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For Distinguished Early Career Contribution to Psychophysiology: Award Address, 1988

Facial Electromyography and Emotional Reactions

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ABSTRACT

The aim of this paper is to review data from my laboratory, which were collected in an attempt to determine whether the facial EMG response is a general component of the emotional reaction.

In a number of studies it was found that facial reactions: first, are spontaneously elicited and differ according to the kind of emotional stimuli to which subjects are exposed; second, are sensitive to learning; third, are consistent with how the subjects perceive the stimuli and their own specific emotions; fourth, are congruent with autonomic responses; fifth, are more pronounced for females than for males; and finally, differ among subjects with specific fears.

These data converge to indicate that facial muscle activity is a general component of the emotional reaction and demonstrate that the facial EMG technique is a sensitive tool for measuring emotional reactions.

The purpose of this paper is to review data collected in my laboratory on facial electromyographic (EMG) responses to different external emotional stimuli. I will summarize converging data which, together with results from other laboratories, are consistent with the theory that the facial muscle reaction is a general component of the emotional response and that the facial EMG technique is a sensitive tool for measuring emotional reactions.

First, I will give a brief background, and then specify some of the questions that I have focused on, and finally, I will review results from the different studies that are consistent with the proposition that our facial muscles constitute an output system for emotional reactions.

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I would like to thank my friend and colleague Arne Öhman for encouragement and helpful comments.

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Facial Expressions and Emotion

Major theories of emotion agree that there are three aspects of an emotion; the expressive, the experiential, and the physiological (for a review see Izard, Kagan, & Zajonc, 1984). A central concern for research in this area has been to determine whether these components are interrelated (e.g., Schachter & Singer, 1962; Mandler, 1975) or whether one of them is primary or more important than the others when emotional reactions are evoked (e.g., Lazarus, 1984; Zajonc, 1980). Ever since Charles Darwin's classical work, *The expression of emotion in man and animals* (1872), facial expressions have been a focus for researchers on emotion. Darwin proposed that emotions and emotional expressions have a biological basis. This view has been incorporated into several modern theories of emotion (e.g., Ekman, 1973; Izard, 1977; Tomkins, 1962), which propose that there are a number of fundamental emotions such as anger, fear, sadness, disgust, surprise, and happiness. Such emotions are presumed to be distinctly manifested in different facial expressions. There is much evidence in support of this view. Indirect support is provided by the fact that complex patterns of facial muscles have evolved. These muscles provide the basis for the display of a variety of emotional expressions. Furthermore, cross-cultural studies (e.g., Ekman, 1973), infant studies (e.g., Izard, 1977), and comparative studies on nonhuman primates (e.g., Andrew, 1963) provide convergent support for the proposition that human facial expressions are part of our biological inheritance (for reviews see e.g., Dimberg, 1983, 1988a; Öhman & Dimberg, 1984).

An important basis for the presumed biological roots of facial expressions is their role in the communication of emotion in face-to-face interactions. It has further been proposed that facial expressions are not only biologically prewired and initiated by a "primary affect programme" (Tomkins, 1962), but also that humans are prepared to decode and respond adaptively to the facial display of others (Buck, 1984; Dimberg, 1983, 1988a; Öhman & Dimberg, 1984). This position has been supported by extensive research in which subjects were aversively conditioned to particular facial expressions while autonomic responses were measured (Dimberg, 1983, 1986a, 1987a; Dimberg & Öhman, 1983; Öhman & Dimberg, 1978). In these studies slides of facial expressions were paired with an aversive unconditioned stimulus (mostly a mild but uncomfortable electric shock to the fingers). In general, angry faces but not happy or neutral faces induced persistent skin conductance responses when used as conditioned stimuli within the aversive conditioning paradigm (Öhman & Dimberg, 1978). In fact angry faces had an excitatory influence but happy faces had an inhibitory influence, on aversively conditioned responses (Dimberg, 1986a). These data were taken as support for the hypothesis that humans are biologically prepared to associate angry faces, but not happy or neutral faces, with aversive consequences. Moreover, because of the inhibitory influence of happy faces (Dimberg, 1986a), it is possible to argue that happy faces are contra-prepared to be associated with aversive consequences.

Interest in the role of facial muscle activity in emotional behavior has not only focused on the *feed-forward* process, which serves as a display function in *inter*-individual interaction. It has also been postulated that our facial muscles serve as a sensory *feedback* system for the *intra*-individual experience of emotion (e.g., Izard, 1977, 1981). According to this latter "facial-feedback-hypothesis," the facial muscles play an active role as a feedback system for the experience of emotion (for reviews see Buck 1980; Laird, 1984; Manstead, 1988).

Thus, it has been argued that the facial muscles can be conceptualized both as a read-out system for emotional reaction and as a feedback system for the experience of emotion.

Facial EMG and Imagery-Induced Emotion

In a number of empirical studies, different facial EMG responses were found to be related to different self-induced emotions and cognitive manipulations (e.g., Cacioppo & Petty, 1981; Schwartz, Fair, Salt, Mandel, & Klerman, 1976; for a review of facial EMG in emotion research, see Fridlund & Izard, 1983). For instance, Schwartz and coworkers found that imagining *pleasant* thoughts increased the activity in the *zygomatic* muscle, the muscle that normally elevates the cheeks to form a smile. *Unpleasant* thoughts, on the other hand, increased the *corrugator* muscle activity, the muscle used when frowning (Hjortsjö, 1970).

These studies, then, demonstrate that different facial EMG reactions are related to "positive" and "negative" imagery-induced emotions. These results emphasize the close relationship between facial muscle activity and emotional experience.

It is important to note that the facial EMG technique provides several advantages compared to other coding techniques for the detection of facial muscle actions. Because the EMG signal is instantaneously detectable and recordable, the technique does not require large amounts of time for visual inspection and observer judgments. Furthermore, compared to visual coding techniques facial EMG offers a precise unbiased measure of muscle activity, and in particular, it allows detection of facial muscle reactions that are too small to be visible as an overt expression (Fridlund & Izard, 1983).

Facial Reactions: A General Component of the Emotional Response

From the background presented above, it is obvious that our facial muscles are closely related to emotions and provide the basis for displaying different emotional expressions. In particular, it has been demonstrated that even invisible facial muscle activity may be detected during imagery of different emotions. This finding further emphasizes that even low-intensity facial muscle activity may be intimately connected to emotions and be an important aspect of emotional activity. This is consistent with the theory that our facial muscles constitute an emotional output system, and that facial expressions have a biological basis (Darwin, 1872; Ekman, 1973; Izard, 1977; Tomkins, 1962).

When I started the present research, most studies (with some exceptions, e.g., Vaughan & Lanzetta, 1980) used cognitive manipulations, such as *imagery* induced emotions and the re-experience of feelings, to study the relation between facial EMG and emotion (for a review see Fridlund & Izard, 1983). Furthermore, in studies performed to investigate the relation between facial feedback and emotion, the reverse manipulation has been used. That is, subjects were instructed to voluntarily produce different facial actions and report the emotion that they experienced (e.g., Buck, 1980; Tomkins, 1981).

However, one important feature of the evocation of emotional reactions is that people are normally exposed to *external* emotional stimuli, which probably evoke short-term *phasic* emotional responses. This feature is lacking in the studies reported above. From a theoretical point of view, it is therefore important to demonstrate that facial muscle reactions are spontaneously elicited by a broad range of stimuli in different situations. Thus, before we can draw the conclusion that facial muscle activity is a general component of the emotional response and that facial EMG activity reflects emotional activity, it is necessary to demonstrate that involuntary facial EMG reactions are spontaneously elicited when subjects are exposed to various external stimuli.

Given this background, I have undertaken a series of studies in an attempt to systematically explore whether the facial EMG response is normally or *generally* detected as a component of the emotional reaction. Thus, the major aims of this research were twofold. The first aim was to test the theoretical prediction that the facial muscle reaction is normally a component in the evocation of emotional reactions. The second aim was to explore whether the EMG technique is able to detect these response patterns.

In these studies I have focused primarily on the following questions: First, do people spontaneously react with different and consistent facial EMG response patterns when they are exposed to different emotional stimuli? Second, are facial EMG reactions sensitive to learning factors? Or more specifically: Is it possible to condition facial EMG responses? Third, are these facial muscle responses related to other aspects of the emotional response system, such as the experience of emotion and autonomic responses? Fourth, are there sex differences in facial EMG responding? And finally, do facial EMG reactions differ between "normal" and clinical groups, such as those suffering from specific fears?

General Method

The method and the laboratory situation were similar in all the studies. The subjects were seated in a chair in a sound-attenuated experimental chamber in which they were repeatedly exposed to different stimuli. The stimuli used were usually slides projected onto a screen in front of the subjects with a stimulus duration of 8 s. In some of the studies subjects were exposed to auditory stimulation, i.e. 1000 Hz tones with different intensities and with a stimulus duration of 4 s. The intertrial intervals varied from 25–45 s. Different studies used different numbers of trials, but usually 6–10 presentations per stimulus.

Surface electrodes were attached over the corrugator and zygomatic muscle regions (Fridlund & Cacioppo, 1986). To conceal the recording of facial EMG activity, and consequently avoid experimental demand characteristics such as inhibition of muscle activity or subjects' willingness to "make good faces" (Fridlund & Izard, 1983), a cover story was used. The subjects were told that their facial sweat gland activity was going to be measured. After the experiments the subjects were systematically interviewed about their awareness of their facial muscle activity being measured. Very few subjects realized the real reason for the electrodes and the data from these few subjects were excluded from further analysis. Thus, in all the reported studies only data from subjects who were *not* aware that their facial muscle activity was measured were included.[1]

The raw EMG signal was analyzed by a contour-following integrator (Fridlund, 1979) and was manually scored second-by-second during each stimulus presentation as change in microvolts from the prestimulus baseline level. This allows the evaluation of both *in*creasing activity and *de*creasing phasic muscle activity.

In most studies autonomic activity (skin conductance responses and heart rate responses) were also measured.

Different Reactions to Different Stimuli?

One of the first questions to be asked is whether subjects *spontaneously* react with different facial muscle response patterns when they are exposed to different stimuli. To investigate this question a series of studies were performed in which subjects were exposed to either visual or auditory stimuli while their facial EMG activity was measured.

Facial Stimuli

In the first type of study (Dimberg, 1982; Dimberg, 1988b; Dimberg & Lundquist, 1988), subjects were exposed to pictures of angry and happy facial

[1]As a matter of fact, we have specifically evaluated whether the awareness that facial muscle activity is measured influences the size of facial EMG responses. In this study (Dimberg & Lundquist, unpublished), one group of subjects was specifically instructed that their facial muscle activity was measured and a second group was told a cover story. The results from this study demonstrated that although the instructed group tended to react more intensely compared to the group given a cover story, this tendency was not statistically significant.

expressions while their own facial EMG activity was measured. Based on the evolutionary perspective presented above (see also Dimberg, 1983, 1988a), it was expected that angry and happy facial stimuli should spontaneously elicit different emotional reactions. The predictions were as follows: Positive emotional stimuli, such as happy faces, should elicit a positive facial muscle response pattern, primarily indicated by an increase in zygomatic activity. A negative emotional stimulus (angry face), on the other hand, should evoke a negative response as indicated by an increase in corrugator activity.

The stimuli used in the first experiments were 14 slides (7 angry and 7 happy faces), selected from Ekman and Friesen's *Pictures of Facial Affect* (1976), showing males producing angry and happy facial expressions. The subjects were exposed to 8 presentations of happy faces and 8 presentations of angry faces in a balanced order.

Typical results from these studies are presented in Figure 1, which shows the overall means for each muscle and emotion. It is obvious that happy and angry faces evoked *different* response patterns. Subjects exposed to happy faces reacted with increased activity in the zygomatic muscle. Angry faces elicited increased activity in the corrugator muscle.

Thus, these results demonstrate that positive and negative emotional stimuli evoke facial EMG responses consistent with positive and negative emotional reactions, respectively. Similar results were obtained in two additional studies (Dimberg, 1988b; Dimberg & Lundquist, 1988, in press), and were replicated by McHugo, Lanzetta, Sullivan, Masters, and Englis (1985) who used dynamic facial stimuli rather than slides of facial expressions.

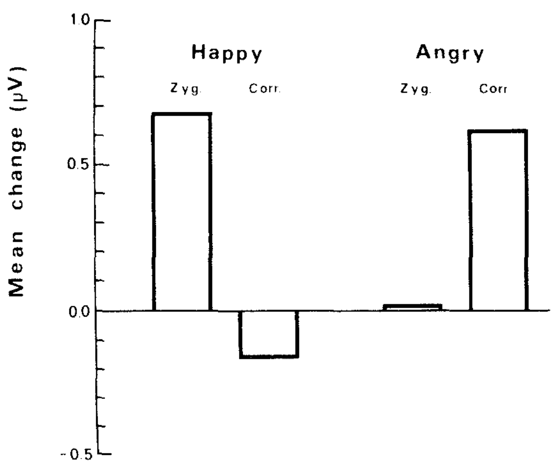

Figure 1. The mean facial EMG response for zygomatic (Zyg.) and corrugator (Corr.) muscle regions when subjects were exposed to happy and angry facial stimuli. Data are expressed as change scores from the prestimulus level (i.e. zero). Positive scores indicate increased activity and negative scores imply decreased activity. From Dimberg, 1982 (Copyright, 1982, The Society for Psychophysiological Research; reprinted with permission of the publisher).

Fear-Relevant Stimuli

Because increased corrugator muscle activity is important when frowning and increased zygomatic muscle activity is an important component to form a happy face, it is also possible to interpret these data to mean that happy and angry faces evoke a mimic response without emotional concomitants. To examine this question, two additional studies were performed in which *other* types of emotional stimuli were used (Dimberg, 1986b; Dimberg & Thell, 1988). For this purpose, slides of fear-relevant stimuli, such as snakes, constituted the negative stimuli, and fear-*ir*relevant stimuli, slides of flowers, were used as positive control stimuli. The logic behind this manipulation was that the evocation of emotional responses to fear-relevant stimuli has also been proposed to have a long evolutionary history (e.g., Öhman, Dimberg, & Öst, 1985). Therefore, humans should be biased to spontaneously respond with a negative emotional reaction to these stimuli.

As can be seen in Figure 2, fear-relevant stimuli did in fact evoke a "negative" response indicated by reliable increased corrugator activity, whereas slides of flowers evoked a "positive" response indicated by reliable increased zygomatic activity. It is clearly unreasonable to interpret these results as the outcome of mimicking behavior. Thus, these data support the interpretation that the facial EMG response reflects emotional activity in the present research paradigm.

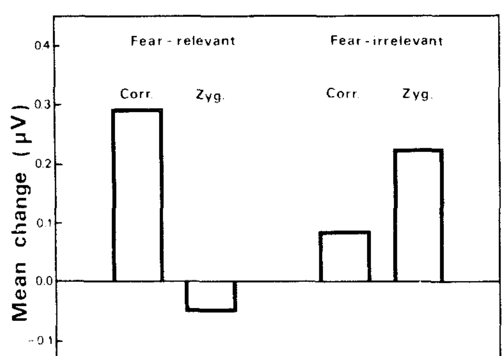

Figure 2. The mean facial EMG response for corrugator (Corr.) and zygomatic (Zyg.) muscle regions when subjects were exposed to fear-relevant and fear-irrelevant stimuli. Adapted from Dimberg, 1986b (permission to reprint received from Elsevier Science Publishers Physical Sciences & Engineering Division.)

Together these studies demonstrate that subjects exposed to positive and negative emotional stimuli, *spontaneously* react with facial EMG responses that are consistent with positive and negative emotional responses, respectively.

Environmental Stimuli

To further explore whether facial EMG reactions reflect the quality of the stimuli, subjects were exposed to scenes of natural environments such as preferred and non-preferred landscape scenes (Dimberg & Ulrich, 1990). The choice of landscape scenes was based on the fact that there is a substantial agreement among people on which scenes of natural environments are preferred (Ulrich, 1983). These stimuli are also potent elicitors of different autonomic responses (for a review see Ulrich, Dimberg, & Driver, 1990, in press). Besides, it has been demonstrated that environmental factors such as window views with spatially open environments can have dramatically positive effects on the rehabilitation of patients in hospitals (Ulrich, 1984). Consequently, it can be predicted that people should react with increased zygomatic activity, indicating a positive reaction, when exposed to positive landscape scenes. Thus, for the present purpose, slides of preferred or positive views (spatially open environments) and less preferred natural scenes (spatially enclosed environments) were selected. The results from this study are given in Figure 3. The positive nature scene (High preferred) evoked overall relatively more zygomatic activity than corrugator activity, as well as more zygomatic activity when compared to the Low preferred scenes.

This study showed that subjects spontaneously react with increased zygomatic activity to positive nature scenes. These data further support the hypothesis that facial muscle activity is a general component in the affective reaction and that the EMG technique is a sensitive tool for detecting these reactions.

Auditory Stimuli

One further interesting question concerned the generality of facial reactions—are facial EMG responses also sensitive to environmental stimuli in modalities other than the visual one, such as for example, auditory stimuli? If this is true, one could expect that tone stimuli with relatively high aversive intensity should elicit a "negative" facial reaction indicated by increased corrugator activity but low intensity tones should not. In previous research (e.g., Davis, Malmo, & Shagass, 1954), it has been found that EMG activity from different bodily muscle sites increased when subjects were exposed to loud auditory stimuli. However, that study did not particularly focus on facial muscles that are specifically related to emotional expressions (e.g., Darwin, 1872; Ekman, 1972; Izard, 1977). Consequently, in the present study subjects were exposed to 1000 Hz tone stimuli with high (95dB) and low (75dB) intensity while facial EMG was measured (Dimberg, 1987b, 1988c). The subjects were instructed to sit calmly and listen to the tones administered through headphones. To prevent the elicitation of startle reactions, the stimulus rise and fall times were set at 40 ms (Graham, 1979). As can be seen in Figure 4, the prediction was confirmed. The figure illustrates data for the first trial block (2 trials) to which the response was most pronounced. The Intensity × Muscle interaction was significant and comparisons among means demonstrated that, compared to the 75dB tone, the 95dB tone evoked a larger corrugator than zygomatic response as well as more corrugator activity.

Thus, this experiment demonstrated that the facial EMG technique is differentially sensitive to

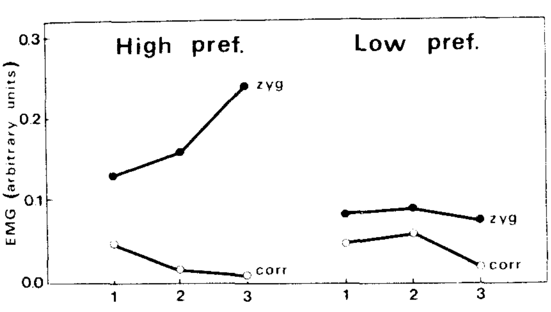

Figure 3. The mean facial EMG response for zygomatic (zyg) and corrugator (corr) muscle regions to high preferred (High pref.) and low preferred (Low pref.) natural landscape scenes, plotted as a function of trial blocks. From Dimberg & Ulrich, 1990.

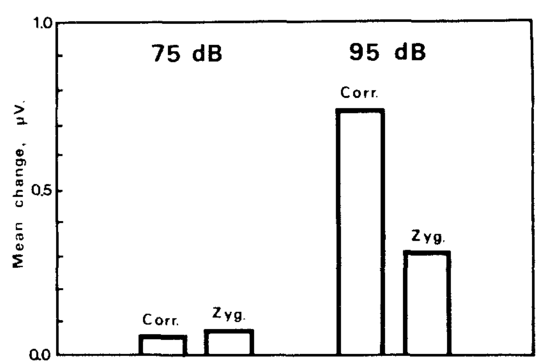

Figure 4. The mean facial response to 75dB and 95dB tone stimuli, for zygomatic (Zyg.) and corrugator (Corr.) muscle regions. Data are shown for the first trial block From Dimberg, 1988c.

simple environmental stimuli, such as auditory stimuli with different intensities.

Sensitive to Learning Factors?

A second question examined was whether facial reactions are sensitive to learning factors. As noted in the introduction, we have found in previous research that supposedly biologically prepared stimuli, such as angry facial expressions, are particularly potent in eliciting conditioned autonomic responses in the aversive classical conditioning paradigm (e.g., Dimberg, 1983, 1988a). Based on this evidence, I reasoned that this paradigm could be used to determine whether it is possible to aversively condition facial muscle responses. Furthermore, by using the facial EMG technique, the autonomic data from earlier studies could be integrated with measures from other aspects of the emotional response system. Consequently, in a second type of study (Dimberg, 1987a) subjects were aversively *conditioned* to slides of angry or happy facial expressions. In this study a differential conditioning paradigm was used. More specifically, subjects were exposed to two different pictures, the CS+ and the CS−, with a stimulus duration of 8 s. The experiment consisted of three phases. During the habituation phase the subjects were exposed to a number of presentations of each stimulus picture. During acquisition the CS+ was terminated by an aversive unconditioned stimulus (UCS; a 100dB noise with a duration of 1 s) whereas the CS− was never paired with the UCS. During extinction the subjects were exposed to nonreinforced presentations of both CS+ and CS−. Furthermore, in this paradigm, conditioning effects as well as *resistance to extinction* can be evaluated in terms of a difference in responding between the reinforced CS+ and the nonreinforced CS−. The group conditioned to angry stimuli discriminated between two reinforced and nonreinforced angry faces whereas the group conditioned to happy stimuli discriminated between two reinforced and nonreinforced happy faces. Because the critical effect in earlier studies (e.g., Dimberg, 1983, 1986a) has been detected as resistant autonomic responding during extinction, it was expected that similar results should be obtained in the present study. Thus, besides inducing resistant autonomic responses, angry stimuli were expected to induce a persistent conditioning effect detectable in corrugator activity during the extinction phase, but happy faces should not. The results are illustrated in Figure 5. As expected, angry faces induced persistent conditioned corrugator activity, but no other effects were statistically significant.

This study demonstrates that it is possible to aversively condition facial reactions within a Pavlovian conditioning paradigm. Note that this effect was obtained only for angry faces. This is consistent with earlier findings on autonomic data (e.g., Dimberg, 1983, 1986a) supporting the hypothesis that humans are biologically prepared to associate angry faces with an aversive outcome (e.g., Dimberg, 1983). It is interesting to note that Vaughan and Lanzetta (1980) presented evidence that facial muscles were also sensitive to contingencies in a *vicarious* conditioning paradigm. This further demonstrates the sensitivity of facial muscles to learning. Furthermore, results of the present study support the proposition that an "affect-program" triggers a negative reaction that is detectable not only in skin conductance responses, but also in other components of the emotional response system. These results, then, support the hypothesis that humans are biologically prewired to react with a "negative" emotional response to angry faces.

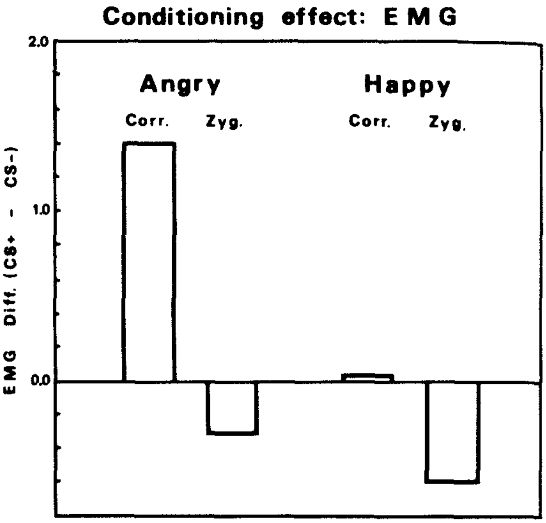

Figure 5. Facial EMG conditioning effects for the corrugator (Corr.) and zygomatic (Zyg.) muscles during extinction for subjects conditioned to angry and happy faces, respectively. From Dimberg, 1987a (permission to reprint received from Elsevier Science Publishers Physical Sciences & Engineering Division).

Related to Emotional Experience?

As mentioned in the introduction, theories of emotion agree that there is an expressive, an experiential, and a physiological component of an emotion. A central concern for emotion research has been to determine whether these components are related to each other. If facial muscle activity is related to emotional reactions, then it should be possible to detect consistent responses in the other components of the emotional response system, such as the subjective experiential and the autonomic system.

Thus, the next question explored was whether different facial EMG responses are accompanied by consistent reactions in the experiential component of the emotional response system. Studying the experiential component involves at least two aspects of experienced emotion. The first is the subjects' evaluation of the stimulus situation, i.e. how they perceive the stimuli, and the second is their perception of their own specific emotional state.

Perceiving the Stimuli

To investigate whether spontaneously evoked facial EMG reactions are consistent with how subjects perceive stimuli in the experiment, subjects were required to rate the stimuli in one of the snake/flower-experiments (Dimberg & Thell, 1988).

As expected, the snakes were reported as reliably more unpleasant than the flowers and flowers were reported as more pleasant. The facial EMG responses were similar to those illustrated in Figure 2. Similar results were also obtained in a study in which the subjects were exposed to angry and happy faces (Lundquist & Dimberg, unpublished). Angry faces were reported as more unpleasant than happy faces and happy faces were reported as pleasant. Findings consistent with these results were also obtained by Cacioppo, Petty, Losch, and Kim (1986) who demonstrated that facial reactions differentiated not only the valence but also the intensity of affective reactions. Moreover, subjects were also required to rate how they perceived the tone stimuli in the study presented in Figure 4 above (Dimberg, 1987b, 1988c). Consistent with their facial reactions, the subjects perceived the 95dB tone as highly unpleasant.

Furthermore, in a second tone habituation study *all* subjects were exposed to 75dB tones (Dimberg, 1990a). After the experiment the subjects rated the unpleasantness of the tone stimuli. Based on these ratings the subjects were divided (at the median value) into two groups, High and Low in perceived unpleasantness. It was predicted that if the evaluation of stimuli is related to the facial EMG reaction, then subjects in the High group should react with a negative facial response but the Low group should not. The results are illustrated in Figure 6. As predicted, and in spite of the fact that the two groups were exposed to the same 75dB stimulus, the High group reacted with a negative facial reaction but the Low group did not. Specifically, comparisons among means showed that the tone stimulus evoked more corrugator than zygomatic activity only in the High group.

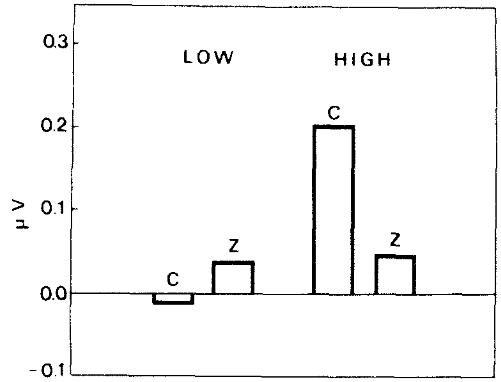

Figure 6. The mean facial EMG response for corrugator (C) and zygomatic (Z) muscles to the 75dB tone stimulus, for the groups perceiving the tone as Low and High in unpleasantness. From Dimberg, 1990a (permission to reprint received from the editor for *Scandinavian Journal of Psychology*).

Perceiving the Emotion

The studies reported above convincingly demonstrate that the facial EMG reaction is closely related to the perception of stimuli. In an additional experiment, I examined whether different facial response patterns also corresponded to changes in perceived emotion (Dimberg, 1988b). In this experiment subjects were required to rate *their own specific emotions* immediately after they had been exposed to angry or happy faces. Ratings were performed for happiness, fear, anger, interest, and surprise.

It was found that, consistent with their facial reactions, the subjects reported more fear after being exposed to angry as compared to happy faces. Happy faces, on the other hand, induced significantly more happiness. The remaining rating dimensions were not affected with the exception that angry stimuli tended to induce more surprise.

These data demonstrate that spontaneously elicited facial EMG reactions are accompanied by a corresponding change in perceived emotion. This was further supported in the conditioning study reported above (Figure 5; Dimberg, 1987a). In this study subjects also rated their own specific emotions immediately after the extinction phase. Consistent with the hypothesis that angry faces induce more negative affect, it was found that the group aversively conditioned to angry faces reported more fear as compared to the group conditioned to happy faces. The fact that angry faces evoked greater fear report casts further doubt on the mimicry hypothesis suggested above.

Related to Autonomic Responses?

A number of investigators have been concerned with the relationship between facial expressiveness and autonomic activity (for reviews see Buck, 1980; Manstead, 1988). Although the results from this research have been equivocal, the study by Ekman, Levenson, and Friesen (1983) was particularly successful. By instructing the subjects to voluntarily move particular patterns of facial muscles they were able to demonstrate that the autonomic nervous system distinguished among the different corresponding emotions.

The studies on which the present paper is based were not concerned with voluntary but rather with involuntary facial actions. Besides facial EMG, skin conductance and heart rate responses were also measured in most of the studies. The overall results were ambiguous. For instance, in Dimberg (1982) the different "negative" and "positive" facial EMG reactions were accompanied by similar skin conductance responses and heart rate decelerations to the respective angry and happy stimuli. On the other hand, when subjects were exposed to fear-relevant and fear-irrelevant stimuli (Dimberg, 1986b) the "negative" and "positive" facial EMG responses were accompanied by different autonomic reactions, that is, larger skin conductance responses and heart rate decelerations to fear-relevant as compared to fear-irrelevant stimuli.

One way to interpret the latter data is that slides of snakes elicit a larger orienting response as compared to flowers. It is possible to argue, then, that the different evoked facial response patterns are not related to negative and positive emotions, but rather reflect an emotional/attentional intensity factor. However, if slides of snakes are more attention-getting than slides of flowers, then the ratings performed in this study should reveal higher levels of perceived unpleasantness to snakes than to flowers. In fact, the reverse was the case (Dimberg & Thell, 1988). Thus, the facial EMG data cannot be explained as an effect solely of an intensity factor but rather as reflecting different emotional reactions. This interpretation is further supported by the study in which subjects were exposed to angry and happy faces (Dimberg, 1982). That is, angry and happy faces evoked similar skin conductance responses and heart rate decelerations. Thus, the two stimuli evoked *similar* orienting reactions but *different* facial reactions indicating a "negative" and a "positive" emotional response, respectively.

These data show that there is no simple relation between facial reactions and autonomic activity. However, the facial EMG reactions and the autonomic responses were more closely related in the studies in which more *discomfort* was introduced, that is, in the aversive conditioning study (Dimberg, 1987a) and the tone habituation study (Dimberg, 1988c). In addition to displaying a persistent conditioned corrugator response (see Figure 5; Dimberg, 1987a), subjects conditioned to angry

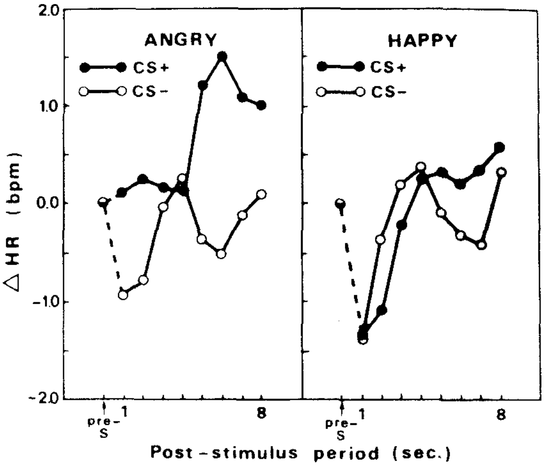

Figure 7. Extinction data to the reinforced (CS+) and non-reinforced (CS−) stimuli for heart rate during the poststimulus interval after conditioning to angry and happy facial stimuli. The data are expressed as change in bpm from the prestimulus level. From Dimberg, 1987a (permission to reprint received from Elsevier Science Publishers, Physical Sciences & Engineering Division).

faces also showed resistant differential skin conductance as well as heart rate responding during extinction. As can be seen in Figure 7, the differential responding was apparent even for heart rate during the poststimulus interval (i.e. the interval in which the UCS was withheld) and was primarily due to a heart rate acceleration to the angry CS+. This response pattern was also accompanied by a slower skin conductance half-recovery time to the angry stimuli. Thus, the conditioned corrugator response to angry faces was accompanied by an autonomic response pattern that suggested that a defense reaction was elicited (Graham, 1979). One question is to what extent this response pattern is related to negative emotions, such as fear and anger. Earlier research has found that both anger and fear induce increased heart rate activity (Ekman et al., 1983). As reported above, the group conditioned to angry faces also reported greater experience of fear. Thus, it is possible to interpret the present response pattern as reflecting a fear response.

Similar results were obtained when subjects were exposed to aversive 95dB tone stimuli (Dimberg, 1987b, 1988c). The corrugator response to 95dB (see Figure 4) was accompanied by larger nonhabituating skin conductance responses with retarded half-recovery time. Furthermore, the heart rate response showed a tendency toward acceleration whereas the response to the 75dB tone was a distinct heart rate deceleration.

Thus, at least for relatively aversive stimulation, the increased corrugator response was accompanied by an autonomic response pattern indicating a defense reaction which may be related to negative affect, such as fear.

Sex Differences?

Previous research on nonverbal communication indicates that females are more facially expressive than males (e.g., Buck, Savin, Miller, & Caul, 1972). Consistent with these findings, Schwartz, Brown, and Ahern (1980) found that females tend to generate larger facial EMG responses than males, during affective imagery. In my research, males and females also displayed similar differences. For instance, when subjects were exposed to snakes or flowers, females tended to react with overall larger facial EMG responses. Similar results were also obtained in a tone habituation study (Dimberg, in press) in which females reacted with larger corrugator responses as compared to males, to the loud high-intensity stimuli.

In a separate study, we examined whether males and females differed in responsiveness when exposed to slides of facial expressions (Dimberg & Lundquist, 1988, in press). From a social interaction point of view, it is interesting to ask whether the sex of the sender influences the response pattern in the receiver in a face-to-face interaction. Thus, in the same experiment we also determined whether the sex of the stimulus faces differentially influences the response patterns. In a 2 × 2 factorial design the two gender variables were manipulated by exposing males and females to facial stimuli displayed by both sexes. This design permits the evaluation of possible interaction effects between groups (i.e., sex of subjects) and the gender of facial stimuli. As in previous experiments, angry and happy stimuli evoked overall negative and positive facial reactions, respectively. As further indicated by a significant Stimulus × Group interaction and as illustrated in Figure 8, females displayed more pronounced response patterns to both angry and happy stimuli. Interestingly, there were no interaction effects between the gender of the perceiver and the gender of facial stimuli.

These studies are consistent with previous research demonstrating that females are more facially expressive than males. It is not obvious, however, how to interpret this difference. For instance, are there genetic differences affecting mediation by the central nervous system or anatomical peripheral dissimilarities resulting in different facial reactivity (for a discussion see Schwartz et al., 1980). The present study further showed that the gender of the person expressing the angry and happy stimuli does not influence the response pattern to the stimuli. Thus, from a social interaction point of view, the sex of the sender does not seem to be a critical factor in eliciting facial reactions to facial expressions of emotion.

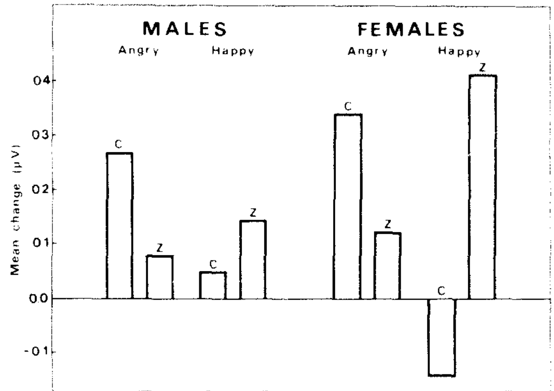

Figure 8. Mean corrugator (C) and zygomatic (Z) region responses for males and females when exposed to angry and happy facial stimuli. From Dimberg & Lundquist, in press (permission to reprint received from Elsevier Science Publishers, Physical Sciences & Engineering Division).

Related to Specific Fear?

Earlier research demonstrates that subjects with specific fears, such as snake phobia, react with increased autonomic activity when exposed to feared objects (e.g., Fredrikson, 1981). We also found (Dimberg, Fredrikson, & Lundquist, 1986) that subjects who were high in public speaking fear showed overreactive autonomic responses when exposed to social stimuli (pictures of human faces). If facial EMG reflects emotional activity, it should be possible to detect different facial muscle response patterns among subjects high and low in, for instance, snake fear when they are exposed to the feared objects.

Thus, to determine whether facial EMG reactions differ between normal groups and groups with specific fears, two types of studies were performed. In the first study subjects were exposed to slides of snakes and flowers (Dimberg, 1990b). After the experiment the subjects were required to rate their fear of snakes on a questionnaire. Based on these ratings subjects were divided, at the median, into high and low fear groups.

The facial EMG results from this experiment are shown in Figure 9. Note that the facial reaction is expressed here as differential responding between the corrugator and zygomatic muscles. This implies that positive scores indicate more corrugator than zygomatic activity, and are interpreted as a "negative" emotional response. Negative scores indicate more zygomatic activity, that is a "positive" reac-

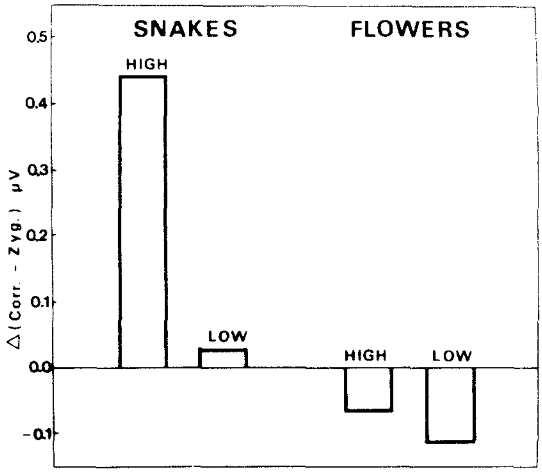

Figure 9. Facial EMG reactions, expressed as differential responding between the corrugator and the zygomatic muscles, to snakes and flowers for subjects relatively high and low in fear of snakes. From Dimberg, 1990b (permission to reprint received from the editor for *Scandinavian Journal of Psychology*).

tion. Thus, Figure 9 illustrates the mean EMG response scores for High and Low fear groups, exposed to snakes or flowers. As can be seen, it was only the high fear group that reacted with a "negative" response to snakes. Although the interaction did not reach significance, this effect was confirmed by specific comparisons among means indicating a larger reaction in the High as compared to the Low fear group to snakes. Note that the effect is specific to snakes. If high fear subjects were "negative" responders *in general*, they should have reacted with a negative response pattern even to flowers. But they did not.

It is important to note, however, that this study was based on only 9 subjects in each group and that the selection of subjects was not based on clinical criteria for snake phobia. Therefore the ratings in the high fear groups were only moderately high. However, even though these preliminary results should be interpreted with caution, they look promising for future research. Furthermore, these results were interpreted as showing that high fear subjects react with a negative facial response to snakes. Note, however, that the exposure of snakes preceded the rating of fear. Therefore, an alternative explanation could be that subjects in the high fear group rated themselves as more fearful *because* they had reacted with a negative response to the snake pictures. If this is true the causal relation between fear ratings and responding may be the opposite to that suggested in the present study. To investigate this question further, future studies should counterbalance the presentation of slides and fear ratings so that fear ratings precede the fear stimuli for some subjects.

To further explore whether facial EMG reactions differ between groups with specific fears, a second study was performed in which two groups, high and low in public speaking fear, were selected on the basis of their responses to a questionnaire (Dimberg & Christmanson, in press). The questionnaire was a Swedish translation (Fredrikson, 1983) of the Public Report of Confidence as a Speaker (Paul, 1966). The prediction was that high fear subjects should react differently to fear-relevant stimuli, that is to *social* stimuli, compared to low fear subjects. Thus, facial EMG was measured while both groups were exposed to angry and happy faces. In this experiment the subjects were also exposed to randomly ordered non-social visual stimuli such as geometric figures. As in earlier studies the results for the low fear subjects showed that happy faces elicited significantly more zygomatic than corrugator activity and angry faces tended to evoke more corrugator than zygomatic activity. The high fear group, on the other hand, did not discriminate between the stimuli as clearly as the low fear group. This absence of discrimination for the high fear group was particularly clear during a second experimental phase when subjects were required to rate the stimuli. That is, during this phase the subjects were first exposed to one presentation of the angry and happy faces and were instructed to rate the stimuli after the exposure. Low fear subjects reacted with increased zygomatic activity to happy faces and increased corrugator activity to angry faces but the high fear group did not discriminate between stimuli.

These results seem contradictory—why do subjects in the group high in social fear not overreact with corrugator activity when exposed to supposedly negative social stimuli? One way to interpret these data is from a social interaction point of view in which the facial muscles function both as a correlate to the emotional state and as a signal for emotional communication. Thus, alternative interpretations would be that the absence of differential responding between corrugator and zygomatic muscles in the high fear group is influenced by submissive behavior resulting in a facial reaction that carries aspects of an appeasing smile. A further interpretation may be that the facial response at least partly reflects mimicking behavior, to which subjects high in social fear are insensitive. Another explanation could be that the responses during the first exposure phase were obscured by the presentation of neutral non-social stimuli. Furthermore, during the second phase the reactions could be obscured by the specific instructions to rate the stimuli and it is possible that high fear subjects are more sensitive to such manipulations.

To investigate this issue further another study (Dimberg, 1990c) was performed in which the experimental design and procedure were more similar to that in the studies presented above. Thus, 16 subjects were exposed to angry and happy faces but *not* to neutral slides and the subjects were instructed only to pay attention to angry and happy faces. After the experiment the subjects were required to rate their fear of public speaking on a questionnaire. Based on these ratings subjects were divided, at the median, into high and low fear groups. Data for facial EMG responses are given in Figure 10. Note that the facial reaction, as in the preceding figure, is expressed as differential responding between the corrugator and the zygomatic muscles. Thus positive scores indicate more corrugator than zygomatic activity, and are interpreted as a "negative" emotional response. Negative scores indicate more zygomatic activity, that is a "positive" reaction. As can be seen in Figure 10 the high fear group discriminated between angry and happy stimuli in the sense that they reacted with a "negative" response to angry as compared to happy faces. The low fear group, on the other hand, discriminated between the stimuli by reacting with a "positive" response to happy as compared to angry faces.

In summary, these data indicate that the facial EMG technique appears to be sensitive in detecting different response patterns among subjects suffering from specific fears as well as in detecting differences

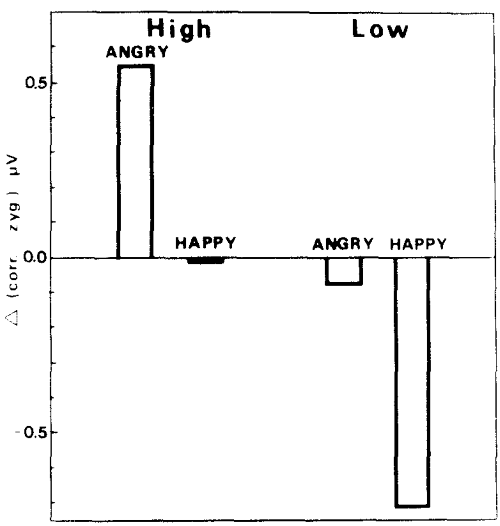

Figure 10. Facial EMG reactions, expressed as differential responding between the corrugator and the zygomatic muscles, to angry and happy faces for subjects relatively High and Low in public speaking fear. From Dimberg, 1990c.

between depressed and nondepressed patients (Schwartz et al., 1976).

Concluding Remarks

The aim of this paper was to review results from my laboratory, which were collected in an attempt to determine whether the facial muscle response is a general component of the emotional reaction and if the EMG technique is sensitive in detecting these responses. The basic experimental paradigm to explore these questions was to expose subjects to different emotional stimuli while their facial EMG activity was measured.

The research demonstrates that different visual emotional stimuli as well as auditory stimuli spontaneously evoke different and consistent facial EMG reactions. Second, it is possible to aversively condition facial reactions. Third, the facial EMG responses are consistent with how the subjects perceive the stimuli and their own specific emotions. Fourth, the facial response is, at least for aversive stimulation, congruent with responses evoked by the autonomic nervous system. Fifth, consistent with earlier studies, it was found that females are more facially expressive than males. Finally, the facial EMG technique appears to be sensitive to different responses among subjects with specific fears.

These results demonstrate that a broad range of external emotional stimuli spontaneously elicit different positive and negative phasic facial reactions. Thus, these data converge in indicating that facial muscle activity is a general component of the emotional reaction. This supports the proposition that our facial muscles constitute a readout system for emotional activity and the results are consistent with the theory that specific "affect programs" trigger biologically prewired facial expressions. The present research also demonstrates that the facial EMG technique can detect facial reactions to a broad range of external stimuli. This is congruent with findings from other laboratories in which the facial EMG technique has been used to detect affective reactions to visual stimuli (e.g., Cacioppo et al., 1986) as well as to detect facial muscle activity related to imagery induced emotions (e.g., Schwartz et al., 1976).

Though the present results are remarkably consistent with regard to the evoked facial reactions as well as to their relation to other components of the emotional response system, the results also raise some questions. For instance, in spite of the fact that angry faces and snake stimuli evoke analogous facial reactions, the accompanying autonomic responses tend to differ for snakes but not for angry faces when compared to their respective control stimuli. One may consider whether the "negative" reaction reflects the same emotional response in each study. The corrugator muscle, for instance, is active in several negative emotions such as fear, anger, and sadness (Ekman, 1979; Hjortsjö, 1970). It is possible therefore that angry faces and snakes evoke different emotional reactions. To investigate this question further, future studies should specifically compare reactions to faces and snakes, and recordings from several other muscle regions and ratings of specific emotions should be obtained.

It is also important to note that the present conclusions are based on between groups and between conditions comparisons. To evaluate the relation between EMG responsiveness and other aspects of the emotional response system more thoroughly, specific correlational data at the individual level should be collected. Such correlational data were obtained in the social fear study reported above (Figure 10; Dimberg, 1990c). Consistent with the prediction that angry faces evoke relatively more corrugator activity in subjects with high self-rated fear, the "negative" response pattern to angry faces correlated significantly with fear ratings, but the response to happy faces did not. Thus, the data in this study showed that the facial EMG activity evoked by negative social stimuli is correlated with self-rated social fear.

One important question concerns whether the facial muscle reaction is a necessary condition for emotion. For instance, in the facial feedback hypothesis it is proposed that the sensory feedback from facial muscles is a necessary condition for emotional experience to occur. A further related controversy is whether cognitive appraisal or physiological responding is more primary or important in the evocation of emotional reactions (e.g., Lazarus, 1984; Zajonc, 1980). One way to approach this question could be to study the time course of the different emotional components. However, the relatively long latency for autonomic responses was one of the main arguments against the classical "James-Lange" theory of emotion which proposed that peripheral physiological feedback was the important trigger for emotional experience to occur. Facial muscle reactions are probably much faster than autonomic responses and one may speculate as to whether future directions in emotion research can use the facial EMG technique to compare the response latency between the expressive and cognitive levels of emotional reactions. Some indication that facial reactions have relatively short response latency was obtained when re-analyzing data in the study in which subjects were exposed to facial stimuli (Dimberg, 1982). In this study the corrugator response to angry faces and the zygomatic response to happy faces were detectable as early as at the first second of exposure. This should be seen in light of the fact that the recording and scoring technique in this study was based on integrated EMG activity with a time constant of .47 s. This implies that the detected response pattern in reality must have been apparent before the end of the first stimulus second, which indicates that the facial reaction to emotional stimuli may be very fast.

In summary, the present research supports the proposition that facial muscle activity, detected as phasic facial EMG reactions, is a general component of the emotional response. This is consistent with the theory that "affect programs" trigger specific facial expressions. This is also congruent with the proposition that facial expressions have an evolutionary origin and consequently are part of our biological inheritance. The data also demonstrate that the measures from the different response systems were fairly coherent. This further emphasizes the notion that emotion is a multi-factor phenomenon, which may be simultaneously manifested in the expressive, the experiential, and the autonomic levels.

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Announcements

Fifth International Conference On Reversal Theory

From June 21–25, 1991, the Fifth International Conference on Reversal Theory will be held in Kansas City, Missouri. Developed by British psychologist Michael Apter, reversal theory is a new theory that accounts for inconsistency in motivations, personality, and behavior. The theory has been applied to psychopathology, psychophysiology, gambling, smoking relapse, and sports psychology. The theme for this first reversal theory conference to be held in the U.S. is Reversal Theory and Health.

For further information, including a reference list, instructions for paper submissions, and conference details, contact: Dr. Mary Cook, Program Chair, Midwest Research Institute, 425 Volker Boulevard, Kansas City, MO 64110 (816/753-7600, ext. 162).

Second International Conference on Biobehavioral Self-Regulation and Health

From 16–20 September, 1991, the German Research Society and the Association for Applied Psychophysiology and Biofeedback will sponsor the Second International Conference on Biobehavioral Self-Regulation and Health, entitled "Advances in Applied Psychophysiology," in Munich, Germany. The conference will include invited workshops, symposia, speakers, and posters on the psychophysiological treatment of cardiovascular disorders, central nervous system disorders, gastrointestinal disorders, pain, pediatric disorders, sleep disorders, stress-related disorders, and neuromuscular disorders. Submissions related to environmental hazards and ethical and philosophical issues are also welcome.

Please send poster and workshop submissions to: (Europe) Niels Birbaumer, Universität Tübingen, Behavioral Neuroscience Department, Gartenstr. 29, D-7400 Tübingen, FRG; or (USA) Ronald A. Seifert, Association for Applied Psychophysiology and Biofeedback (AAPB), 10200 West 44th Avenue, Suite 304, Wheat Ridge, CO 80033-2840 (303/422-8436). For general information about the conference, contact Francine Butler at AAPB (303/422-8436) or Rainer Schandry, Psychologisches Institut, Klinische Abteilung, Leopoldstraße 13, D-8000 München 19, FRG.