UNOBSERVABLE FACIAL ACTIONS AND EMOTION

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Abstract—*Surface electromyographic recordings in humans were first made less than 70 years ago, and the electromyographic study of covert facial actions during affect and emotion has less than a 20-year history. Despite the relative youth of facial electromyography, its use in combination with autonomic measures and comprehensive overt facial action coding systems has provided a sensitive and effective armamentarium for investigating emotion and affect-laden information processing. Research over the past decade has demonstrated that facial electromyographic activity varies as a function of the intensity, valence, and sociality of emotional stimuli and shows that facial electromyographic activity is slightly different in deliberately manipulated and spontaneous expressions of emotion. The multiply determined nature of facial actions and expressions, however, has limited the inferences that can be made about the psychological significance of facial electromyographic responses. These limitations have begun to recede in recent years as a result of advances in the psychometric properties of facial electromyographic measurements, the quantification of electromyographic waveforms and patterns, the conjoint measurement of facial electromyographic and electrocortical activity, the conceptualization of psychophysiological relations, and the formalization of psychophysiological inference.*

Among the hundreds of individual striated muscles in the human body, the muscles of facial expression have assumed a unique status in psychology since the seminal writings of Charles Darwin on the expression of emotion (Darwin, 1872/1873). Although there are multiple reasons for this unique status, two that have attracted considerable scientific research are the direct adaptive effects of facial actions (Ekman, 1971; Steiner, 1979) and the important communicative function subserved by these muscles (Andrew, 1965; Fridlund, 1991). The dynamics of facial configurations carry a variety of messages, and individuals are able to exercise considerable control over most of them. Classes of nonverbal messages carried by these facial configurations include *emblems* (symbolic communication, e.g., wink), *manipulators* (self-manipulative associated movements, e.g., lip bite), *illustrators* (actions punctuating speech, e.g., raised brow), *regulators* (communication modulators, e.g., head nod), and *emotions* (Ekman & Friesen, 1975). Regarding emotions, the states of happiness, surprise, sadness, fear, anger, disgust, and contempt have been linked to distinctive facial displays across cultures and with infants, whereas variability in the relationship between facial efference and emotion has been linked to several sources, including differences in the emotions evoked by a common stimulus, the timing of one or more emotional reactions, the social intention, and the idiosyncratic learning histories and culture-specific display rules of individuals (Ekman, 1989; Ekman, Davidson, & Friesen, 1990).

SENSITIVITY LIMITS

Analyses of overt facial actions in emotion have contributed in myriad ways to theory and research on emotion (see Ekman, this issue). However, many emotional and affect-laden information processes are not accompanied by visually perceptible facial actions, a fact that has limited the utility of analyses of facial actions in investigations of affect-laden information processing and emotion. Graham (1980), for instance, attempted to assess viewers' emotional responses to television advertisements using the overt facial action coding scheme of Ekman and Friesen (1978). Although the verbal responses differed to the stimuli, preliminary analyses revealed there were too few content-related facial expressions to make facial action analyses worthwhile.

This "sensitivity problem" has been diminished by the use of facial electromyography (EMG) (see Cacioppo, Losch, Tassinary, & Petty, 1986). Overt facial expressions are the result of varied and specific movements of the facial skin and connective tissue caused by the contraction of facial muscles. These movements create folds, lines, and wrinkles in the skin and the movement of facial landmarks, such as the brows and corners of the mouth. Although muscle activation must occur if these facial actions are to be achieved, muscle action potentials in the face can occur in the absence of any overt facial action if the activation of the muscles is weak or very transient or if the overt response is aborted sufficiently early in the facial action. Methods designed to measure the muscle action potentials (rather than the overt effects of the muscle action potentials) can provide a more complete record of the facial response throughout its entire dynamic range. Indeed, Freeman (1948) argued decades ago that this was the primary theoretical advantage of EMG for psychophysiological research; that is, somatic responses could be tracked

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This manuscript is dedicated to John T. Lanzetta, who passed away in the fall of 1989. John and his collaborators at Dartmouth College were instrumental in establishing the validity of facial electromyographic techniques in the measurement of emotion. We will always be grateful to him for both his seminal contributions and his friendship.

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throughout their development and thereby reveal the continuous seam binding apparently discrete overt behaviors.

Furthermore, the use of facial EMG in combination with overt facial action coding systems can reveal discontinuities in the transition from covert to overt somatic actions. Facial actions can serve deceptive as well as trustworthy communicative and emotionally expressive functions. The display rules and contingencies that govern overt facial expressions in social contexts may be less powerful when the efference is so subtle or fleeting as to be undetectable by observers. Discrepancies between facial EMG activity underlying covert versus overt facial expressions can therefore be of interest in much the same manner as are discrepancies between private and public actions.

FACIAL EMG ACTIVITY

Surface EMG recording in humans was first reported by Edmund Jacobson (1925, 1930), whose pioneering work linked the mental performance of an action (e.g., throwing a ball) with incipient actions over the skeletomuscles involved in the overt performance of the imagined action. Although isolated uses of *facial* EMG recordings can be found in the late 1950s and early 1960s (Whatmore & Ellis, 1959, 1962; Sumitsuji, Matsumoto, & Kaneko, 1965), the bulk of facial EMG research has been conducted over the past two decades. In an important early study, Schwartz and his colleagues (Schwartz, Fair, Salt, Mandel, & Klerman, 1976) found that clinically depressed subjects displayed higher levels of EMG activity over the brow (*corrugator supercilii*) muscle region and lower levels of EMG activity over the cheek (*zygomaticus major*) muscle region when they imagined unpleasant experiences than when they imagined pleasant experiences. A comparison group of normal subjects displayed a similar pattern of facial EMG response, with three exceptions: (1) the EMG response accompanying unpleasant imagery was attenuated in normal compared with depressed subjects; (2) the EMG response accompanying pleasant imagery was accentuated in normal, relative to depressed, subjects; and (3) when asked to imagine a typical day, normal subjects produced a pattern of EMG responses similar to that produced during pleasant imagery, whereas depressed subjects produced a pattern of EMG responses similar to that produced during unpleasant imagery.

In an extension of this early work to affect-laden information processing (Cacioppo & Petty, 1979), subjects were forewarned and, 1 min later, were exposed to a communication advocating a position with which they agreed or disagreed. Subjects exposed to the counterattitudinal communication showed less EMG activity over the cheek (*zygomaticus major*) muscle region and tended to show more activity over the brow (*corrugator supercilii*) muscle region than subjects exposed to the proattitudinal communication. A weaker form of this same pattern of facial EMG activity was found following the forewarning but prior to the presentation of the communication, as if subjects were thinking about the upcoming communication. Further early evidence that facial EMG was related to affect-laden information processing was provided by Teasdale and Rezin (1978). They investigated nine clinically depressed outpatients and reported that, although EMG activity over the brow region was unrelated to depressed mood, it was highly correlated ($r = +.81$) with the frequency of negative thoughts.

Research over the past decade has focused on further specifying the conditions under which facial efference, in the absence of socially perceptible expressions, can be used to infer the occurrence and extent of affect-laden information processing (Cacioppo, Petty, & Tassinary, 1989; Dimberg, 1990; Fridlund & Izard, 1983; Lanzetta & McHugo, 1989). In one study (Cacioppo, Petty, Losch, & Kim 1986), subjects were exposed to a series of slides of natural scenes that were pretested to vary from moderately pleasant to moderately unpleasant. Subjects viewed each stimulus for 5 s and rated how much they liked the depicted scene, how familiar the scene appeared, and how aroused it made them feel. Judgments of the video recordings of subjects' facial actions during the 5-s stimulus presentation indicated that the scenes were sufficiently mild to seldom evoke socially perceptible facial expressions. Nevertheless, analyses revealed that EMG activity over the brow (*corrugator supercilii*) and periocular (*orbicularis oculi*) muscle regions varied as a function of the valence and intensity of the subjects' affective reactions to the scenes: The more subjects liked a scene, the lower the level of EMG activity over the brow region; EMG activity was higher over the periocular region when moderately pleasant as opposed to mildly pleasant or unpleasant stimuli were presented. EMG activity over the cheek (*zygomaticus major*) muscle region also tended to be greater for liked than disliked scenes. Neither EMG activity over the brow region nor EMG activity over the cheek region covaried with reported arousal, nor did EMG activity over the perioral (*orbicularis oris*) region or a peripheral muscle region (*brachioradialis*) vary as a function of stimulus valence. Similar findings have been reported for stimuli that consist of either spontaneous expressions of well-known political leaders (McHugo, Lanzetta, Sullivan, Masters, & Englis, 1985) or posed expressions of unknown actors (Dimberg, 1982).

In an attempt to validate that the patterns of covert facial efference observed when subjects viewed static images or generated affect-laden images were similar to those observed during posed prototypical expressions, Smith, McHugo, and Lanzetta (1986) directly compared the facial muscle patterning of posed and imagery-induced expressions of emotion by both expressive and nonexpressive posers. With a few minor caveats, their data supported the hypothesis that the pattern of facial efference across the face was similar for both posed and image-induced expressions.

The reliability of the finding that induced affect leads to consistent changes in the pattern of facial efference has been further enhanced by experiments which explicitly asked subjects to inhibit or exaggerate their facial response to known positive and negative stimuli. In an illustrative study, 20 subjects briefly viewed slides of pleasant, neutral, or unpleasant scenes and people (Cacioppo, Bush, & Tassinary, in press). Facial EMG activity varied as a function of the affective valence of visual stimuli whether subjects privately viewed each slide (spontaneous expression condition), deliberately attempted to construct subtle facial expressive movements to communicate the affective valence of each stimulus (amplify expression condition), or deliberately attempted to inhibit any facial reaction that might signal the affective valence of each stimulus (inhibit expression condition). The configuration of facial EMG activation was generally similar across these instructional conditions, with EMG activity over the brow (*corrugator supercilii*) muscle region varying most consistently as a function of stimulus valence.

Of course, emotional expressions serve important communicative functions, and recent research has highlighted the important impact of the social context on facial responses (Englis, Vaughan, & Lanzetta, 1982; Fridlund, 1991; Jones, Collins, & Hong, 1991). In Fridlund's (1991) study, subjects viewed a pleasant videotape either alone, alone but with the belief that a friend nearby was occupied with another task, alone but with the belief that a friend was viewing the same videotape in another room, or with a friend. The EMG activity over the cheek muscle region increased as the sociality of the viewing context increased, but did not vary with reported emotion. This latter finding may be due in part to the relatively dramatic variations in social context and relatively narrow range of affective stimulation, and to the focus on smiling rather than, for instance, efference to the muscles in the upper face (see Ekman & Friesen, 1982).

MULTIPLE DETERMINISM

An important implication of the foregoing overview is that facial actions and expressions are multiply determined (Cacioppo & Tassinary, 1990). Some investigators have quantified facial EMG or overt facial activity for the purpose of drawing inferences about the presence and timing of specific emotions. Although research has demonstrated that specific patterns of facial EMG activity can reliably differentiate both the valence and the intensity of affective states, neither the forms nor the boundary conditions of the relationships between these classes of emotional experience and facial efference are currently known. It is only within carefully controlled assessment contexts that it has been possible to predict the pattern of facial efference based on self-reported global affective states (see reviews by Cacioppo, Tassinary, & Fridlund, 1990; Fridlund & Izard, 1983) or, more interesting, to predict the pattern of self-reported global affective states based on the temporal dynamics and spatial location of the concurrent facial EMG activity (Cacioppo, Martzke, Petty, & Tassinary, 1988).

Although it is certainly possible that a yet-to-be-performed microanalysis of the facial EMG response will provide unique signatures for specific emotions (Hess, Kappas, McHugo, Kleck, & Lanzetta, 1989), we believe there are simply too many potential psychological and nonpsychological antecedents, as well as environmental contexts, for one-to-one relationships between facial EMG activity and emotion to be the rule.

Despite this guarded conclusion, facial EMG has made it possible to investigate emotions and affective states that are so weak that autonomic activity (e.g., heart rate, skin conductance) and overt expressions are relatively unchanged (Cacioppo, Petty, Losch, & Kim, 1986). This achievement does more than open an avenue for investigating weak affective states: it enables investigators to examine the emergence of somatovisceral supports as the intensity of an emotion increases. For instance, facial EMG studies of weak emotions have yielded differential activity for the positive and the negative emotions, but finer differentiations among the emotions appear unreliable. Thus, two distinct conceptualizations of covert facial efference and emotion have been suggested: (1) The *microexpression* hypothesis posits the existence of emotion-specific patterns in the absence of overt expression, with the configuration of facial muscle activity emerging as visibly distinct expressions of emotion within an individual as emotional intensity increases (Brown & Schwartz, 1980; Haggard & Isaacs, 1966). (2) The *motor recruitment* hypothesis, in contrast, posits that facial efference varies only as a function of emotional valence at weak levels of emotional intensity, and that greater emotion-specific differentiation is achieved across the facial muscles at higher levels of emotional intensity (Cacioppo, Petty, & Marshall-Goodell, 1984; Cacioppo et al., 1989).

Geen (1989) recently provided data bearing on these hypotheses. Twenty subjects with acting experience were instructed to generate five emotions (happiness, sadness, anger, fear, and disgust) at four intensity levels (0%, 10%, 50%, and 90% of maximum) while EMG activity was recorded from surface electrodes over the medial and lateral forehead (*medial frontalis* and *lateral frontalis*), brow (*corrugator supercilii*), periocular (*orbicularis oculi*), nasal (*levator labii superioris*), and cheek (*zygomaticus major*) muscle regions. Heart rate, skin conductance, and vasomotor responses were also recorded to investigate whether emotion-specific autonomic patterns would be found after holding constant the factors of emotional intensity and imagined physical activity (see Ekman, this issue).

A test using truly covert facial efference proved difficult to achieve, a result that should favor the microexpression hypothesis.[1] Nevertheless, the results clearly favored the motor recruitment over the microexpression hypothesis. At the 10% level, contrasts (comparing facial EMG activity as a function of specific emotions) were significant for EMG activity over the brow, cheek, and medial forehead muscle regions. At the 50% level, the contrast for EMG activity over the nasal muscle region became significant, and at the 90% level, the contrast for EMG activity over the periocular region became significant.

The pattern of autonomic responses proved less reliable than the facial EMG

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[1] Specifically, naive judges were able to distinguish above chance the happy from the negative self-induced emotional states at the 10% intensity level; distinctions within the negative conditions were no better than chance at this intensity level, however. The fact that the facial expressions were observable in this study, but not in some of our previous work (e.g., Cacioppo, Bush, & Tassinary, in press; Cacioppo, Petty, Losch, & Kim, 1986), may be attributable to procedural differences. For instance, actors were used in Geen's study, and their task was to generate specific emotional experiences at designated intensity levels. In most previous research, subjects have been undergraduates who simply viewed mildly positive and negative slides.

activity. Skin conductance activity did not differ across emotional conditions in the fashion reported by Ekman, Levenson, and Friesen (1983). Instead, skin conductance tended to be highest for fear, a result that is consistent with Ax (1953). Analyses also revealed that heart rate differed across emotions in a manner consistent with a pattern reported by Ekman et al. (1983). Briefly, they reported heart rate was lower during happiness and disgust than during fear, sadness, and anger. Hence, Geen conducted a contrast to examine heart rate differences between these two groups of cells. The contrast was significant at the 50% and 90% levels of emotional intensity, but not at the 10% level of intensity. Although these data seem to conform to the results of Ekman et al., two caveats are in order. First, in contrast to Ekman et al., the mean change scores (from 0% intensity conditions) were positive for all emotions, indicating that the mere act of engaging in the emotional reliving task produced cardiac acceleration regardless of the type of emotion: the increases for happiness and disgust were simply less than the increases observed for the other emotions. Second, verbal ratings of task effort, which were collected following each trial, paralleled the emotion-specific patterns of heart rate increases. Hence, whether the heart rate data are related to emotion per se remains an open question.

A new line of research indicates that electrocortical activity might be used in conjunction with facial EMG to address one of the fundamental issues in human emotion research, that is, how to characterize voluntary versus spontaneous facial efference. Efforts to discover the cortical and autonomic activity reliably associated with discrete emotional states depend critically on theoretically based facial response criteria for deciding when in fact an emotion is said to occur (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). The validity of these somatic criteria may be compromised, however, by the fact that humans have excellent voluntary control of the skeletal musculature. Fortunately, reliable changes in ongoing electroencephalographic (EEG) activity preceding deliberate movements have been demonstrated (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Kornhuber & Deecke, 1965). Known as the *Bereitschaftspotential*, or readiness potential, these changes refer specifically to a monotonically increasing negative scalp beginning approximately 0.5 to 1 s prior to the onset of EMG activity in the task-relevant musculature. In addition, a few investigators have reported that this particular negative premovement potential is absent prior to either spontaneous laughter (Sumitsuji, 1975) or involuntary muscular spasms (Obeso, Rothwell, & Marsden, 1982).

In a recent experiment, we made a systematic attempt to evaluate the diagnostic validity of the readiness potential as a marker of deliberate, voluntary facial movement (Tassinary, Cacioppo, Geen, & Marshall-Goodell, 1991). In order to do this, we chose to use the human eyeblink as a model system for investigating four theoretically distinct antecedents. These antecedents were derived by crossing a process variable (deliberate vs. automatic) with a situation variable (elicited vs. occasioned). Briefly, the classes of blinks were *initiated* (i.e., constant foreperiod reaction time task using the blink as the timed response), *voluntary* (i.e., decision to blink under subject control within a restricted time window), *reflex* (i.e., mechanical tap to the glabella), and *spontaneous* (i.e., unsolicited blink). In the context of this 2 (deliberate vs. automatic) × 2 (elicited vs. occasioned) within-subjects experimental design, concurrent measurements were taken of the overt form of the blink and EEG activity from three midline scalp locations.

On average, the deliberate blinks were longer in duration than the automatic blinks, and the elicited blinks were larger in amplitude and characterized by faster proportional rise times than the occasioned blinks. More important, a reliable readiness potential was observed only prior to the voluntary blinks. Such blinks were indicated in the readiness potential by significantly greater peak negativity, larger area, and steeper slopes, compared with all other blink categories. These data suggest that the specificity of the relationship between facial efference and emotion may be improved by the conjoint measurement of particular event-related brain potentials and facial EMG activity; specifically, the presence of a significant readiness potential prior to a given facial action increases the likelihood that the observed facial action was intentionally executed rather than spontaneously emitted.

CONCLUSION

Developments in facial EMG over the past two decades have contributed to a solution of the sensitivity problem in studies of facial actions and emotion. The multiply determined nature of facial actions and expressions, however, has continued to limit the inferences that can be made about the psychological significance of facial EMG responses. These limitations have begun to recede in recent years as a result of advances in the psychometric properties of facial EMG measurements (Tassinary, Cacioppo, & Geen, 1989; Tassinary, Cacioppo, Geen, & Vanman, 1987; van Boxtel, Goudswaard, & Shomaker, 1984), the quantification of EMG waveforms and patterns (Cacioppo & Dorfman, 1987; Cacioppo, Marshall-Goodell, & Dorfman, 1983; Dorfman & Cacioppo, 1990), the application of multivariate procedures to quantify the spatial patterning of facial responses (Fridlund, Schwartz, & Fowler, 1984), the conjoint measurement of facial EMG and electrocortical activity (Davidson, this issue; Tassinary et al., 1991), and the formalization of psychophysiological inference (Cacioppo & Tassinary, 1990). We anticipate further progress in the field with the codevelopment of explicit quantitative models of the expressive system and theories of the dynamics of emotion.

Advances in our understanding of emotion may also be fostered by the adoption of two additional notions about the facial response system. First, the face represents a coherent, open communication system rather than merely a convenient site for the measurement of intrapersonal events. By coherent, we mean that the facial musculature is a self-contained system of muscles that is both anatomically and functionally distinct from the other muscle systems of the body. By open, we mean simply that the facial musculature is influenced by inputs and generates outputs that influence other systems. Thus, viewing the face as an open system makes the multiply determined nature of facial efference explicit, and modeling the various inputs and outputs (rather than championing any one of any subset of inputs and outputs) and the moderating variables governing their operation becomes a priority. Second, emotions are fundamentally dynamic events. Static patterns of intercorrelations in principle are inadequate to deal with the problems of dynamic organization, even when applied at the level of the individual. The conjoint measurement of facial EMG and events from other physiological (e.g., electrocortical, autonomic) systems across a range of emotional intensities may therefore contribute significantly to our understanding of the interdependence of and interaction among constituent processes in emotion, and to theoretical statements modeling the essentials of these relationships.

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