

Neuromuscular Circuits in Affect-laden Information Processing

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Abstract—Substantial evidence has accrued indicating the involvement of neuromuscular circuits in covert information processing. The physiological systems imparting *emotional tone* to covert processing, however, are less well understood. Reviewed here are findings from a variety of methodologies which suggest that somatic patterns, particularly in the face, reflect moment by moment emotional reactions. These findings imply neuromuscular involvement in affect-laden information processing; less conclusive, though suggestive, are data indicating that the proprioceptive feedback from these phasic and specific patterns of response are integrated cortically and influence covert processing and overt responding.

THE NEUROMUSCULAR CIRCUITS of the face and body provide the major pathways through which we act upon and learn about our environment. For instance, neuromuscular circuits, including feedback components, are important in movement and in object manipulation (Bernstein, 1966). Moreover, neuromuscular circuits appear to be involved in the comprehension and covert manipulation of symbols, particularly when the stimuli are new or complex (Bell, 1842; Jacobson, 1967; McGuigan, 1978; Osgood, 1957; Snyder & Pronto, 1952; Sokolov, 1971). The phasic components of neuromuscular activity, which are defined as transient changes in electromyographic (EMG) activity (Sokolov, 1968), manifest temporal and spatial patterns during information processing (e.g., Bills, 1927; Davis, 1939; Jacobson, 1930, 1932; McGuigan, 1971; McGuigan & Boness, 1975; Shaw, 1940). These patterns of somatic response are the result of the efferent component of the neuromuscular circuit and provide an observable measure of covert information processing. Furthermore the orchestration of these somatic patterns results in a reverse volley of proprioception that in many instances retains the specificity of the eliciting cognitive response (Faaborg-Anderson & Edfeldt, 1958; Hardyck & Pet-

rinovich, 1970; McGuigan & Winstead, 1974). This afferentiation represents the feedback component of the neuromuscular circuit and may be vital in various aspects of information processing and awareness, particularly when the S-R connection is not yet automated (McGuinan, 1978; Sokolov, 1969).

Research on neuromuscular circuits in information processing has, for the most part, focused on nonaffect-laden tasks. Less well understood are the neuromuscular circuits and somatic patterns evidenced during affect-laden information processing. More than a century has passed since Darwin (1872) compiled his observations of discrete somatic patterns during affect and emotion in his treatise, *The Expression of the Emotions in Man and Animals*. And contemporary research indicates that discrete albeit covert somatic patterns differentiate among the various subjective states of affect and emotion. This and the research on nonaffect-laden processing collectively yield the intriguing notion that discrete neuromuscular circuits provide proprioceptive feedback during cognitive and affective processing, and that the feedback within these circuits are integrated continuously in the brain, contributing to covert processing and subjective experience. At this stage of methodological development in psychology, we can offer only correlative evidence regarding this thesis. Our purpose, here, then, is modest. We shall consider briefly the evidence contraindicative of the once (and still) popular notions that (a) somatic activity in response to an emo-

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tional stimulus is diffuse and undifferentiated (*e.g.*, Cannon, 1929), and (b) somatic activity is involved in affect and emotion only insofar as it influences visceral responses, which alone yield feelings and emotions (Lange, 1885; Wenger, 1950). We review here the behavioral and electromyographic evidence that somatic patterns are a component of affect and emotion, and we discuss briefly the possible nature and function of the neuromuscular circuits involved in affect-laden information processing.

Early Observations of the (Somatic) Expression of Emotion

Casual observations of human behavior long ago led to the belief that postural and/or facial expressions differentiated emotional states. Some 2500 years ago, actors at the Dionysian Theater wore facial masks from which the audience inferred the actors' emotional state or disposition. Yet in 1840, Müller stated that "the bases of the relations of the facial muscles to specific emotions are completely unknown" (Peiper, 1963), a statement that characterized the state of knowledge for scores of years hence. The first empirical treatise to address this issue appears to be Darwin's (1872) collected observations of emotional expressions. In this work, Darwin provided evidence that specific somatic patterns in emotion, particularly in the face, were universal as indicated by their commonality among various cultures. He noted also the similarity of somatic patterns in emotion between man and animals, the antithetical nature of the somatic patterns for pleasant and unpleasant emotions in man and animals, and the possible functional significance of the various somatic patterns. Regarding this last point, Darwin held that: "The free expression by outward signs of an emotion intensifies it. On the other hand, the repression, as far as possible, of all outward signs, softens our emotions" (1872). And in a subsequent section of his text, Darwin stated "Most of our emotions are so closely connected with their expression that they hardly exist if the body remains passive."

In 1884, James put forth his theory of emotions. In his original statement, he proposed that visceral, glandular, and muscular responses were all important determinants of feeling states. James considered the glands and viscera as too undifferentiated in their actions to distinguish emotional states, and relied heavily upon the feedback from the unique postural and facial expressions to differentiate the emotions (Izard, 1971). "If our hypothesis be true, it makes us realize more deeply

than ever how much our mental life is knit up with our corporeal frame" (James, 1884). As Izard (1971, 1976) notes, James' later writings focused on the role in emotions of the viscera. Perhaps for this reason James (1884) is so often misinterpreted with respect to the role of somatic patterning.

Similar positions were espoused by Souriau (1907; McGuigan, 1978) and by F. H. Allport (1924). Souriau observed that different emotional states were accompanied by different physical appearances, particularly in the face, and suggested that the somatic expression *was* the emotion. Hence, his position was a blend of James' theory of emotion and the motor theories of thinking proposed by his contemporaries (*e.g.*, Dunlap, 1912; Watson, 1913). Allport (1924) believed that affect and emotion were different from, but the result of, the fusion of facial, postural, and visceral proprioception. "We propose that the differentiating factor arises from the stimulation of the proprioceptors in the muscles, tendons, and joints of the somatic part of the organism: and that afferent impulses from these somatic patterns of response add to the autonomic core of affectivity the characteristic sensory complexes by which one emotion is distinguished from another of the same affective class" (Allport, 1924). And Allport, like James (1884), believed that inhibiting the muscular component of the emotion would attenuate or disrupt the emotion (see also Bull, 1951).

In sum, the notion of unique neuromuscular involvement in the various psychological expressions of emotion has a rich intellectual history and anecdotal support. We next consider the behavioral data bearing upon this notion.

Behavioral Evidence of Somatic Patterns

The object of the studies reviewed in this section is to determine whether or not unique overt facial and/or postural expressions result from the presentation of stimuli of various emotional natures. Much of the early research yielded negative results (*e.g.*, Landis, 1924a, 1924b) only later to be found deficient methodologically (cf. Davis, 1934; Izard, 1971). Two methodological issues that were especially problematic were as follows: (a) Complex stimuli (*e.g.*, paintings, classical music, pornography, electric shock) were employed which elicited a variety of different emotional reactions, between individuals or sequentially within an individual. This made the matching of an "emotional stimulus" with "an emotion" difficult; and (b) The emotional reac-

tions that *were* reported often appeared to be mixtures of several more basic "primary" emotions (e.g., fear, anger).^{*} These mixed or "secondary" emotions appear as mixtures of somatic patterns which may have been too subtle or transient for reliable identification in the early studies.

Ruckmick (1921) illustrated a method used to circumvent many of the problems of the early research. Subjects were shown photographs of facial expressions, each of which represented a standard emotional response. Subjects then were asked to judge which emotion was displayed. Affirmative results would signify that unique somatic patterns accompanied emotions, at least in their extreme form; negative results would indicate that somatic patterns were not unique, that they were too fleeting or subtle for observation, or that persons could not distinguish among them without training. The standardization of stimuli greatly improved the accuracy of the subjects' judgments of emotional expressions (e.g., Frois-Whittmann, 1930), though minimal accuracy was still reported when numerous expressions were employed (Feleky, 1924). Woodworth (1938) contributed greatly to the clarification of this research when he noted the accuracy of judges at classifying primary emotions. Investigators whose subjects inaccurately judged the depicted emotion typically employed facial expressions for all types of emotions while failing to distinguish between primary and secondary emotions. Much subsequent research noted and elaborated on this distinction between primary and secondary emotional expressions and thereby confirmed the existence and identifiability of unique overt somatic patterns for the primary emotions (e.g., Hanawalt, 1944; Schlosberg, 1952).

The possibility existed, too, that unique somatic patterns were evident in the various secondary emotions, but that subjects could not distinguish among them. Subjects *can* learn to increase their accuracy of judged emotional expressions, e.g., Gates (1923, 1925) found that aging in children resulted in fewer judgmental errors. Similarly, Mittenecker (1960) found that the accuracy of subjects within a single session improved when feedback was provided about the accuracy of their previous judgments. Hence, the discouraging results for judgmental accuracy in

^{*} Primary emotions possess the following characteristics (Izard, 1971): (a) manifestation in some form at all evolutionary levels, (b) some relevance to basic adaptive processes, and (c) behavioral definitions. Secondary emotions may possess some but not all of these characteristics.

classifying secondary emotions may reflect the subjects' poor ability to discriminate the more subtle distinctions, rather than the absence of discrete somatic patterns for secondary emotions (cf. Ekman, Friesen, & Tomkins, 1971).

Finally, the argument for the existence of discrete somatic patterns would be more compelling if common patterns for the emotions could be demonstrated. Several basic tacks have been taken in this search: (a) Standard photographs of the various emotions are shown to subjects from various cultures, and subjects are asked to identify the emotion displayed; (b) Subjects from different cultures are asked to imagine various emotion-producing events, and similarities in their expression are studied; and (c) Congenitally blind children are observed during various emotional states to assess whether or not "characteristic" facial activity is displayed. Impressive consensus has been found in the cross-cultural research (Ekman & Friesen, 1975) and in the research of the congenitally blind (Fulcher, 1942; Eibl-Eibesfeldt, 1972) for the discrete somatic representation of the primary emotions: "... the fundamental emotions of man are a product of evolutionary-genetic processes ... each of these emotions has a characteristic expression or pattern which conveys particular meaning or information for the expressor and the perceiver" (Izard, 1971).

Given the existence of discrete somatic patterns in emotion, we move next to the question of their function in information processing and their contribution to experience. In the following section we examine the research about the speed, sensitivity, and specificity of these somatic patterns to determine if the afferentiation from their manifestation could potentially provide emotional tone for, or an affective component to, information processing.

Neuromuscular Circuits in Affect-Laden Information Processing

Spencer (1890) argued that there was interdependence between thought and emotion, that every cognition was more or less agreeable or disagreeable, and that the nature of the interdependence determined in part the selection of the overt response:

... only in those rare cases in which both its terms and its remote associations are absolutely indifferent, can an act of cognition be *absolutely* free from emotion. Conversely, as every emotion involves the presentation or representation of objects and actions; and as

the perceptions, and by implication the recollections, of objects and actions, all imply cognition: it follows that no emotion can be *absolutely* free from cognition (Spencer, 1890).

Contemporary theories of affect and emotion are in fundamental agreement with Spencer's analysis in that *cognitions and affects* are seen as interacting in some complex manner to yield experience and an overt response (e.g., Izard, 1976; Janis & Mann, 1977; Petty, Ostrom, & Brock, in press). However, the mechanisms by which emotional tone is imputed to information processing are not well understood. Visceral and glandular reactions are too slow and undifferentiated to provide the kind of *continuous* neural coding of affect that is implied in these theories. But as noted in the previous sections, feedback from the skeletal musculature, particularly in the face, can distinguish between the basic affects and may serve as a mechanism by which this information is recycled to the brain. The brain then may integrate the various affect-specific and cognitive-specific proprioception it continuously receives and thereby alters the subsequent efferent flow and the experience.

But these notions assume that the somatic patterns of the face can occur covertly and with incredible speed. In a study of information processing, McGuigan and Boness (1975) investigated the time lapse between a stimulus and a response in a simple reaction-time task. This task requires a simple percept, decision, and overt response. Hence, the time delay found in this study provides information about the lower limit of the time range for somatic proprioception in covert information processing. If our notions are correct, that is, if neuromuscular circuits encode and generate neural codes about affect for brain processing, and if this information then is combined with the somatic proprioception of cognitive responses, it seems to require that the discrete somatic expressions of affect and emotion be as quick to manifest as are the somatic expressions of covert information processing. McGuigan and Boness (1975) found mean overt response to the reaction-time task was 225 msec, and the mean covert (EMG) response in the finger used to press the microswitch preceded this overt response by 40 msec.

Wieser (1961) has provided pertinent information about the temporal characteristics of overt facial activity. He employed high speed photography (1000 frames per second) in a study of the startle response, which was elicited by an unexpected gunshot. His findings included: (a) eye-closing was the first of a sequence of reactions,

being evidenced at an average delay of 87 msec; (b) the next observable response was the onset of muscular contraction in the neck, evidenced at an average delay of 99 msec; (c) the opening of the mouth followed next in the sequence, with an average delay of 122 msec from the gunshot; and (d) reactions from the shoulders, arms, and body followed, but not until an average of 233 msec had passed since the stimulus onset. Although this study illustrates the potential for micro-momentary facial expressions, the best evidence that these fleeting expressions actually occur was provided by Haggard and Issacs (1966). While scanning motion picture films of psychotherapy interviews, Haggard and Issacs detected unique facial expressions which appeared and disappeared within the span of 125–200 msec. "... occasionally the expression on the patient's face would change dramatically within three to five frames of film (as from smile to grimace to smile), which is equivalent to a period of from one-eighth to one-fifth of a second" (Haggard & Issacs, 1966).

Hence, the proprioception from the discrete patterns of facial activity appear to be rapid enough to provide useful feedback for information processing as they manifest as quickly as the EMG responses studied by McGuigan & Boness (see also, Jacobson, 1967). Moreover, following the findings of McGuigan and Boness (1975), these reaction times may be inflated since overt facial changes were assessed rather than the initiating covert electromyographic responses. Indeed, Bickford, Jacobson, and Cody (1964) obtained EMG response latencies to an auditory stimulus of 8 msec in the neck, 25 msec in the arm, and 40 msec in the leg.

The notion that the neuromuscular circuits primarily from the face impute a relatively continuous emotional tone further assumes that specific covert patterning in the face exists in the normal course of imagining, anticipating, listening, thinking, and so forth, and that these patterns are detectable though perhaps not by the casual observer. Electromyographic procedures have been used to examine these discrete patterns and have provided evidence that favors this formulation (e.g., Schwartz, 1975).

Perhaps the first investigator to relate electromyographic (EMG) activity to the emotional experience was Jacobson (1927). Jacobson trained his subjects in progressive relaxation, obtaining near zero levels of muscular tension in some subjects. He found that the elimination of neuromuscular activity appeared to be incompatible with various mental processes, including affect and emotion. About 20 years later, Strother

(1949) conducted a study "to determine the relation between the reading of material expressive of emotion and concomitant muscle action." However, Strother monitored only the EMG activity of the arms and legs while subjects read aloud several excerpts that had been selected for their emotion-eliciting characteristics. He found little evidence of patterning from these EMG sites and that, in descending magnitude, muscular tension was exhibited for fear, hate-anger, happiness, and tranquility-reverence.

It was not until the recent investigations by Schwartz, Fair, Salt, Mandel, and Klerman (1976a, 1976b) that covert EMG patterns of the face during affect and emotion were examined and observed. In the first study (Schwartz *et al.*, 1976b), twelve normal and twelve depressed persons were instructed to generate happy, sad, or angry imagery while continuous EMG recordings were obtained from the masseter, depressor, frontalis, and corrugator muscle regions. They found that unique patterns of neuromuscular activation and inhibition were displayed for the self-generated images. And importantly, these patterns were "covert" in the sense that neither the subject nor an observer could detect these somatic patterns.

When these subjects were asked to imagine a "typical day," an instruction that was included originally as a control imagery period, the largest difference between the normal and depressed subjects was manifested. The normal subjects displayed a "miniature happy pattern" whereas the depressed subjects displayed a pattern more similar to that obtained during sad imagery. Schwartz *et al.* (1976a) replicated and extended this initial study to determine the effect of instructions to "feel" versus "think" about happy or sad images. EMG activity from the corrugator, zygomatic, depressor, and mentalis muscle regions was monitored continuously for 12 normal and 12 depressed subjects. They found that differential patterns of facial activity were obtained for the happy and sad conditions, that the "feel" instructions produced greater expressive differentiation than did the "think" instructions, and that depressed subjects relative to the normal subjects displayed an exaggerated pattern for the sad condition and an attenuated pattern for the happy condition.

These studies demonstrated neuromuscular involvement when imaging emotional experiences and provided a means by which to explore the existence of unique neuromuscular coding during affect-laden information processing: that is, when cognition and affect interact to influence behavior and yield an experience. We had been

investigating which of a variety of psychophysiological measures best predicted the cognitive activity that accompanies attitude change (Cacioppo, 1979; Cacioppo, Petty, Snyder, Braccio, Calibrese, & Quintanar, 1979). For instance, persons were forewarned of an impending counterattitudinal communication, such as "You will hear a taped message in which the university president advocates that student tuition be increased \$25 (\$100, \$300) per quarter." Heart rate, speech (lip, chin, and throat) and back muscle tension, respiration, and cephalic pulse amplitude were monitored, and afterwards, subjects listed what they had been thinking during the preceding few minutes. The results revealed that as communication discrepancy increased, counterarguing (*i.e.*, unfavorable thoughts about the advocacy) increased, the production of favorable and neutral/irrelevant thoughts decreased, and agreement with advocacy decreased. Total thought production, however, remained constant. When the psychophysiological results were analyzed, we found that increased speech EMG and cardiac activity, previously found to accompany fairly neutral types of problem solving activity, also occurred in the minute following each forewarning. That is, it appeared the subjects were engaging in anticipatory cognitive activity in preparation for the upcoming attack on their belief system, a hypothesis supported by recent research (Cialdini, Levy, Herman, Kozlowski, & Petty, 1976; Petty & Cacioppo, 1977, 1979; Ronis, Baumgardner, Leippe, Cacioppo, & Greenwald, 1977). Moreover, the excitation of the speech musculature was probably not due to general body tension, since our measure of trapezius EMG activity demonstrated a stable and quiescent level of activity throughout the experiment. Furthermore, the affective nature of the cognitive responses generated by the subjects were not distinguished by analysis of speech EMG activity.

These findings provide evidence for neuromuscular involvement in affect-laden processing, but the involvement was not specific to the type of affects displayed. That is, speech EMG activity appeared to be involved in the cognitive (or semantic) rather than the affective aspects of information processing (*cf.* Cacioppo & Petty, in press-b, c).

To determine if neuromuscular involvement in affect-laden information processing also existed, as we hypothesize here, we replicated and extended this investigation by forewarning and presenting either a proattitudinal, counterattitudinal, or neutral advocacy to subjects (Cacioppo & Petty, in press-a). This time,

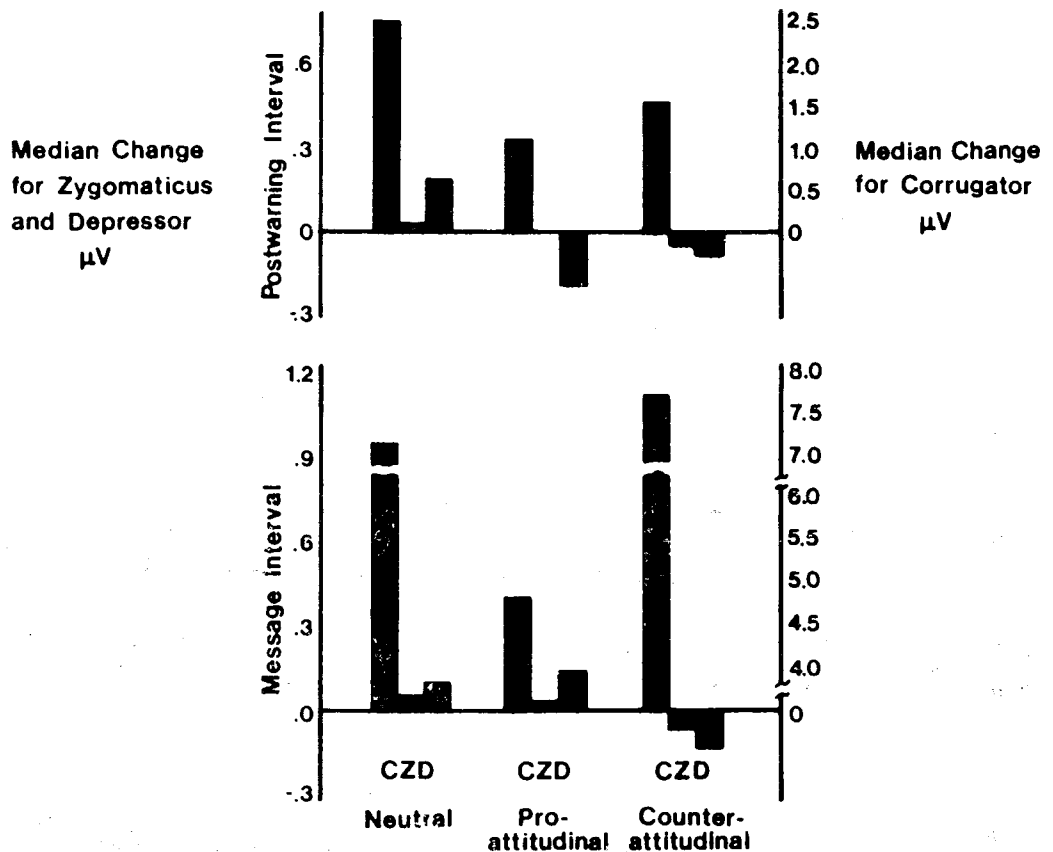


FIG. 1. Changes from baseline for corrugator (C), zygomatic (Z), and depressor (D) EMG activity during postwarning-premessage (top panel) and message (bottom panel) intervals. The data are displayed separately for subjects who anticipated and heard the neutral ($N = 12$), proattitudinal ($N = 24$), and counterattitudinal ($N = 24$) advocacies. Adapted from Cacioppo, J. T., & Petty, R. E., *J. Person. Soc. Psychol.* in press-a.

however, we continuously monitored the EMG activity from the corrugator, zygomatic, depressor, and mentalis muscle regions on the left side of the face (cf. Sackeim, Gur, & Saucy, 1978) using sixty male undergraduates. We expected discrete covert somatic patterning in the facial muscles, and we expected this patterning would be related to the idiosyncratic cognitive responses generated in anticipation of and in response to the presentation of the advocacy. Since we were uninterested in the overt facial expressions that might have been displayed, we programmed a PDP-8I minicomputer to disregard any sizeable (overtly observable) EMG responses. We found that subjects liked more and generated more favorable thoughts and fewer counterarguments to the pro- than to the counter-attitudinal communications, but that the pro-attitudinal and neutral communications (the latter concerned an archeological dig) were evaluated and processed similarly. And we found mentalis EMG activity to increase during the anticipation of the counterattitudinal advocacy (replicating

our previous finding) and during the presentation of all communications: but, as in the previous study, mentalis EMG activity did not differentiate between agreeable and disagreeable covert information processing. The crucial test, however, was whether or not our findings would be in agreement with Schwartz *et al.* (1976a, 1976b) observations of EMG patterning in the remaining EMG sites.

As is evident in Figure 1, we found the expected somatic patterns during both the anticipation and presentation of the advocacy. Additionally, we found significant relationships between the affective nature of the thoughts subjects listed (Cacioppo, Harkins, & Petty, in press) and the pattern of facial EMG activity displayed. And we found that the discrete patterns displayed became more apparent or accentuated when the stimulus was actually presented than when it was only anticipated (Cacioppo & Petty, in press-a).

Together these results suggest the existence of rapid, covert, and differential neuromuscular involvement during spontaneous affect-laden in-

formation processing. Hence, neuromuscular circuits involving facial and postural muscle regions appear to be able to carry specific and useful neural codes concerning affect back to the brain. There they may be integrated with input involving cognition and contribute to the subsequent efferent flow involving cognitive and emotional activity and overt behavior. Izard's (1971, 1976) neurophysiological theory of emotion posits such self-regulated internal feedback loops. The neurophysiologic formulations of Arnold (1960), Gellhorn (1964), and Tomkins (1962) likewise possess neuromuscular circuits serving the conscious experience of emotion (*i.e.*, "feeling"):

The efferent aspect of this neural activity innervates the striate muscles involved in the facial-postural patterning of the given emotion. If the neuromuscular activity runs its normal course, the given emotion is represented by a physical patterning of musculature (primarily facial, secondarily postural and locomotor) which is a source of cues and information both to the subject having the emotion and to any observer capable of interpreting the cues. . . . If the feedback follows a normal course it generates via the affected brain areas the subjective experience . . . which follows from the original neural activity and the facial pattern. At this level, emotion may exist in consciousness or awareness, independent of cognition (Izard, 1971).

In sum, the somatic pattern reflects an emotional reaction which then feeds back for cortical integration, generates the subjective experience and perhaps guides further cognition, emotion, and action.†

Conclusion

Historically, monistic philosophies have held that psychological phenomena are bodily processes. More recently, researchers have argued that neuromuscular circuits contribute to covert information processing and, presumably, to subjective states or experience. Our purpose here

† According to Izard (1971, 1976), the activity of the autonomic and glandular systems, which are too slow and diffuse to constitute unique emotions, provide a less specific auxiliary function in emotion. Izard (1976) explains the misconception regarding the role of these processes in emotion as follows: "Since (changes in visceral and glandular activity) can demand more of the individual's attention than impulses from the face, it is easy to infer that they are the real 'cause' of emotion. . . ." Thus, the early misconceptions were due to misattribution.

was to extend this notion by examining the neuromuscular involvement in emotion, affect-laden information processing, and experience. No definitive answer from this review is offered as the needed methodologies for conclusive empirical tests do not exist presently (McGuigan, 1978). However, the current data support several hypotheses: (a) reciprocal influence via neuromuscular circuits exists between bodily and cortical processes; (b) distinct neuromuscular circuits are involved in the transmission of neural codes for cognition and/or affect; (c) these neural codes are sensitive, phasic, and specific to the eliciting stimulus (or class of eliciting stimuli), and fairly universal to mankind; and (d) these disparate neural codes may interact or be combined in the brain in some complex manner, with possible effects on the (i) subsequent efferentiation to glands, effectors and organs; (ii) selection of an overt response; and (iii) experience.

Although further research is necessary to test these individual hypotheses, the evidence does favor the notions that psychological phenomena are aspects of biological processes that include peripheral as well as central nervous system activity.

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