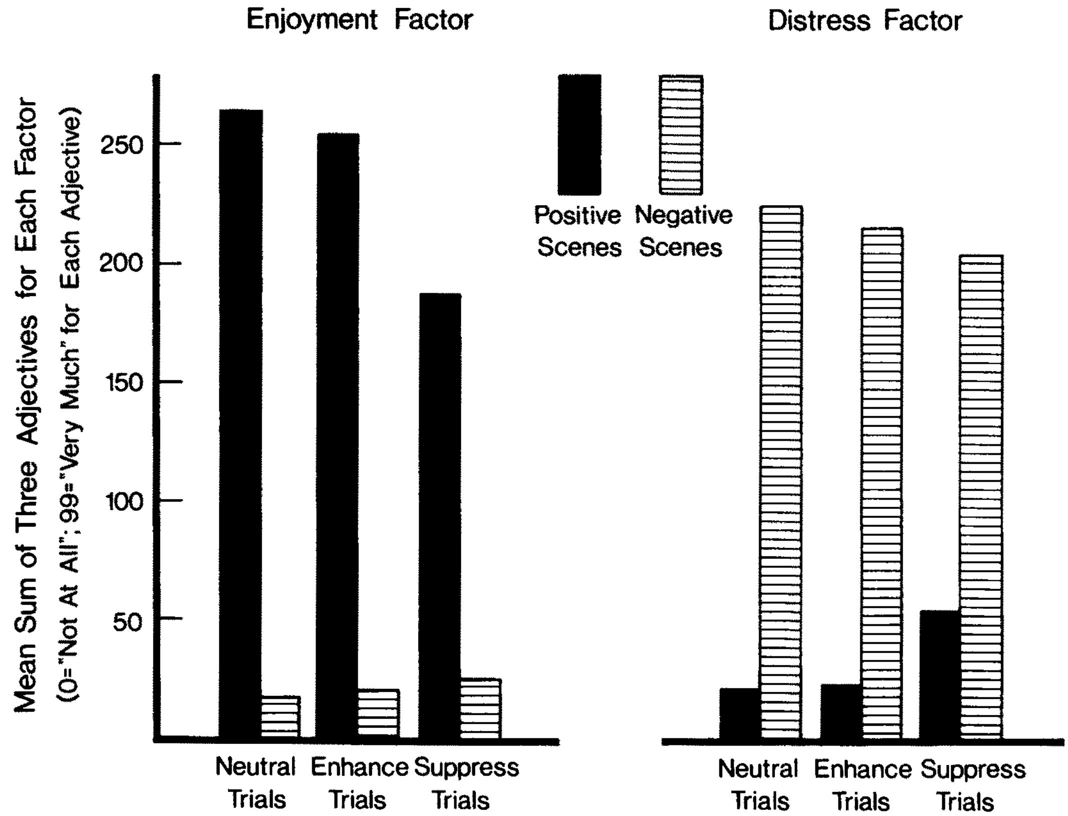

Figure 3. Mean self-report of distress and enjoyment during neutral, enhancement, and suppression instructions for positive and negative affective scenes.

trials, $F(2, 26) = 7.81, p < .01$, with ratings during suppression trials being significantly higher than those noted during neutral or enhancement trials ($p < .05$ for Newman-Keuls test). A follow-up F test for the distress ratings during negative affective scenes indicated differences among the three types of trials that were marginally significant, $F(2, 30) = 2.45, p < .10$. Thus, as presented in Table 2 and Figure 3, the results from the first trial block were virtually identical to those detected during all 18 of the affective trials.

Correlations Between EMG Responses and Self-Report Data

In addition to the ANOVAS already reported, it was also of interest to determine the relations between changes in EMG activity during the positive and negative affective scenes and self-report on the enjoyment and distress factors of the DES during those scenes. If facial muscle activity contributes to the experience of emotions, increases in zygomatic EMG should be positively associated with higher levels of self-report on the enjoyment factor of the DES, and increases in corrugator EMG should be positively associated with higher scores on the distress factor of the DES.

Separate between-subjects correlations were computed during the three positive affective scenes and during the three negative affective scenes. Change in EMG responding for each type of trial was calculated by subtracting the pretrial EMG level from the mean EMG level during the last 20 s of the trial. Separate change scores were computed for zygomatic EMG and corrugator EMG for each subject for each trial. The mean EMG change scores of subjects during positive affective scenes with neutral instructions were then correlated with subjects' mean self-report scores on the enjoyment and distress factors of the DES during these trials. Parallel procedures were used for positive affective scenes with enhancement and suppression instructions and for all three types of instructions associated with negative affective scenes. In addition, correlation coefficients were calculated between mean change in EMG responding during all nine positive affective stumuli and mean self-report on the enjoyment and distress factors of the DES for the nine positive affective scenes. The same procedures were also used for the nine negative affective scenes. The correlation coefficients resulting from these procedures are presented in Tables 3 (positive affective scenes) and 4 (negative affective scenes).

During positive affective scenes, mean changes in zygomatic EMG responding were significantly positively correlated with mean self-report on the enjoyment factor of the DES during each type of instruction and during all nine positive affective scenes averaged together (see Table 3). Mean changes in zygomatic EMG were not significantly correlated with mean self-report on the distress factor of the DES during positive affective scenes, although the directions of the correlation coefficients consistently indicated negative relations between zygomatic EMG and distress for all three types of instructions and for all

Table 3
Correlations Between Mean Change in Zygomatic and Corrugator EMG Activity and Mean Self-Report of Enjoyment and Distress During Positive Affective Scenes

EMG type	Neutral trials	Enhancement trials	Suppression trials	All positive trials
Zygomatic				
Enjoyment factor	.42*	.46**	.39*	.58**
Distress factor	−.15	−.06	−.11	−.27
Corrugator				
Enjoyment factor	−.07	−.09	−.14	−.24
Distress factor	.12	.17	.08	.14

Note. $n = 30$. EMG = electromyographic responding.
* $p < .05$.
** $p < .01$.

nine positive affective scenes averaged together. Similarly, mean changes in corrugator EMG during positive affective trials (the zygomatic muscle was the target) were not significantly correlated with mean self-report on either the enjoyment or distress factors of the DES, although the directions of the correlation coefficients consistently indicated that corrugator EMG was negatively correlated with enjoyment and positively correlated with distress.

During negative affective scenes, mean changes in corrugator EMG were significantly positively correlated with mean self-report on the distress factor of the DES during each type of instruction and during all nine negative affective scenes averaged together (see Table 4). Mean change in corrugator EMG was not significantly correlated with mean self-report on the enjoyment factor of the DES during negative affective scenes, although the directions of the correlation coefficients consistently indicated negative relations between corrugator EMG and enjoyment for all three types of instructions and for all nine negative affective scenes averaged together. Similarly, mean changes in zygomatic EMG during negative affective trials (the corrugator muscle was the target) were not significantly correlated with mean self-report on either the enjoyment or distress factors of the DES, although the directions of the correlation coefficients consistently indicated that zygomatic EMG was positively correlated with enjoyment and negatively correlated with distress.[2]

Table 4
Correlations Between Mean Change in Zygomatic and Corrugator EMG Activity and Mean Self-Report of Enjoyment and Distress During Negative Affective Scenes

EMG type	Neutral trials	Enhancement trials	Suppression trials	All negative trials
Zygomatic				
Enjoyment factor	.09	.22	.17	.12
Distress factor	−.10	−.19	−.23	−.19
Corrugator				
Enjoyment factor	−.05	−.14	−.14	−.17
Distress factor	.36*	.38*	.41*	.46**

Note. $n = 30$. EMG = electromyographic responding.
* $p < .05$.
** $p < .01$.

Discussion

As the EMG data presented in Figures 1 and 2 clearly indicate, subjects were successful in enhancing and suppressing both zygomatic and corrugator muscle activity when instructed to do so. In addition, as reported by Schwartz and his associates (Schwartz et al., 1978; Schwartz & Weinberger, 1980), increases in zygomatic activity occur during the imagination of positive affective scenes, and increases in corrugator activity occur during the imagination of negative affective scenes. The changes in the target muscle tension during the experimental conditions were generally not paralleled by changes in the nontarget muscle, indicating that subjects can alter muscle tension in one group of facial muscles without altering the muscle tension in the other group. In general, it was clear that subjects were able to produce relatively brief, discrete changes in both zygomatic and corrugator muscle activity when instructed to do so and provided with feedback.

Ratings of changes in facial muscle activity during the experimental trials indicated that the noted facial EMG changes were not associated with readily detectable changes in the overt facial musculature of subjects. Thus, as Schwartz et al. (1976b) observed, the changes in muscle tension that occur during the positive and negative affective scenes are relatively minute and difficult to observe. In addition, our results indicate that subjects can both enhance and suppress the target muscle activity associated with the affective scenes without visibly altering their overt facial musculature as rated by observers. These results are consistent with the observations of other investigators (e.g., Ekman, Friesen, & Ellsworth, 1972) who have noted the difficulties in correctly classifying gross facial changes, although it remains possible that a specially trained observer might be able to approximate by visual inspection of the videotapes the magnitude of the EMG changes noted in Figures 1 and 2 (cf. Ekman & Friesen, 1975).

In previous research concerning the relations between facial muscle activity and emotions, investigators used instructions to produce visible alterations of facial muscle patterns (cf. Laird, 1984). The instructions used in our research focus on two discrete muscle groups that appear to be closely related to positive

[2] Separate within-subjects correlation coefficients were also computed for each subject between mean change in EMG responding and self-report on the enjoyment and distress factors of the DES during positive and negative affective scenes. Each of these within-subjects correlations was based on nine observations. During the nine positive affective scenes, the mean within-subjects correlation between change in zygomatic EMG and enjoyment (calculated with Fisher's *z*-score transformation) was .62., and the mean within-subjects correlation between change in zygomatic EMG and distress was −.17. During the nine negative affective scenes, the mean within-subjects correlation between change in corrugator EMG and distress was .53, and the mean within-subjects correlation between change in corrugator EMG and enjoyment was −.03.

and negative affective experiences and thus provide a test of the relations between specific facial muscle groups and emotions. In addition, the instructions and feedback used in this research resulted in covert and unobservable alterations in facial muscle tension, compared with the overt alterations manipulated in previous studies. Thus, these experimental manipulations constitute a fairly rigorous test of the effects of facial muscle activity on emotions under fairly restrictive conditions.

Clear support for the effects of facial muscle tension on affective experience was obtained only for the effect of suppression of zygomatic muscle tension during positive affective scenes (see Figure 3). When subjects suppressed the increase in zygomatic muscle tension normally associated with imagining a positive situation, they reported experiencing less enjoyment and more distress on the DES than when they imagined the scene without altering zygomatic muscle activity. Support for the effects of suppression of facial muscle tension on negative affective experiences was not obtained, although the means for enjoyment and distress during neutral and suppression trials were ordered in the correct direction, and the *F* test comparing the three conditions approached an acceptable level of statistical significance (see Figure 3). Thus, it appears that the suppression of the normal increases in zygomatic muscle tension during positive scenes results in decreases in enjoyment and increases in distress.

One possible alternative explanation of the effects of suppression on emotional experience in this experiment is that subjects were more distracted or relaxed during suppression trials, thus leading to reductions in the experience and self-report of affect. The reduced ability to imagine and experience the imaginal scenes reported by subjects during the suppression trials (relative to the neutral and enhancement trials) provides some support for this alternative explanation (see Table 1). Anecdotally, during debriefing several subjects reported that they were trying to relax the target muscle during suppression trials and that the effort they expended relaxing the muscle interfered with their ability to imagine the required scene. Relaxation procedures are used frequently in clinical situations because the experience of relaxation is viewed as being incompatible with emotional arousal.

In considering the possible effects of distraction and relaxation during suppression trials, note that the suppression of the naturally occurring increase in zygomatic EMG activity during positive affective scenes produced higher levels of distress in comparison with the distress reported during neutral and enhancement trials. If subjects were more distracted or relaxed during the suppression trials than during neutral and enhancement trials, it would seem unlikely that higher levels of distress would be reported. In addition, the correlations between change in EMG responding and affect consistently indicated positive relations between zygomatic EMG and enjoyment and positive relations between corrugator EMG and distress during all three types of instructions (see Tables 3 and 4), although the correlations were statistically significant only between the target muscle and the appropriate affect. If subjects were more distracted or relaxed during the suppression instructions than during the neutral and enhancement trials, it would seem likely that the pattern of correlations between change in EMG activity and self-report of affect would have been differentially effected. However, the possible differential effects of distraction and relaxation during the three types of instructions cannot be entirely ruled out. The alterations in affect produced by the suppression instructions may be a result of the interactive effects of distraction combined with alterations in subjects' affective experiences because of the lack of facial cues and afferent feedback during suppression trials.

Support was not obtained for the effects of enhancement of EMG responding on positive and negative affective experiences. In fact, even the ordering of the means for neutral, enhancement, and suppression trials was not consistent with the hypothesized contribution of enhancement to emotional responding (see Figure 3). There are several possible explanations for these negative findings. First of all, for increases in emotional responding to occur during these imaginal experiences, it may be necessary for alterations in facial musculature to exceed certain threshold levels. Although the increases in the target EMG activity were large during enhancement trials (see Figures 1 and 2), the increases were not large enough to be detected visually and may not have been large enough to result in altered affect. Second, discrete muscle groups were manipulated in this experiment, in contrast to manipulations of larger areas of the face in previous studies. Thus, the enhancement trials in our research were relatively restrictive in assessing the effects of two particular muscle groups on affect. Finally, subjects reported very strong emotional responses when simply imagining the stimuli but not enhancing or suppressing EMG activity, particularly when imagining the positive stimuli (see Figure 3). Thus, a ceiling effect may have occurred that limited the ability of subjects to report increases in responding during enhancement trials. However, if such a statistical ceiling occurred, it likely affected only the enjoyment factor during positive imagery, as ratings on the distress factor during negative imagery were clearly not as close to the maximum as were ratings of enjoyment during positive imagery.

Although the potential effects of the demand characteristics of the experiment cannot be ruled out, subjects' emotional responses during the first stimulus block were virtually identical to those noted throughout the course of the experiment. Thus responding during the initial stages of the experiment, when demand effects would be expected to be least strong, was the same as responding during later stages of the experiment, when demand effects should be most strong. These data suggest that the emotional results of this study were not attributable to demand characteristics.

A number of investigators have theorized that (a) changes in facial musculature may alter brain functioning through afferent feedback (Izard, 1972, 1977; Tompkins, 1962), and (b) subjects use facial muscle cues in making inferences about their own behavior (Laird, 1984). It seems likely that both of these theoretical positions are correct and that both neural feedback and the subject's self-perception of facial cues are essential in determining emotional state. The results of our research are consistent with a growing body of literature indicating that alterations in facial musculature play an important role in producing changes in emotional responding. The results of this study also begin to delineate more precisely the roles played by unobservable alterations in facial muscle activity in determining differential emotional responding. The procedures used to manipulate facial EMG activity in this research can be used in the future to provide a more precise understanding of how feedback from specific muscle groups is related to affective experience.

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