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Voluntary Facial Action Generates Emotion-Specific Autonomic Nervous System Activity

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ABSTRACT

Four experiments were conducted to determine whether voluntarily produced emotional facial configurations are associated with differentiated patterns of autonomic activity, and if so, how this might be mediated. Subjects received muscle-by-muscle instructions and coaching to produce facial configurations for anger, disgust, fear, happiness, sadness, and surprise while heart rate, skin conductance, finger temperature, and somatic activity were monitored. Results indicated that voluntary facial activity produced significant levels of subjective experience of the associated emotion, and that autonomic distinctions among emotions: (a) were found both between negative and positive emotions and among negative emotions, (b) were consistent between group and individual subjects' data, (c) were found in both male and female subjects, (d) were found in both specialized (actors, scientists) and nonspecialized populations, (e) were stronger when the voluntary facial configurations most closely resembled actual emotional expressions, and (f) were stronger when experience of the associated emotion was reported. The capacity of voluntary facial activity to generate emotion-specific autonomic activity: (a) did not require subjects to see facial expressions (either in a mirror or on an experimenter's face), and (b) could not be explained by differences in the difficulty of making the expressions or by differences in concomitant somatic activity.

DESCRIPTORS: Facial action, Emotion, Autonomic activity during emotion, Emotion-specific autonomic activity.

The experiments in this report are relevant to two major theoretical issues. The first, whether there are different patterns of autonomic nervous system (ANS) activity for different emotions, is one of psychophysiology's oldest. The second, understanding how voluntary facial activity can generate emotion-specific autonomic activity, has a much shorter history, but has potentially important implications for emotion theory.

Autonomic Specificity in Emotion

Psychophysiological research on the question of autonomic specificity in emotion has come in three waves: (a) the theoretical disputes between James (1884) and Cannon (1927) and their followers, (b) the empirical psychophysiological studies beginning with Ax (1953) and continuing for over a decade (e.g., Averill, 1969; Funkenstein, King, & Drollette, 1954; Schachter, 1957; Sternbach, 1962), and (c) the recent revival of interest in this issue (e.g., Ekman, Levenson, & Friesen, 1983; Roberts & Weerts, 1982; Schwartz, Weinberger, & Singer, 1981). Although considerable evidence for ANS specificity was reported in the second wave of studies, their long-term impact may have been blunted by a number of factors (see Levenson, 1988 for a detailed discussion) including: (a) methodological problems (e.g., failure to verify subjects' emotional state by self-report or observation of behavior, obtaining physiological measurements long before or long after the emotions were likely to have been felt by the subjects), (b) theoretical shortcomings (e.g., lack of consideration of how long an emotion lasts and which emotions might be primary), (c) nonincremental research (e.g., idiosyncratic meth-

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ods, lack of replication), and (d) the ascendance of models of emotion that emphasized cognition (e.g., Mandler, 1975; Schachter & Singer, 1962) and cultural relativism (e.g., Birdwhistell, 1970). The third wave of studies was stimulated by the new support for biological/evolutionary models of emotion provided by evidence of cross-cultural universality in emotional facial expression (e.g., Ekman, 1989; Ekman, Sorenson, & Friesen, 1969; Izard, 1971) as well as studies of emotion in human infants, animals, and blind adults (reviewed by Ekman & Oster, 1979; Fridlund, Ekman, & Oster, 1987).

The hypothesis that voluntary production of emotional facial configurations would produce emotion-specific patterns of autonomic activity grew out of experiences Ekman and Friesen had while developing their technique for measuring facial movement, the Facial Action Coding System (FACS; Ekman & Friesen, 1976, 1978). While contracting various facial muscles to learn how they were related to changes in facial appearance, both researchers found themselves experiencing strong physical sensations when they contracted muscles that produced facial configurations that resembled the universal facial expressions for certain emotions.

The first report of our work (Ekman et al., 1983) presented findings from a study using two experimental tasks that represented the extremes on a physiological-cognitive dimension. In the physiological task (directed facial action task), subjects followed muscle-by-muscle instructions to contract voluntarily sets of facial muscles, which together would produce a facial configuration that resembled an expression that universally signals one of six emotions: anger, fear, disgust, sadness, happiness, and surprise. In the cognitive task (relived emotions task), subjects were asked to relive a past emotional experience for each of these emotions.

Results from this study indicated that both the directed facial action task and the relived emotions task produced autonomic changes that enabled distinctions to be made among emotions. There were differences between negative and positive emotions that were common to both tasks: (a) anger and fear produced larger heart rate increases than did happiness, and (b) anger produced a larger finger temperature increase than did happiness. There were also differences among negative emotions only in the directed facial action task: (a) the anger, fear, and sadness configurations produced larger heart rate increases than did the disgust configuration (which actually produced a heart rate decrease); and (b) the anger configuration produced a larger temperature increase than did the fear configuration (which actually produced a temperature decrease). A difference among negative emotions only in the relived emotions task was that sadness produced a larger skin conductance increase than did anger, fear, or disgust.

Beyond this evidence for autonomic specificity in emotion, perhaps the most intriguing finding was that voluntarily contracting facial muscles into emotional configurations produced patterned autonomic activation that bore some similarity to that obtained using the more conventional relived emotions task.

Fundamental Questions

Questions raised by these initial findings caused us to launch a series of additional studies that focused on voluntary facial action and emotion-specific ANS activity. In this paper we will report the results of new analyses from our previously published experiment and the results from three new experiments, which address 11 fundamental questions in three categories: (a) emotional report and autonomic specificity, (b) generalizability across situations and populations, and (c) alternative explanations.

Emotional report and autonomic specificity. The first set of questions concerns the extent and nature of subjective emotional experience produced by the directed facial action task and whether this task reliably produces emotion-specific autonomic differentiation: (1) Does voluntary production of emotional facial configurations result in subjective report of the associated emotion? (2) Are there reliable autonomic differences among the negative emotions of anger, disgust, fear, and sadness, the positive emotion of happiness, and surprise? (3) Are autonomic differences among emotions that are found in group data also found in the data from individual subjects? (4) Are autonomic differences among emotions more pronounced and self-reports of the associated emotion more prevalent when subjects produce facial configurations that most closely resemble emotional expressions? (5) Are the distinctions among negative emotions more pronounced when subjects report feeling the emotion associated with the facial configuration?

Generalizability across situations and populations. This second set of questions concerns the extent to which these findings are limited to certain experimental situations or to certain populations: (6) Are these findings limited to either male or female subjects? (7) Are these findings limited to specialized populations whose work focuses on the face (actors or scientists who study the face)? (8) Are these findings limited to situations in which subjects can see an emotional facial configuration (either in a mirror or on the face of an experimenter)?

Alternative explanations. The third set of questions considers a number of alternative nonemotional explanations for these findings. An affirmative answer to any of these questions would cast doubt on our hypothesis (Ekman et al., 1983) of a direct, central connection between voluntary emotional facial configurations and emotion-specific ANS activity: (9) Are differences in the difficulty of making the different facial configurations responsible for these findings? (10) Are differences in the amount of concomitant muscle activity associated with making the different configurations responsible for these findings? (11) Could these findings result from subjects identifying the target emotion from the instructions to contract facial muscles?

Method

EXPERIMENT 1[1]

Subjects

Sixteen subjects were recruited from the San Francisco area. Twelve (6 males, 6 females) were actors recruited from the American Conservatory Theater; the remaining 4 (3 males, 1 female) were researchers who study emotional facial expressions. These specialized subject samples were used: (a) to minimize the likelihood that embarrassment would contaminate the target emotions, (b) to maximize the likelihood that subjects would be successful in following the instructions to contract certain facial muscles in the directed facial action task, and (c) to maximize the likelihood that subjects would be able to relive past experiences in which only a single target emotion was felt in the relived emotions task. Subjects were paid $10 for participating in the experiment.

Apparatus

Physiological. A Biosystems unit which combined a microcomputer with polygraph circuitry was used to collect the physiological data and store the information on disk for subsequent calculation of second-by-second averages for each measure. This unit was augmented with oscilloscopes to allow for monitoring of signal quality. Four measures were obtained: (a) Heart rate: Beckman miniature electrodes with Redux paste were placed in a bipolar configuration on opposite sides of the subject's chest. (b) Skin conductance: Beckman regular electrodes with Beckman paste were attached to the palmar surface of the middle phalanx of the first and third fingers of the nondominant hand. The Biosystems unit measured skin resistance, which was mathematically converted to skin conductance. (c) Finger temperature: thermistors were taped to the palmar surface of the distal phalanx of the second finger of both hands. (d) Forearm flexor muscle tension: Beckman miniature electrodes with Redux paste were attached using the standard placement for recording EMG from this muscle. The Biosystems unit provided a simple integration of the EMG signal.

Video. A mirror with a small hole cut in its center was mounted on a tripod and placed in front of the subject. A video camera placed behind the mirror recorded the subject's facial activity through the hole. Subjects were informed about the camera and video recording. A locally constructed video frame counter superimposed the number of elapsed frames on the video cassette recording. Synchronization between the physiological and facial data was achieved at the start of each trial by having the Biosystems unit start the frame counter at the same time it began timing the physiological data for that trial. In this manner, once facial activity of interest (i.e., the standard control face or one of the emotional configurations) was located on the video recording, the elapsed frames that bracketed that activity could be readily converted to elapsed seconds and matched with the concomitant physiological activity.

Procedure

After subjects arrived at the laboratory, the transducers were attached for recording the physiological data. Subjects were told that the experiment would consist of two tasks; in the first task they would be asked to move certain facial muscles and in the second task they would be asked to relive memories from their past. The experiment consisted of 12 trials; the first 6 were the directed facial action task, and the second 6 were the relived emotions task. Because this report is exclusively concerned with the directed facial action task, we will describe only this task in detail.

The mirror was adjusted so that subjects could see their own faces. A coach (P.E.) was seated to the left of the mirror so that he could see the subject's face. The coach gave the subject the instructions for making the "standard control face," a facial configuration unrelated to emotion (cheeks puffed out gently, eyes closed) that would be made at the start of each trial. A trial began with a 30-s rest, then the coach asked the subject to make the standard face and hold it for 10 s. Following a brief rest, the coach began giving the subject the muscle-by-muscle instructions for one of the six emotional facial configurations without mentioning the associated emotion. For example, to construct the facial configuration for anger, the subject would be asked to:

> (a) Pull your eyebrows down and together.
> (b) Raise your upper eyelid.
> (c) Push your lower lip up and press your lips together.

These three instructions, if successfully followed, would contract the following muscles: (a) *depressor glabellae, depressor supercilii,* and *corrugator* in the eyebrow and forehead; (b) *levator palpebrae superioris* in the eyelids; and (c) *mentalis* and *orbicularis oris* in

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[1] Some results from Experiment 1 were reported previously (Ekman, Levenson, & Friesen, 1983); however, the format of that report did not allow for a full presentation of the results or methods.

the mouth. The coach provided feedback and suggestions as needed to help the subject comply with the instructions (e.g., "that's right," "don't raise your eyebrows, lower them," "try to raise your eyelid higher"). The final facial configuration was held for 10 s. The subject was then asked if any feelings, memories, or sensations had occurred while holding the facial configuration. Following a 2-min rest period, the next trial began.

This procedure was repeated for the six emotional configurations (anger, disgust, fear, happiness, sadness, and surprise) in one of three counterbalanced orders. Each configuration represented a universal emotional facial expression, based on evidence from cross-cultural studies of both the recognition and expression of emotion (Ekman et al., 1969; Izard, 1971; Ekman, 1989). Subjects were provided with only one opportunity to make each configuration[2].

Although this task is somewhat novel, it does resemble a posing task (e.g., asking someone to "look" sad). However, in the directed facial action task no emotion was mentioned by name, and subjects were not asked to feel or think anything; subjects were asked only to contract facial muscles. Quite apart from our interest in the phenomenon of such voluntary facial action generating emotion-specific ANS activity, the directed facial action task has several methodological advantages over other techniques for sampling emotions: (a) examination of video recordings can verify that all of the requested muscle contractions did occur without any extraneous contractions, and (b) the moment when the facial configuration was fully formed and the moment when the configuration left the face can be located and the physiological responses that occurred during this time can be extracted for analysis.

EXPERIMENT 2

Subjects

In contrast to the professional actors from San Francisco used in Experiment 1, Experiment 2 used Indiana University college students as subjects. One hundred and three undergraduates were recruited from the introductory psychology classes. Their participation fulfilled part of a course requirement. These subjects were screened individually to determine their ability to control voluntarily their facial muscles using a procedure that required moving certain facial muscles singly and in combination (but not making full emotional configurations). Sixteen subjects (9 males, 7 females) who demonstrated good voluntary control participated in Experiment 2 at a later date and were paid $15.

Apparatus

Physiological. A system consisting of a Grass Model 7 polygraph and a PDP 11/10 minicomputer was used for acquisition and on-line analysis of physiological data. Second-by-second averages were obtained for: (a) Heart rate: same as in Experiment 1, (b) Skin conductance: a constant voltage device passed a small voltage between Beckman regular electrodes (same sites as Experiment 1) using an electrolyte of sodium chloride in Unibase, (c) Finger temperature: a thermistor was taped to the palmar surface of the distal phalanx of the second finger of the dominant hand, and (d) General somatic activity: an electromechanical transducer attached to a platform under the subject's chair generated an electrical signal proportional to the amount of movement in any direction. Four additional physiological measures were obtained but will not be used for this report because they were not obtained in Experiment 1: (a) pulse transmission time to the finger, (b) finger pulse amplitude, (c) pulse transmission time to the ear, and (d) respiration rate.

Video. Similar apparatus to that of Experiment 1 was used except that a FOR.A video time code generator, which superimposed the elapsed time in hundredths of a second on the video recording, was used instead of the frame counter. The video camera was mounted on the wall in front of the subject behind a wooden partition with a small hole in its center. Subjects were informed about the camera and video recording.

Procedure

In this experiment, subjects participated in only the directed facial action task. Three changes were made from the procedures used in Experiment 1: (a) no mirror was used; (b) the coach (P.E.) was not in the same room as the subject, but instead viewed the subject's face on a video monitor and made comments over an intercom system; and (c) following each trial subjects were asked whether they experienced any emotions (the word "feelings" had been used in Experiment 1), memories, or sensations. For any reported emotion, the subject was asked to rate its intensity on a 0–8 scale (0 = no feeling of the emotion; 8 = the most intense feeling of the emotion ever experienced).

EXPERIMENT 3

Subjects

Subjects were again nonactors, but this time were recruited from the San Francisco area using advertisements in local newspapers. One hundred and nineteen respondents were screened for ability to control voluntarily their facial muscles as in Experiment 2, and were paid $8. Thirty subjects (9 males, 21 females) who demonstrated good voluntary control participated in Experiment 3 at a later date and were paid an additional $17.

Apparatus

Physiological. A system consisting of an LSI 11/23 microcomputer and two Lafayette Instruments 6-channel polygraphs was used to obtain the same physiological measures obtained in Experiment 2.

Video. The same equipment was used as in Experiment 2. The camera, however, was located in another

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[2] In Experiments 1, 2, and 3 there were a total of three instances in which a second attempt was allowed due to procedural problems. In these instances, an additional trial was added at the end of the task.

room behind a glass partition. Subjects were again informed of the camera and the video recording.

Procedure

Subjects participated in the directed facial action task as in Experiment 2 with two changes: (a) as in Experiment 1, a mirror was provided to help subjects make the facial configurations; however, as in Experiment 2, the coach (P.E. or W.F.) remained in a separate room and viewed the subject's face on a video monitor; and (b) after each trial the subject was asked to rate the intensity of any reported feelings on a 0–8 scale and the difficulty of making the configuration on a 1–5 scale (1 = extremely easy, 5 = extremely difficult).

EXPERIMENT 4

Experiment 4 was performed to determine whether subjects could identify the target emotion only by reading the instructions used to construct each facial configuration in the directed facial action task.

Subjects

Thirty-nine undergraduates (6 males, 33 females) at the University of San Francisco participated in this experiment in fulfillment of a course requirement.

Procedure

Subjects were given a questionnaire with the following instructions:

> "We are interested in learning what emotions you think someone would feel when he or she shows a particular facial expression. On the following pages a number of facial expressions are described. After each expression is described, you are to indicate how you think someone who showed that expression would feel. It is very important that you don't try to make the expression on your own face. Just make your judgments from reading the description."

The expressions were described with the same language used in the directed facial action task. For each expression, subjects used 0–8 scales to rate the amount of anger, disgust, fear, happiness, sadness, and surprise they thought someone making that expression would feel.

Results[3]

Data Reduction: Experiments 1, 2, and 3

Physiological. The videotape recording for each subject was examined to locate the standard control face and the target emotional face on each trial. The physiological data for those seconds during which each face was being held (usually 10 s) were then extracted and averaged, and a change score (target face average minus standard control face average) was calculated for the four physiological measures (heart rate, finger temperature, skin conductance, and muscle activity).

Facial. The Facial Action Coding System (FACS; Ekman & Friesen, 1978) was used to determine which facial muscles were actually contracted on each trial. FACS is an anatomically based system which enables decomposing any facial expression into its visually distinguishable muscular actions through repeated slow-motion viewing of the videotape recording. Working with the numerical FACS codes and silent video tape records, a rater (who was blind to both the experimental design and the associated target emotion) assigned a performance score (on a 0–4 scale) to each facial configuration indicating the extent to which: (a) the configuration included all of the muscle contractions specified in the instructions and no others, and (b) the contractions were held steadily throughout the 10-s holding period[4]. Thirty-six faces sampled from the three experiments and the six target affects were scored for reliability by a second coder (who was blind to the target emotion). The inter-coder correlation was 0.89.

Self-report. The open-ended self-reports obtained after each trial in Experiments 1, 2, and 3 were transcribed from the video recordings. An assistant (who was blind to both the experimental design and the associated target emotion) assigned codes to each statement indicating whether the subject had experienced an emotion and/or recalled an emotional memory. If a statement fell within one of these broad categories, it was further classified in terms of the specific emotion involved (22 specific emotion subcodes were used). A sample of 330 self-reports was randomly selected and rated by a second coder (who was blind to the target emotion). Inter-coder agreement as to the specific emotion was 81%.

Using these codes, we later determined on each trial whether the emotion associated with the facial configuration was reported most strongly. If a subject reported only the target emotion, it was considered to be the strongest reported emotion. If a subject reported more than one emotion, the target emotion had to be rated as being experienced more intensely than any other emotion. If the target emotion and another emotion tied for the highest rating, this somewhat rare event (1.9% of the trials) was counted as a trial in which the target emotion was *not* reported most strongly. Hereafter, whenever we

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[3] The .05 level was adopted for all tests of significance unless otherwise stated.

[4] Because this method for scoring facial quality differed slightly from the method used in our earlier report (Ekman, Levenson, & Friesen, 1983), the group data results involving high quality expressions will differ somewhat from those presented in the earlier paper.

refer to the target emotion being reported, it means that it was either the only emotion reported or, if more than one emotion was reported, the target was reported as the strongest.

Data Analysis

Group data. The analyses for this report focused on the elements that were common to Experiments 1, 2, and 3: (a) the directed facial action task (data from the relived emotion task were not included); (b) the six facial configurations representing anger, disgust, fear, happiness, sadness, and surprise; and (c) the four physiological measures of heart rate, skin conductance, finger temperature, and muscle activity. Because autonomic distinctions among negative emotions are of greater theoretical interest to us than differences between negative and positive emotions, differences among the facial configurations for the negative emotions of anger, disgust, fear, and sadness received greater emphasis in the analyses. Because the three experiments all involved the same experimental task and dependent measures, their data were combined in a single analysis treating Experiment as a between-subjects factor, a recommended approach for research involving replications (Keppel, 1973; Winer, 1971). Whenever possible, the analytic strategy included an overall MANOVA to protect against Type I errors, and univariate ANOVAs within significant MANOVA effects. Tests of sphericity were performed for ANOVA effects involving within-subject factors and, when deviations from sphericity occurred, degrees of freedom were adjusted using the Huynh-Feldt epsilon. Planned pairwise comparisons among the six emotional configurations were accomplished using t-tests utilizing the modified Bonferroni procedure (Kirk, 1968) to adjust the rejection level.

Individual subject data. Once the basic physiological distinctions among emotional facial configurations had been determined, a series of idiographic analyses were carried out to determine the extent to which these distinctions were also found in the data from individual subjects. These analyses are described in more detail in the results below concerning question 3.

Baseline Differences Between Emotions

Because change scores would be most convenient to use in analyses of group data and in the idiographic analyses of data from individual subjects, an overall 3×6 (Experiment × Emotional Configuration) MANOVA with emotional configuration as a within-subjects factor was carried out using the baseline (i.e., standard control face) data for the four physiological measures. This MANOVA revealed that there were no significant differences in baseline levels for the two effects critical for the computation of change scores: emotional configuration, $F(20/32)=1.02$, and Experiment × Emotional Configuration, $F(40/66)=1.29$.

The remainder of the presentation of results will address the 11 questions posed in the introduction to this paper.

Emotional Report and Autonomic Specificity

1. Voluntary production of emotional facial configurations produced self-report of the associated emotion on a significant proportion of trials. In both Experiments 1 and 3, subjects could see their faces in a mirror and, after each trial, an open-ended self-report was obtained asking them if they had any "feelings." Despite the differences in subject populations (actors and facial researchers in Experiment 1, nonactors in Experiment 3), the self-report data from the two experiments were quite similar. Subjects reported having some emotional experience on 54 of 96 trials (56.3%) in Experiment 1 and on 91 of 172 trials (52.9%) in Experiment 3. More importantly, subjects reported experiencing the emotion associated with the target facial configuration most strongly on 25 of 96 trials (26.0%) in Experiment 1 and on 48 of 178 trials (27.0)% in Experiment 3. With a chance level of reporting the target emotion set conservatively at 16.7% (i.e., one of six emotions), this report of the target emotion in both experiments was significantly greater than chance: Experiment 1, $z=2.46$, $p=.007$; Experiment 3, $z=3.69$, $p<.001$.

In Experiment 2, subjects were not actors and there was no mirror. In the open-ended inquiry following each trial they were asked if they had any "emotions" (rather than being asked if they had any "feelings" as in Experiments 1 and 3). Subjects reported having some kind of emotional experience on 75 of 96 trials (78.1%) and reported experiencing the target emotion most strongly on 51 of 96 trials (53.1%), which was significantly greater than chance (16.7%), $z=9.59$, $p<.001$. Analysis of the intensity of the target emotion (when it was reported) revealed a mean rating of 4.8 on the 0–8 scale (with 8 being the most intense experience of the emotion the subject had ever experienced). Broken down by target emotion, the mean ratings for emotional experience were: anger=5.8, disgust=4.5, fear=3.9, happiness=4.5, sadness=5.2, and surprise=4.9.

In Figure 1, the percentage of trials in which the target emotion was reported is presented separately for each of the six emotions for Experiments 1, 2, and 3. Across the six emotional configurations, in each of the three experiments, no nontarget emotion was reported more often than would be expected by chance (16.7%). The percentage of trials in which the target emotion was reported was significantly greater in Experiment 2 than in Experiment 1, $z=3.84$, $p<.001$, and Experiment 3, $z=4.30$, $p<.001$.

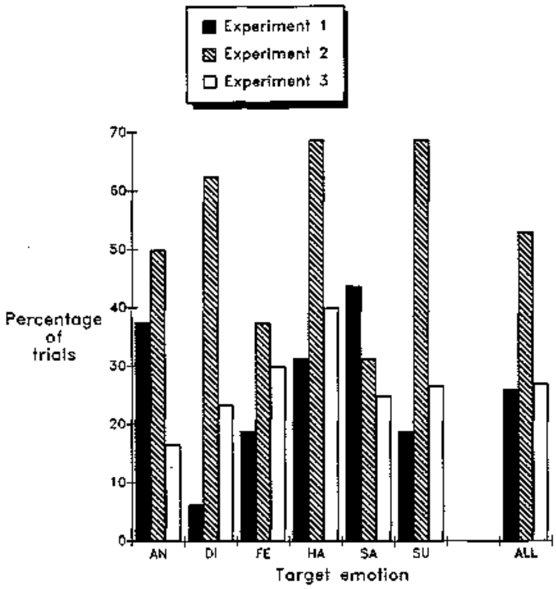

Figure 1. Percentage of trials in which subjects reported the target emotion in the directed facial action task. Experiments 1 and 3 used open-ended reports of "feelings" and a mirror was present. Experiment 2 used open-ended reports of "emotions" and there was no mirror present. AN=Anger trials, DI=Disgust trials, FE=Fear trials, HA=Happiness trials, SA=Sadness trials, SU=Surprise trials, ALL=All trials.

2. There were reliable autonomic differences among the negative emotions of anger, disgust, fear, and sadness, the positive emotion of happiness, and surprise. An overall 3×2×6 (Experiment × Sex × Emotional Configuration) MANOVA with emotional configuration as a within-subjects factor was carried out on changes from baseline (i.e., target emotional face minus standard control face) for all four physiological measures. A significant main effect for emotional configuration, $F(20/29)=4.56$, $p<.001$, indicated that there were autonomic differences among the six emotional configurations. Within the significant emotional configuration main effect, univariate ANOVAs revealed that the physiological variables that differentiated the six emotional facial configurations were heart rate, $F(5/240)=11.13$, $p<.001$, and skin conductance, $F(5/240)=3.16$, adjusted (Huynh-Feldt) $p=.02$. The effect for skin temperature approached significance, $F(5/240)=1.97$, adjusted $p=.09$, whereas the effect for muscle activity was not significant, $F(5/240)=0.42$. Figure 2 portrays the means for these four measures for the six emotional facial configurations.

For heart rate, skin conductance, and finger temperature, planned pairwise comparisons among the six emotional configuration means were made. For

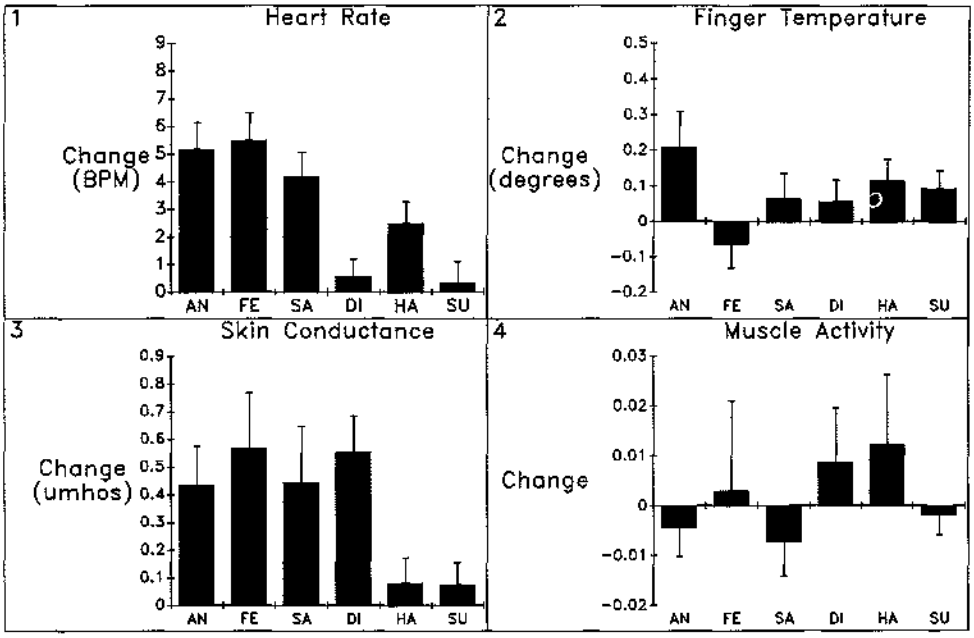

Figure 2. Heart rate (panel 1), finger temperature (panel 2), skin conductance (panel 3), and muscle activity (panel 4) changes and standard errors during six emotional configurations. AN=Anger, FE=Fear, SA=Sadness, DI=Disgust, HA=Happiness, SU=Surprise.

this number of comparisons (i.e., 15), the modified Bonferroni procedure established the rejection level at $p<.017$.

For heart rate, the emotional facial configurations fell into three groups. Significantly larger cardiac accelerations were found for the three negative emotions of anger, fear, and sadness than for the fourth negative emotion of disgust and the emotion of surprise. Intermediate between these two groups and not completely differentiated from them was happiness, which had significantly smaller heart rate acceleration than did anger and fear, and significantly larger heart rate acceleration than did surprise (happiness did not differ significantly from sadness or disgust).

For skin conductance, the emotional facial configurations fell into two groups. The two negative emotions of fear and disgust produced significantly larger skin conductance increases than did the positive emotion of happiness and the emotion of surprise. The differences in skin conductance increases between the other two negative emotions, anger and sadness, and happiness and surprise approached significance (anger vs. happiness, $t(240)=1.98$, $p=.023$; anger vs. surprise, $t(240)=2.02$, $p=.021$; sadness vs. happiness, $t(240)=2.04$, $p=.020$; sadness vs. surprise, $t(240)=2.08$, $p=.018$).

For finger temperature, there was one significant difference. Finger temperature increased more for the anger configuration than for the fear configuration, $t(240)=2.22$, $p=.013$.

In the foregoing analyses, data from the three experiments were combined. This enabled us to do a reduced number of pairwise comparisons among the emotions with greater statistical power than if the three experiments were analyzed separately. Further, it enabled us to use the interaction of Experiment × Emotional Configuration as an indicator of significant differences in the patterns of emotion-specific physiological changes among the three experiments. This combined analysis revealed a nonsignificant Experiment × Emotional Configuration interaction, $F(40/60)=0.97$, in the overall MANOVA (this interaction was also nonsignificant in the univariate ANOVAs for heart rate, skin conductance, finger temperature, and muscle activity).

3. Autonomic differences among emotions found in group data were also found in data from individual subjects. *Data reduction.* To address this question, we devised a method for determining the extent to which an individual subject's data evidenced the distinctions among emotional configurations found in the group data. First, differences between configurations for the negative emotions and for the positive emotion of happiness presented under question 2 were translated into four distinctions between pairs of emotional configurations: (a) heart rate acceleration was larger for anger than for happiness, (b) heart rate acceleration was larger for fear than for happiness, (c) skin conductance increase was greater for fear than for happiness, and (d) skin conductance increase was greater for disgust than for happiness. Then differences among negative emotional configurations presented under question 2 were translated into four distinctions between pairs of negative emotions: (a) heart rate acceleration was larger for anger than for disgust, (b) heart rate acceleration was larger for fear than for disgust, (c) heart rate acceleration was larger for sadness than for disgust, and (d) finger temperature increase was larger for anger than for fear. Because we consider the emotion of surprise to be neither a negative emotion nor a positive emotion, the six distinctions involving surprise (heart rate acceleration: anger, fear, sadness, and happiness were greater than surprise; skin conductance increase: fear and disgust were greater than surprise) were not included in these idiographic analyses.

For each subject, the change score data (i.e., target emotional face minus standard control face) from trials relevant to each of the eight patterns were examined. If the subject's data for the two relevant emotional configurations matched the pattern, that was considered a "hit" (e.g., if the subject's heart rate acceleration was larger on the anger trial than on the disgust trial); if the subject's means were in the opposite direction, that was considered a "miss." For any given distinction between pairs of emotions we would expect a 50% "hit rate" by chance alone (to be conservative, we counted ties as misses).

Distinctions between negative and positive emotional configurations. Aggregating data from all subjects in the three studies across the four distinctions between the negative and positive emotions, there were 243 opportunities to determine whether a pattern was shown. Of these 156 (64.2%) matched the pattern, which was significantly greater than chance (50%), $z=4.43$, $p<.001$.

Examination of Table 1, which presents the hit rates for each distinction individually, reveals that the hit rate for each was greater than 60%. The differences among hit rates for the four distinctions were not significant, Cochran's $Q(3)=0.77$.

Distinctions among negative emotional configurations. Aggregating data from all subjects in the three studies across the four distinctions among negative emotions, there were 236 opportunities to determine whether a pattern was shown. Of these, 161 (68.2%) matched the pattern, which was significantly greater than chance (50%), $z=5.60$, $p<.001$.

Table 1

Hit rates for individual subjects showing distinctions between emotions found in group data

Distinctions	Number of Matches	Number of Cases	Hit Rate
Between negative and positive emotions:			
Heart rate acceleration larger for anger than happiness	38	60	63.3%
Heart rate acceleration larger for fear than happiness	42	61	68.9%
Skin conductance level increase greater for fear than happiness	39	61	63.9%
Skin conductance level increase greater for disgust than happiness	37	61	60.7%
All	156	243	64.2%
Among negative emotions:			
Heart rate acceleration larger for anger than disgust	43	59	72.9%
Heart rate acceleration larger for fear than disgust	44	60	73.3%
Heart rate accleration larger for sadness than disgust	38	58	65.5%
Finger temperature increase larger for anger than fear	36	59	61.0%
All	161	236	68.2%

Examination of Table 1, which presents the hit rates for each distinction individually, reveals that the hit rate for each was greater than 60%. The differences between hit rates for the four distinctions among negative emotional configurations were not significant, Cochran's $Q(3)=3.27$. Similarly, when the four distinctions between negative and positive emotional configurations were added to the four distinctions among negative emotional configurations, differences among the eight hits rates were not significant, Cochran's $Q(7)=5.76$.

Proportion of subjects showing distinctions. In the foregoing analyses, hits and misses were aggregated across subjects. To determine the extent to which individual subjects showed all or most of the distinctions, a second set of analyses were performed.

For the distinctions between negative and positive emotional configurations, 15 of 62 subjects (24.2%) showed all four patterns, which was significantly greater than chance (6.25%), $z=5.84$, $p<.001$, and 34 of 62 subjects (54.8%) showed three or four of the patterns, which was also significantly greater than chance (12.5%), $z=10.08$, $p<.001$.

For the distinctions among negative emotional configurations, 20 of 62 subjects (32.3%) showed all four patterns, which was significantly greater than chance (6.25%), $z=8.46$, $p<.001$, and 39 of 62 (62.9%) showed three or four of the patterns, which was also significantly greater than chance (12.5%), $z=12.00$, $p<.001$.

4. When subjects produced facial configurations that most closely resembled the associated emotional expression, autonomic differences among emotions were most pronounced and self-reports of the associated emotion were most prevalent. *Group data.* A series of $3\times2\times6$ (Experiment $\times$ Sex $\times$ Emotional Configuration) ANOVAs were carried out on the four physiological dependent measures using data from only those trials with high quality voluntary facial configurations (i.e., those most closely resembling the morphology of the associated emotional expression and, thus, receiving scores of 3 or higher on the 0–4 scale described above). These analyses revealed significant main effects for emotional configuration in heart rate, $F(5/144)=27.42$, $p<.001$, skin conductance, $F(5/144)=18.21$, $p<.001$, and finger temperature, $F(5/144)=3.44$, $p=.006$. Figure 3 portrays the means for these four measures for the six emotional facial configurations.

These results using high quality trials should be compared to those in which data from all trials were analyzed without regard to configuration quality (reported in question 2). In both sets of analyses the main effect for emotional configuration was significant for heart rate and for skin conductance, but was nonsignificant for muscle activity. The effect for finger temperature, which had not reached significance in the previous analysis, was now significant when only the high quality facial configurations were considered.

For heart rate, skin conductance, and finger temperature, planned pairwise comparisons were carried out among the six emotional configuration means using a rejection level set at $p<.017$ by the modified Bonferroni procedure. Compared to the previous analyses of all trials reported under question 2, there was further evidence that autonomic distinctions among emotional configurations were sharpened when only trials with high quality facial configurations were examined.

For heart rate, the differences between the two analyses were minor. The emotional configurations again fell into two clear groups with the three negative emotions of anger, fear, and sadness having significantly larger cardiac accelerations than did the fourth negative emotion of disgust and the emotion of surprise. The intermediate emotional configuration of happiness remained incompletely discriminated, still having a significantly smaller heart

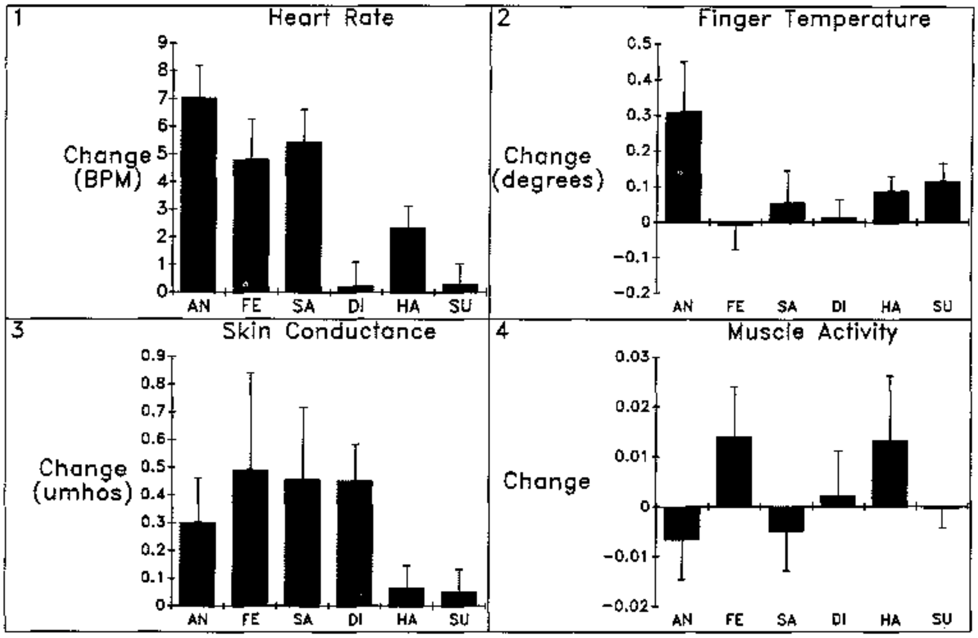

Figure 3. Heart rate (panel 1), finger temperature (panel 2), skin conductance (panel 3), and muscle activity (panel 4) changes and standard errors during six emotional configurations that most closely resembled universal emotional expressions. AN=Anger, FE=Fear, SA=Sadness, DI=Disgust, HA=Happiness, SU=Surprise.

rate acceleration than did anger and fear, but now, in addition, having a significantly smaller heart rate acceleration than sadness. The larger heart rate acceleration for happiness than surprise found in the earlier analysis was no longer significant, $t(144)=1.99$, $p=.023$.

For skin conductance, the emotional configurations again fell into two groups. However, sadness now joined fear and disgust as having significantly larger skin conductance increases than happiness and surprise. The larger skin conductance increase in anger than in happiness and surprise, which had approached significance in the earlier analysis, was now clearly not significant.

For finger temperature, the differences between the anger configuration and the other emotional configurations were enlarged. Whereas in the previous analysis, the finger temperature increase in anger was significantly greater only than fear, in the analysis of high quality configurations anger's finger temperature increase was significantly larger than disgust, happiness, sadness, surprise, *and* fear.

A visual indication of the extent of consistency across experiments for the autonomic differences among the negative emotions is shown for heart rate in Figure 4 and for finger temperature in Figure 5.

Individual subjects' data: Negative emotions. The impact of expression quality on the four autonomic distinctions among negative emotions (see Table 1) was also examined. Hit rates obtained when *both* facial configurations involved in a distinction met the highest criterion for resembling the associated emotional expression (quality ratings of 3 or higher on the 0–4 scale) were compared to those obtained when both facial configurations did not meet this criterion. The hit rate for high quality expressions was 73.0% (54 hits out of 74 possible comparisons), which was significantly greater than chance (50%), $z=3.95$, $p<.001$. The hit rate for low quality expressions was 60.0% (36 hits out of 60 possible comparisons), which approached being significantly different from chance (50%), $z=1.55$, $p=.06$. The 13% difference between these two proportions also approached significance, $z=1.59$, $p=.055$.

Self-report of emotion. Experiment 2 provides the best test of the relation between configuration quality and report of the associated emotion. In that experiment subjects could not see the facial configuration either in a mirror or on the face of the coach, and they were asked explicitly whether they experienced any emotions in the open-ended inquiry after each trial. For the 65 trials in Experiment 2 on which facial configurations most closely resembled the emotional expressions, the associated emotion was reported 43 times (66.2%), which was significantly greater than chance (16.7%), $z=10.71$, $p<.001$. For the 30 trials on which facial configurations did not closely resemble the emo-

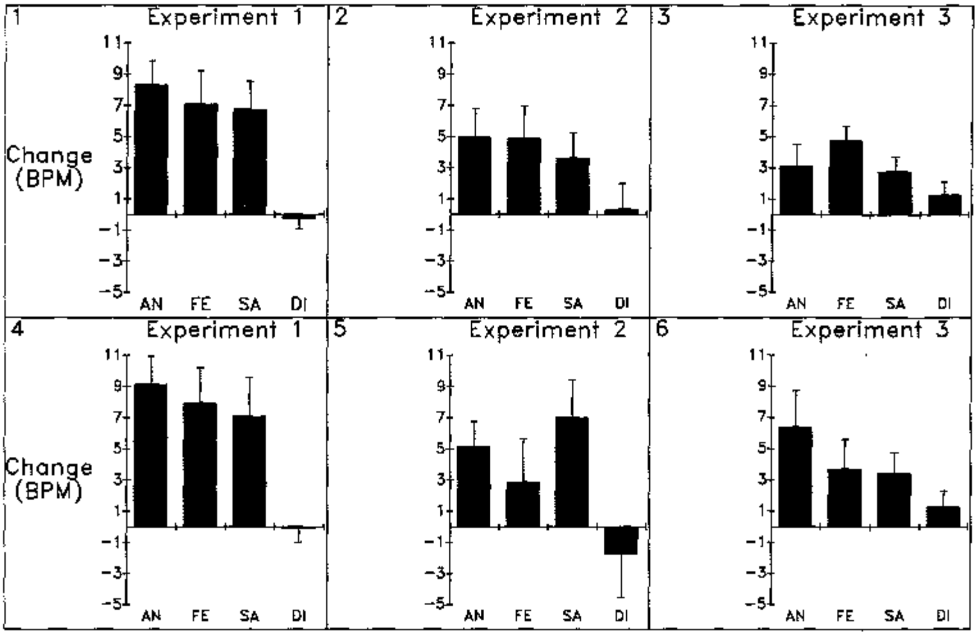

Figure 4. Heart rate changes and standard errors during four negative emotional configurations in Experiments 1, 2, and 3. Panels 1, 2, and 3 portray data from all trials; Panels 4, 5, and 6 portray data from trials in which configurations most closely resembled universal emotional expressions. AN=Anger, FE=Fear, SA=Sadness, DI=Disgust.

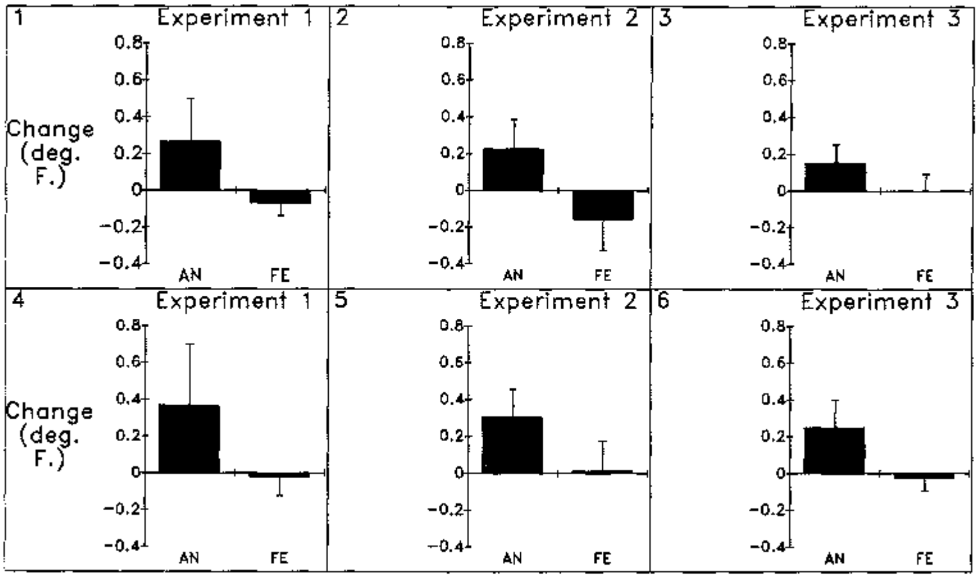

Figure 5. Finger temperature changes and standard errors during two negative emotional configurations in Experiments 1, 2, and 3. Panels 1, 2, and 3 portray data from all trials; Panels 4, 5, and 6 portray data from trials in which configurations most closely resembled universal emotional expressions. AN=Anger, FE=Fear.

tional expressions, the associated emotion was reported 8 times (26.7%), which was not significantly different from chance (16.7%). The 39.5% difference between these two proportions was significant, $z = 3.59$, $p < .001$.

5. The distinctions among negative emotional configurations were more pronounced when subjects reported actually feeling the emotion associated with the facial configuration. Only data from individual subjects could be used to address this issue, because sample sizes in some cells were too small to carry out ANOVAs on group data. Thus, hit rates for distinctions among negative emotional configurations when subjects reported experiencing the associated emotion for both configurations in the distinction were compared to hit rates obtained when subjects did not report experiencing the associated emotion for either configuration. Hit rates were 77.4% (24 hits out of 31 possible comparisons) when the target emotion was reported, which was significantly greater than chance (50%), $z=3.05$, $p=.002$. Hit rates declined to 61.1% (77 hits out of 126 possible comparisons) when the target emotion was not reported, but this was still significantly greater than chance (50%), $z=2.49$, $p=.007$. The 16.3% difference between these two proportions was significant, $z=1.70$, $p=.044$.

Generalizability Across Situations and Populations

6. The findings were not limited to either male or female subjects. *Group data.* In the overall MANOVA of the six emotions, neither the main effect for sex, $F(4/45)=0.88$, the Sex × Emotional Configuration interaction, $F(20/29)=1.54$, nor the Sex × Experiment × Emotional Configuration interaction, $F(40/60)=0.97$, were significant.

Individual subjects' data: Negative emotions. Hit rates for the distinctions among negative emotional configurations were 71.2% for male subjects (74 hits out of 104 possible comparisons) and 65.9% for female subjects (87 hits out 132 possible comparisons). The 5.3% difference between these two proportions was not significant, $z=0.86$.

Configuration quality and report of the associated emotions. The mean configuration quality rating for male subjects (2.80 on a 0–4 scale) did not differ from the mean for female subjects (2.88), $t(361)=-0.61$. Male subjects reported experiencing the emotion associated with the facial configuration on 59 of 161 trials (36.6%), which was significantly greater than chance (16.7%), $z=6.80$, $p<.001$. Female subjects reported experiencing the emotion on 65 of 209 trials (31.1%), which was also significantly better than chance, $z=5.60$, $p<.001$. The 5.5% difference between these two proportions was not significant, $z=1.12$.

7 and 8. These findings were not limited to specialized populations whose work focuses on the face (actors or scientists who study the face), and were not limited to situations in which an emotional facial configuration could be seen (either in a mirror or on the face of an experimenter). The three experiments provide tests of the necessity of employing specialized subjects, using the mirror, and seeing the coach's face. In Experiment 1, subjects were actors and scientists who study the face, but in the other two experiments they were either college students (Experiment 2) or young adults (Experiment 3). In Experiment 2, subjects could neither see their own faces in a mirror nor see the coach's face. In the other two experiments subjects could see their faces in a mirror, and either could not see the coach's face (Experiment 3) or could see the coach's face (Experiment 1).

If there were significant differences in the pattern of ANS differences among emotions associated with either the subject population, the mirror, or the coach, then significant Experiment × Emotional Configuration interactions would be expected to appear in either the overall MANOVAs for the six emotional configurations, or in the univariate ANOVAs for the four physiological dependent variables. However, in none of these instances was the Experiment × Emotional Configuration interaction significant: overall MANOVA, $F(40/60)=0.97$; heart rate, $F(10/240)=1.26$; finger temperature, $F(10/240)=1.43$; skin conductance, $F(10/240)=0.65$; muscle activity, $F(10/240)=0.30$.

Thus, there was no indication in these analyses that the three experiments with their varying conditions of subjects, mirror, and visible coach affected the physiological distinctions among emotions. Visual examination of Figures 4 and 5, which depict the data pertinent to the distinctions among negative emotions, also reveals the consistent pattern of ANS changes across the three experiments.

Additional information relevant to these questions was obtained by calculating two scores for each subject: (a) the proportion of the four distinctions between negative and positive emotions shown by that subject, and (b) the proportion of the four distinctions among negative emotions shown by that subject. These distinctions are listed in Table 1. The proportion scores were analyzed in a 3×2×2 (Experiment × Sex × Distinction Type (between negative and positive emotions or among negative emotions)) MANOVA with distinction type treated as a within-subjects factor.

This MANOVA revealed that the variations in procedures concerning the mirror, coach, and subject populations had an impact on the extent of autonomic differentiation of emotions. The Experiment × Distinction Type interaction was significant, $F(2/56)=4.06$, $p=.023$. Analysis of the means of this interaction revealed that the proportion of distinctions among negative emotions shown by subjects was greater in Experiment 1 than in Experiments 2 and 3 (Experiment 1, .87; Experiment 2, .58; Experiment 3, .58), $t(56)=3.48$, $p=.001$. In contrast, there were no significant differences among experiments for the proportion of hits for the distinctions between negative and positive emotions (Experiment 1, .66; Experiment 2, .67; Experiment 3, .62).

To determine whether it was the actors, the facial scientists, or both groups of subjects who accounted for the greater proportion of distinctions among negative emotions shown by subjects in Experiment 1, we examined the percentage of subjects of each type who showed at least three of the distinctions among negative emotions. This revealed that 91.7% of the actors in Experiment 1 showed at least three of the distinctions, compared to 75.0% of the scientists. The difference between these two percentages was not significant, $z=.087$. However, only the percentage for the actors was significantly larger than the comparable percentages for the nonactor subjects in Experiment 2 (56.3%), $z=2.05$, $p=.040$, and Experiment 3 (53.3%), $z=2.34$, $p=.020$.

These results concerning the distinctions among emotions based on data from individual subjects can be summarized as follows: (a) neither using a mirror, seeing the coach's face, nor the subject population had any impact on the distinctions between negative and positive emotions; (b) using a mirror had no impact on the distinctions among negative emotions; and (c) the combination of seeing the coach's face and using actors as subjects improved the distinctions among negative emotions.

Alternative Explanations

9. Differences in the difficulty of making the different facial configurations were not responsible for these findings. In Experiment 3, ratings were obtained following each trial of how difficult the subject found the task of making that facial configuration. Within each of the six target emotions, these difficulty ratings were correlated with the magnitude of physiological change in each of the four dependent variables. None of these 24 correlations were significant.

In addition, the difficulty ratings were analyzed in a within-subjects ANOVA, which revealed a significant main effect for emotional configuration, $F(5/135)=23.52$, $p<.001$. Comparisons revealed that these six emotions fell into three groups: the fear and sadness configurations were rated more difficult to make than the anger and disgust configurations $t(135)=3.98$, $p=.001$, and the anger and disgust configurations were rated more difficult to make than the happiness and surprise configurations, $t(135)=3.67$, $p<.001$. These difficulty distinctions among emotional configurations do not match any of the autonomic distinctions among emotional configurations reported for questions 2 and 3 above.

10. Differences in the amount of concomitant muscle activity associated with making the different configurations were not responsible for these findings. There was no evidence that the six facial configurations were associated with differences in the amount of concomitant nonfacial muscle activity. As reported in question 2 above, MANOVAs revealed that there were no significant main effects for emotional configurations for our measures of muscle activity (Experiment 1, forearm flexor EMG; Experiments 2 and 3, general somatic activity).

A related issue of differences in the amount of facial muscle activity associated with the different configurations will be addressed in the discussion.

11. All of the findings were unlikely to result from subjects identifying the target emotion from the instructions to contract facial muscles. Using the data from Experiment 4 in which subjects read the instructions for producing the facial configurations but did not make the target faces, the percentage of subjects who correctly identified the associated emotion was determined (anger=39.5%, disgust=47.4%, fear=2.6%, happiness=61.5%, sadness=66.7%, surprise=76.9%). For all of these configurations, with the exception of fear, the associated emotion was correctly identified at levels significantly greater than chance (16.7%), $p<.001$.

The fact that almost no one could identify fear from the instructions for making that face, and that more than half of the subjects failed to identify anger or disgust from their instructions, decreases the likelihood that subjects in the other experiments identified the emotion label on each trial solely from hearing the facial instructions. The related issue of whether mere knowledge of the label, if and when this occurs, could be responsible for producing emotion-specific autonomic activity will be addressed in the discussion.

Discussion

Emotion or Only Physiological Change

Although theorists differ in their precise definition of emotion, most would agree that phenomenological experience, a distinctive expression in the face and/or the voice, physiological activation, cognitive appraisal, and some form of coping behavior are included. Ekman (1977) argued that the presence of any one of these elements is not sufficient to establish that an emotion has occurred. Nor is the absence of any one element sufficient to establish that an emotion has not occurred. Rather, confidence that an emotion has occurred increases as does the number of elements present.

Although emotions are certainly not typically activated by voluntarily produced facial muscle contractions, a number of the elements of emotion were present in our experiments. The directed facial action task ensures the presence of emotion-relevant facial muscle activity (albeit activated by voluntary rather than involuntary neural pathways), and our physiological measures revealed the presence of differentiated autonomic nervous system activity. Although we do not believe that self-report is the *sine qua non* of emotion, our self-report data indicate that most subjects reported experiencing emotion when they voluntarily produced these facial configurations. What was absent in these experiments were the typical eliciting events, the cognitive appraisals considered by many to be typical of emotion (although there is not universal agreement about whether cognitive appraisal always precedes emotion; Lazarus, 1984; Zajonc, 1984a, 1984b), and coping behavior.

A number of findings support a conclusion that the directed facial action task generates emotion, and not just physiological change. First, subjects' emotion reports were not random. In Experiments 1, 2, and 3, subjects reported experiencing the emotion associated with the facial configuration at significantly greater than chance levels. Experiment 2 provided perhaps the fairest test, because its subjects could see neither their own faces nor the face of the coach, were asked explicitly if they felt any "emotions" in an open-ended fashion, and were Midwestern college students without any special training in acting, emotion, or facial expression. In this experiment, the target emotion was reported on 53.1% of the trials, an amount that far exceeds chance expectations.

Second, when the target emotion was reported in these experiments, its intensity was quite high (i.e., a mean rating of 4.8 on a 0–8 scale, with 8 representing the most intense experience of that emotion in the subject's life). Third, reports of the target emotion increased when the facial configuration most resembled the associated emotional expression. And finally, autonomic distinctions among emotions were also more pronounced when facial configurations were of the highest quality.

It might be argued that these reports of emotion only reflect demand characteristics, and do not indicate that the subjects actually experienced the emotions they reported. Such reasoning would presume that the subjects could determine from the muscle-by-muscle instructions which emotion was being targeted in each trial. Once knowing the target emotion, compliant subjects would report experiencing that emotion when asked. Although demand characteristics undeniably play a large role in any study of emotion using self-report data, it is unlikely that they are totally responsible for the findings reported here. For example, in Experiment 4 virtually no one (2.6%) could identify fear from the instructions for producing the fear configuration. Yet, the subjective experience of fear was reported on a substantial number of trials when subjects followed these same instructions for making the fear configuration (37.5% of the trials in Experiment 2, which is significantly greater than chance, $z=2.24$, $p=.013$).

Autonomic Specificity

Differences among emotions. Evidence from group and individual subjects' data indicated that voluntary production of the six emotional facial configurations resulted in a set of 14 autonomic distinctions among emotions (see question 2 above). These findings included: (a) four distinctions between three negative emotions (anger, disgust, fear) and a positive emotion (happiness) made on the basis of heart rate and skin conductance, (b) four distinctions among the four negative emotions made on the basis of heart rate and finger temperature, and (c) six distinctions involving the emotion of surprise.

We consider those autonomic differences found among negative emotions to be the most theoretically important. It would be easy to dismiss differences between negative emotions and positive emotions as merely indicating a state of undifferentiated high arousal associated with negative affect and a state of undifferentiated low arousal or relaxation associated with positive affect. Our findings indicate that emotions are differentiated in a greater number of ways than would be predicted by such a simple model. The fact that the distinctions among negative emotions show reliability across multiple experiments provides additional support for their robustness.

Idiographic analyses. At levels significantly greater than chance, individual subjects showed the distinctions among emotions that were found in group data. This is a very conservative test of autonomic specificity, which to our knowledge has not been applied previously to these kinds of data. That individual subjects evidenced the distinctions found in group data 68.2% of the time is encouraging. It is even more encouraging that this figure reached 73.0% when the facial configurations most closely resembled the universal emotional expressions, and reached 77.4% when subjects reported actually experiencing the associated emotion.

The possibility of additional distinctions among emotions. Using just the four physiological measures reported in this paper, a number of distinctions among emotions are possible, but it has not been possible to untangle completely the six primary emotions. For example, it has been difficult to distinguish sadness from the other negative emotions. With additional autonomic measures (e.g., we are now obtaining respiratory measures and measures of sympathetic cardiovascular functioning), other distinctions may well be made. However, one possible outcome of the search for emotional specificity may be that not all six of the emotions that we are studying are distinguished by autonomic activity, but only some of these emotions. If this were the case, it would raise the intriguing question of why and with what implications some emotions are distinguished by the two biological systems we are sampling—the face and the autonomic nervous system—whereas others are distinguished by the face, and not by the autonomic nervous system.

Individual-response specificity. We did not attempt in these experiments to assess or control for individual-response specificity, in part because any tendency of subjects to respond in a fixed manner across stimulus conditions would work against our finding evidence for emotion-specificity in group data. Our idiographic analyses would be less influenced, given that stimulus-specificity (i.e., emotion-specificity in our studies) and individual-response specificity often co-exist (e.g., Engel, 1960; Levenson, 1979a). Thus, a "stomach responder" might still have a faster heart rate in anger than in disgust, but the absolute difference could be very small. Finally, findings by others that have been interpreted as supporting individual-response specificity might have resulted in part from subjects who responded to a range of stimuli with the same emotion (and its associated autonomic profile). For example, a subject who responded to a number of different stimuli with anger (and its relatively large heart rate acceleration) would appear to be more of a "cardiac responder" than a subject who responded to these same stimuli with disgust (and its small heart rate change).

Generalizability Across Situations and Populations

Configuration quality. We determined whether our findings were limited to instances in which facial configurations most closely resembled the actual emotional expression. Although results indicated that the distinctions among emotions were sharpened when only the high quality facial configurations were considered (e.g., sadness joined disgust and fear as having greater skin conductance increases than happiness), autonomic distinctions still existed when all facial configurations were included regardless of quality. Probably the strongest evidence for the importance of facial configuration quality was found in the analysis of hit rates for distinctions among negative emotions using data from individual subjects. Here a deterioration of 13% was associated with low quality facial configurations, compared to high quality configurations. Furthermore, the hit rate for the low quality configurations did not exceed chance levels.

The magnitude of these effects of facial configuration quality may well be an underestimate. Subjects in these experiments could be expected (by training or by screening) to be more skilled at voluntary facial control than the average person. Thus, we did not obtain a good sampling of configurations of the lowest quality. To do so would require including subjects who are not as adept at voluntarily controlling their facial muscles. For now, we conclude that the extent to which voluntary configurations resemble emotional expressions clearly does matter, but precisely how much is uncertain.

Reporting the target emotions. Hit rates for autonomic distinctions among negative emotions reached their highest level (77.4%) on those trials on which subjects reported feeling the emotion associated with the facial configurations, significantly surpassing hit rates obtained on trials when the emotion was not reported (61.1%). Nonetheless, the latter were still significantly greater than chance. Thus, feeling the target emotion clearly improved the autonomic distinctions among emotions, but was not necessary for autonomic specificity to occur.

Populations. Three subject characteristics were examined: (a) gender, (b) acting training, and (c) scientific training in research on the face. We found no evidence that men and women differed significantly in the extent that they showed autonomic differences among emotions. There was also no evidence that trained actors or facial scientists differed from untrained subjects in any of the group data or in the individual subjects' data on differences between negative and positive emotions. The only evidence for population differences came from the individual subjects' data, where actors (confounded with being able to see the coach's face in Experiment 1) showed more consistent differences among negative emotions than did nonactors. We will return to this finding in the next section.

Alternative Explanations

We have proposed that the capacity of voluntary facial activity to generate emotion-specific ANS activity is due to a direct central connection between the two systems. Although clearly not establishing this direct link, these experiments have failed to support several alternative indirect explanations.

Mediation by seeing an emotional facial configuration. In our first experiment, we allowed subjects to see both their own facial configurations in a mirror and those of a coach. This introduced the possibility that *seeing* a configuration (rather than *making* one) might be responsible for generating emotion-specific autonomic activity. Subsequent experiments revealed that the mirror was clearly not necessary, because it showed no effects in group data or in data from individual subjects. Although seeing the face of the coach had no effect in most of our analyses, it did increase the differentiation among negative emotions found in the analyses of data from individual subjects. As indicated above, seeing the face of the coach was confounded with using actors and scientists as subjects in Experiment 1. Thus, we cannot apportion responsibility for this increased differentiation among negative emotions between these two factors. Without ignoring this one exception, it can be concluded that most of the evidence demonstrated that emotion-specific ANS activity was unaffected by these factors, and was still found in subsequent experiments in which the subjects could not see the coach's face and were not actors.

Mediation by configuration difficulty. We examined whether facial configurations that are more difficult to make were associated with greater "arousal" in our measures (i.e., faster heart rate, lower finger temperature, higher skin conductance, higher levels of muscle activity) than those that were easier to make. Subjects' difficulty ratings confirmed previous findings (Ekman, Roper, & Hager, 1980) about the relative difficulty of voluntarily contracting the muscles required for each of the six facial configurations. Fear and sadness were rated the most difficult configurations to make, anger and disgust were of intermediate difficulty, and happiness and surprise were the easiest configurations to make. Examining our four dependent measures, only finger temperature fell into a pattern that in any way matched these difficulty groupings (i.e., finger temperature was lower in fear than in anger). The other three measures showed quite different groupings among emotions. Further, when we looked within emotions at the correlations between difficulty and the magnitude of physiological change, none of the 24 possible correlations were significant. Thus, we feel that we can safely reject differences in difficulty as an alternative explanation for these findings.

Mediation by somatic activity. In psychophysiology a wise dictum might be: "wherever there is heart rate change, suspect muscle activity" (e.g., Obrist, Webb, Sutterer, & Howard, 1970; Levenson, 1979b; Levenson & Ditto, 1981). We evaluated muscle activity of two sorts in our experiments (EMG from a specific nonfacial muscle in Experiment 1 and a measure of general somatic activity in Experiments 2 and 3) to determine whether greater muscle activity accompanied the emotions that produced larger heart rate increases (i.e., anger, fear, sadness). We found that there were no such differences. Thus, within the limits associated with these kinds of measures, our data argue strongly against somatic mediation of emotion-specific heart rate changes.

Mediation by facial muscle activity. Another question that might be raised is whether differences in the amount of *facial* muscle activity associated with the different facial configurations were responsible for the autonomic differences among emotions. The importance of this question is tempered somewhat by consideration of the small metabolic demand that would be produced by the movement of these small facial muscles (almost all of which move only skin and do not move bone). Although facial EMG was not measured in these experiments, we do know the number of facial muscles that was requested for each of the six facial configurations. The autonomic distinctions among emotions did not parallel the number of muscles requested. For example, fear and anger both involved six muscles, yet they differed in finger temperature. Sadness and disgust both involved four muscles, yet they differed in heart rate. Disgust and surprise both involved four muscles, yet they differed in skin conductance. Happiness was the only configuration that involved only two muscles, yet its heart rate increase was not smaller than the configurations of surprise and disgust, which involve four muscles.

Mediation by decoding emotional labels. In Experiment 4, we evaluated the possibility that subjects would be able to decode the target emotion simply from hearing the instructions to move facial muscles used in the directed facial action task. Results indicate that, with the exception of fear, subjects identified the target emotion at better than chance levels. Assuming that subjects complied with the request not to make the facial movements that were described, we are left with the possibility that for some subjects knowledge of some emotional labels could be obtained simply by listening to the muscle-by-muscle instructions.

It is unlikely that the simple act of coming up with the names of different emotions would lead directly to the activation of differentiated patterns of autonomic nervous activity, but it might do so indirectly (e.g., through association with an emotional memory). However, our questions regarding such memories after each trial revealed that memories related to the target affect occurred on only 17.0% of the trials across the three experiments. Further, even if this low rate were considered to be sufficiently high, an explanation based on decoding of the emotional label could not account for the autonomic distinctions involving fear, given the extremely low rate (2.6%) of decoding that label from the instructions. It would also have difficulty accounting for our findings on anger and disgust because fewer than half of the subjects could decode those emotional labels from their instructions.

The findings concerning facial configuration quality also argue against knowledge of the label being solely responsible for the emotion-specific autonomic activity. When configurations were of high quality, hit rates for the autonomic differences among negative emotions were greater than chance; when configurations were of low quality, these hit rates were not better than chance. Yet all of these subjects, both those who produced high quality configurations and those who produced low quality configurations, heard the same instructions and presumably could derive the emotion label for some of the instructions. If knowledge of the label alone were sufficient to produce the emotion-specific autonomic patterns, then even subjects who did not do as well in producing these configurations should have evidenced the autonomic patterns. Nonetheless, this is an issue that will require further study before definitive conclusions can be drawn concerning the role that knowledge of the emotional label plays in these findings.

Theoretical Implications

Having now discussed the nature of the findings from this series of experiments, we will turn briefly to a consideration of some of their implications for emotion theory.

Autonomic specificity: Affect programs and motor programs. In our view there is an innate affect program for each emotion that, once activated, directs and coordinates changes in the organism's biological state by providing instructions to multiple response systems including facial muscles, skeletal muscles, and the autonomic nervous system (see Tomkins, 1963, and Ekman, 1977, for a discussion of the concept of an affect program). These changes produce patterns of activity that will support the behavioral adaptations and associated motor programs that are most likely for that emotion. Thus, the emotion of anger might create an organization of facial muscle contractions, skeletal muscle tonus, and autonomic activity that is optimal for the behavior of "fighting." Similarly, fear might recruit biological support for "fleeing," surprise might recruit support for "attention," and disgust might recruit support for "rejecting or shutting out" an unpleasant environmental object.

An interesting theoretical issue arises if an affect is thought to have more than one associated motor program. Fear, for example, could be associated with "fleeing" or "freezing." This would raise several possibilities for autonomic specificity. First, it might be that one motor program is "primary" for fear and its associated autonomic activity would be produced during a "secondary" motor program as well. Thus, if we assume that "fleeing" is primary for human fear, we would predict that a "freezing" human would still have elevated heart rate and decreased finger temperature. Alternatively, different variants of fear might exist, each with its own motor program and associated pattern of ANS activity. If this second model were true, it would be important to determine if variants of the voluntarily produced facial configuration for fear could be found that would activate these different patterns of ANS activity. Clearly, this is an area that could benefit from additional empirical work using directed facial actions as well as other eliciting tasks.

Autonomic specificity: A functional view. If we believe that the autonomic changes that accompany different emotions should be adaptive, the patterns that we found can be examined in terms of their possible utility. Admittedly this type of examination is purely speculative, but most of our findings do seem reasonable. For example, the two negative emotions of fear and anger are usually associated with the behavioral adaptations of fleeing and fighting, both of which involve high degrees of somatic activity. Thus, it is reasonable to expect that these two emotions would be associated with greater heart rate acceleration than would the negative emotion of disgust, the positive emotion of happiness, or the emotion of surprise, none of which are associated with increased levels of somatic activity and thus make no increased metabolic demands on the heart. Further, if fear is primarily associated with fleeing, it would be functional for blood flow to be diverted away from the periphery and redirected toward the large skeletal muscles. This would be consistent with the decrease in peripheral finger temperature that we found for fear. Similarly, anger, with its close association with fighting, might recruit increased blood flow to the muscles of the hand to support grasping weapons and opponents. This would be consistent with the increase in peripheral finger temperature that we found for anger. Disgust, with its association with ridding the body of noxious materials, could be accompanied by increased vagal outflow resulting in greater salivary and gastrointestinal activity. One side effect of such vagal outflow could be a restraining of the heart rate increase associated with other negative emotions, which would be consistent with our finding of unchanged or small decelerations in heart rate during disgust.

Evidence against a general arousal model. In characterizing the physiological distinctions among emotions, we should consider whether a general arousal model could adequately explain our findings. In its most generic form (e.g., Cannon, 1927), the autonomic nervous system is viewed as capable of only one pattern of global arousal; thus all emotions in which the ANS is activated would be the same autonomically. As Mandler (1975) states:

> . . . "there is no evidence that patterns of physiological response or autonomic discharge determine different kinds of emotion. . ." (p. 127), and ". . . widely different emotions show relatively little differences in physiological patterns. . . it is highly unlikely that different emotions depend on different patterns" (p. 133).

Clearly, our findings create problems for these models. First and foremost, the many autonomic differences among emotions found in these experiments are not compatible with the global arousal position. Second, models proposing that negative emotions differ from positive emotions in global arousal would predict that all physiological indices of arousal should differ among emotions. However, we found that two different measures of muscle activity fail to distinguish between positive and negative emotions (or between any other subsets of emotions). Third, models that allow for global or specific differences between positive and negative emotions would predict that measures that do distinguish among emotions would separate negative emotions from positive emotions. But we found that two physiological measures make distinctions among the four negative emotions (heart rate distinguishes disgust from anger, fear, and sadness; finger temperature distinguishes anger from fear). Finally, a general arousal model would predict that there would be redundancies among measures in the distinctions they make among emotions. However, for the three measures in this report that did make distinctions among emotions, each made a different set of distinctions.

The global arousal model could be modified somewhat to allow for distinctions between negative and positive emotions on the basis of high arousal and low arousal respectively. In a more refined version of this kind of model, Winton, Putnam, and Krauss (1984) propose that heart rate distinguishes between negative and positive emotions, whereas skin conductance distinguishes between intense and mild emotions. Our findings are not totally inconsistent with such a model. Although we emphasized the capacity of heart rate to make distinctions among negative emotions, we found it to make several distinctions between positive and negative emotions as well.

Replication and Generality: Relation to Other Work on Autonomic Specificity

We will consider briefly the extent to which our findings using the directed facial action task replicate other findings using different eliciting tasks. In the introduction to this paper, we presented results obtained when Experiment 1's subjects used a relived emotions task to elicit emotions (reported in Ekman et al., 1983). A comparison between these results and those found in the three experiments using the directed facial action task reported here reveals generalizability across eliciting tasks for distinctions involving heart rate and finger temperature but not for those involving skin conductance. In the relived emotions task, anger and fear were associated with larger heart rate increases than happiness; this was also true of the directed facial action task regardless of whether or not configuration quality was considered. In the relived emotions task, anger was associated with larger finger temperature increase than happiness; this was also true of the directed facial action task when configuration quality was considered. And finally, in the relived emotions task, sadness was associated with larger skin conductance increase than anger, fear, and disgust; however, in the directed facial action task this was not found.

Comparing these findings with those of other investigators, the heart rate differences that we found between the four primary negative emotions (i.e., heart rate faster in anger, fear, and sadness than in disgust) are the same as those found by Schwartz et al. (1981) using an imagery task. Faster heart rate for anger and fear can also be inferred from Ax's (1953) report of large numbers of "heart rate increases" for both his anger and fear conditions. Our findings that finger temperature distinguished anger from fear bears some similarity to other investigators' findings that these two emotions are distinguished by changes in diastolic blood pressure, which also reflects changes in vascular activity (Ax, 1953; Roberts & Weerts, 1982; Schwartz et al., 1981).

Work with specific "attitudes" (e.g., Graham, 1962) provides some additional support for our temperature findings in that a fear-like attitude (". . . person feels that he is threatened with harm and has to be on guard") was associated with lower hand temperature than an anger-like attitude ("person feels he is taking a beating [being unfairly treated or mistreated], and is helpless to do anything about it"). However, another anger-like attitude ("person wishes to take hostile action, such as hitting or strangling") was also associated with lower hand temperature.

Looking further into the specificity literature, it becomes increasingly difficult to compare our findings with those from studies that did not sample comparable emotions, that used different ANS measures or quantification schemes, or for which serious questions can be raised about the adequacy of the emotion elicitation. Still, we believe that sufficient similarities do exist to support some preliminary claims of generality.

The Capacity of Directed Facial Actions to Produce Emotion-Specific Autonomic Activity

Explanatory models. We have discussed how these experiments have helped us eliminate a number of indirect ways in which this task could produce differentiated autonomic activity. Unfortunately, these studies do not provide a critical test that would allow us to determine precisely how this task does produce these effects. In our earlier report (Ekman et al., 1983), we speculated that the capacity of directed facial actions to recruit emotion-specific autonomic activity was direct rather than indirect, and centrally rather than peripherally mediated. We still believe that to be the case. How such central mediation works and, perhaps even more elusively, why it should exist are intriguing questions for which we have considered four models.

The first model, which we endorse, posits that when a voluntary facial configuration is made, the signals that go out from the motor cortex to the facial nucleus to contract certain sets of facial muscles are accompanied by a set of parallel commands that go out to the organs of the autonomic nervous system. We believe that such a central connection would be hard-wired at birth, but could well be strengthened by the learned associations that occur as certain signals going to the facial muscles are paired with certain signals going to the organs of the ANS during emotions. This model is reminiscent of work by Wall and Pribram (1950) in which direct stimulation of areas of motor cortex in monkeys produced changes in blood pressure even when motor activity was inhibited by curare.

A second model, which also seems plausible to us, posits a central pattern detector which scans *efferent* outflow to the facial nucleus for signs of emotional expressive responses. When these are detected, the appropriate affect program is activated, thereby producing changes in autonomic nervous system activity.

The third model, which we do not embrace, is that of the peripheralist theorists of the role of the face in emotion (e.g., Izard, 1981; Laird, 1974; Tomkins, 1962, 1963, 1982; Zajonc, 1985). These views suggest that it is something derived from the movement of the facial muscles (either *afferent* feedback from the facial muscles or regulation of blood flow to the brain) that "creates" the emotion. A related view is found in Gellhorn's (1964) notion that afferent stimulation produced by contractions of various facial muscles could arouse distinct patterns of hypothalamic excitation, thus leading to different patterns of autonomic nervous system response. Our difference with such theorists is quite basic. We do not believe that facial muscle movement per se or the afferent feedback from this movement is necessary for emotion or for emotion-specific autonomic activity to occur, only that the central efferent commands for those movements are sent. We are currently testing this notion in patients with several kinds of facial paralysis.

The fourth model, which we also do not endorse, presumes that a central connection between voluntary facial activity and emotion-specific autonomic activity exists, but that this connection is established entirely through learning. According to this model, in the usual circumstances in which emotion is aroused, facial expression and autonomic activity occur together. Thus, through this contiguity, a learned connection between the two activities is established such that simply making an emotional configuration generates the associated set of ANS changes. An extreme version of this model would posit that the pattern of autonomic activity that occurs for each emotion is socially learned and culturally variable, and that in cultures which deemphasize expression and/or internal experience in emotion, no connection would be learned between making an expression and generating emotion-specific ANS activity. We have explored this notion by repeating these experiments in a non-Western culture which is very different in emotional behavior and attitudes from our own culture and will soon be able to report the results of these experiments.

For now the choice among centralist, peripheralist, and learning explanations of this phenomenon can be based only on speculation. However, each model results in quite different sets of predictions which can be tested empirically.

Implications. Although we do not believe that voluntarily producing an emotional facial configuration is the typical route by which emotions are produced, the capacity of these configurations to generate emotional experience and emotion-specific autonomic activity could play an important role in our social-emotional life. Most emotion theorists consider the experience of emotion to be passive, in that people cannot deliberately choose when to have an emotion, which emotion to have, or for how long. Our findings suggest that there may be a need to modify that view. If we can determine the conditions under which voluntarily producing an emotional facial configuration produces the subjective experience of emotion and emotional-specific autonomic activity, it could provide a more active means of altering our emotional life.

Dimburg (1982) reported that people often make an expression on their own faces when viewing the expression of another person. Meltzoff and Moore (1977) and Field, Woodson, Greenberg, and Cohen (1982) showed that facial imitation appears as early as the second day of life. Combined with our findings, a new social role for facial expression is suggested. By making the configuration seen on the face of another person, the imitator may begin to experience the same affective and physiological state as the other person. Viewed in this way, facial expression may not simply be a social signal, but may also provide a means for establishing mutual feeling, thereby playing a role in the establishment of empathy, attachment, and bonding. Although this clearly reaches beyond our present data, it is somewhat reassuring to find ourselves in the company of a quite astute observer of the human condition, Edgar Allan Poe, who wrote more than a hundred years ago:

> "When I wish to find out how wise or how stupid or how good or how wicked is anyone, or what are his thoughts at the moment, I fashion the expression of my face, as accurately as possible, in accordance with the expression of his, and then wait to see what thoughts or sentiments arise in my mind or heart, as if to match or correspond with the expression."

Conclusions

First we will consider some of the issues that were raised but not settled by these studies:

1. We did not demonstrate that the different patterns of autonomic activity generated by voluntarily making emotional facial configurations are the same as would be found when emotion is aroused spontaneously. However, based on similarities with the relived emotions task in our work, similarities with other tasks used by others, and the important role played by the subjective experience of emotion in our findings, we expect to find that many of these patterns generalize across modes of elicitation.

2. We did not fully rule out the possibility that derivation of the emotional label from the instructions to make the emotional facial configurations could play a role in these findings.

3. We do not know if the capacity of directed facial actions to generate emotion-specific autonomic activity will generalize to subjects who are not selected on the basis of their ability to control their facial muscles.

4. We do not yet know the temporal relation between subjective emotional experience and autonomic nervous system activity when both are generated by voluntary facial action (i.e., does the autonomic activation precede, follow, or occur simultaneously with the subjective experience?). A definitive answer to this question will be difficult to obtain given the delays involved between central impulses and measurable peripheral manifestations for both subjective experience and autonomic activity.

5. We do not yet have the evidence needed to specify the mechanism by which directed facial actions generate emotion-specific activity.

We will now consider what we believe the results of these five experiments *did* demonstrate:

1. The directed facial action task produces significant levels of subjective experience of the associated emotions.

2. The directed facial action task produces a number of reliable autonomic differences among the six primary emotions of anger, disgust, fear, happiness, sadness, and surprise. These differences take the form of distinctions between negative and positive emotions, distinctions among negative emotions, and distinctions involving the emotion of surprise.

3. Three common psychophysiological measures (heart rate, finger temperature, and skin conductance) each distinguish different subsets of emotions. Of these three measures, only heart rate and finger temperature make distinctions among negative emotions. A fourth measure of muscle activity does not distinguish among any of the emotions that we studied.

4. Autonomic distinctions between negative and positive emotions and among negative emotions that are found in group data are also found in the data from individual subjects.

5. Autonomic distinctions among emotions occur for both men and women, and for trained actors, facial scientists, and untrained subjects.

6. The capacity of the directed facial action task to produce autonomic distinctions among emotions does not require that subjects see their own faces in a mirror or see the face of a coach.

7. The autonomic distinctions among emotions produced by the directed facial action task still occur when the associated emotion is not experienced,

but the differences are more pronounced when the associated emotion is experienced.

8. Autonomic differentiation among emotions produced by the directed facial action task does not require that the facial configuration that is produced is a perfect representation of the associated universal emotional expression; however, the differences are more pronounced and the subjective experience of the associated emotion is increased when facial configurations closely resemble the associated emotional expressions.

9. The capacity of the directed facial action task to produce autonomic distinctions among emotions is not an artifact of somatic muscle activity or of differences in the difficulty of making the different facial configurations.

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Announcements

Postdoctoral Training in Human Behavioral Genetics

The Departments of Psychology, Psychiatry, and Genetics at the University of Minnesota are accepting applications for an NIMH-sponsored postdoctoral traineeship to begin on or after August 1, 1990. Postdoctoral trainees collaborate closely with one or more program faculty in the context of ongoing research projects. The main areas of faculty interest include the behavioral genetics of personality, and cognitive development. Currently funded research projects include a prospective high risk twin study of substance abuse, family studies of schizophrenia, a study of reared apart twins, a twin study of aging, and the Minnesota Twin Registry. Although preference will be given to candidates whose interests overlap with those of the program faculty, applications from all areas of Psychology are encouraged. Stipend depends upon the number of years since receiving Ph.D., and is consistent with the standard NIH postdoctoral salary schedule.

To apply, submit curriculum vitae, research statement, and three letters of recommendation to: Professor Matt McGue, Department of Psychology, Elliott Hall, 75 East River Road, Minneapolis, MN 55455. Review of applications will begin on July 15 and continue until the position is filled. The University of Minnesota is an Equal Opportunity/Affirmative Action Employer.

Cardiovascular Psychophysiologist at the University of Pittsburgh

A postdoctoral research position will be available September 1990, which is funded by two NHLBI grants using impedance cardiography, ambulatory blood pressure monitoring, and standardized laboratory stress protocols. Projects include the effects of reproductive hormones on cardiovascular, neuroendocrine, and metabolic responses during stress; personality and stress responses; and the psychophysiology of family interactions.

To apply, send a curriculum vitae and three letters of recommendation to: Karen A. Matthews, Department of Psychiatry, University of Pittsburgh, 3811 O'Hara Street, Pittsburgh, PA 15213, or call 412/624-2041.