CONSCIOUSNESS AND COGNITION 2, 237–254 (1993)

Consciousness, Volition, and the Neuropsychology of Facial Expressions of Emotion

DAVID MATSUMOTO[1] AND MIJA LEE

Department of Psychology, San Francisco State University, 1600 Holloway Avenue, San Francisco, California 94132

Although we have learned much about the neuropsychological control of facial expressions of emotion, there is still much work to do. We suggest that future work integrate advances in our theoretical understanding of the roles of volition and consciousness in the elicitation of emotion and the production of facial expressions with advances in our understanding of its underlying neurophysiology. We first review the facial musculature and the neural paths thought to innervate it, as well as previous attempts at understanding the neural control of facial expressions of emotion, focusing on the voluntary–involuntary dichotomy and studies of hemispheric specialization. In the second section, we discuss four major aspects of the psychology of facial expressions of emotion that have particular import to their neurophysiological substrates. We offer these as a starting point for a better integration of psychological and neurophysiological perspectives in considering the neuropsychological control of facial expressions of emotion.

Previous attempts at understanding the neural control of facial expressions of emotion have relied to a large degree on differentiating between voluntary and involuntary expressions and making inferences about the underlying neurophysiology involved in these two types of expressions. Our understanding of the neural control of facial expressions of emotion is undoubtedly better now than ever before. But, theoretical and empirical work on this topic cannot ignore improvements in our understanding of the role of volition with respect to emotion and expression. Different degrees of voluntary control and consciousness involved in the production of facial expressions suggest a more complex picture of the neural circuitry.

We contend that advances in our theoretical understanding of the nature of volition and consciousness in the production of emotional expressions must be integrated with advances in neurophysiology. We do not discount research using simple models of volition (e.g., the voluntary vs involuntary dichotomy) to date. Rather, we suggest the need for a better integration of two literatures, both of which are large, complex, and somewhat confusing. If we are to improve our understanding of this complex neuropsychological process, efforts at better integration must occur.

In the first section of this article, we provide an overview of the facial musculature and the neural paths innervating it. More complete reviews of the neural circuitry currently thought to innervate the facial muscles are available elsewhere

[1] To whom reprint requests should be addressed.

1053-8100/93 $5.00

(e.g., see Kuypers, 1987; LeDoux, 1987; Rinn, 1984). The presentation here is meant to serve solely as a brief introduction. We summarize two ways in which the neural control of facial expressions has been conceptualized: the voluntary–involuntary distinction and hemispheric specialization (Hager, 1982; Rinn, 1984).

Second, we focus on four major topics that have particular import to our understanding of the neurophysiological substrates of facial expressions of emotion. Each area is related to issues of volition and consciousness with respect to facial expressions. Other behavioral systems are undoubtedly involved in emotional responses, such as gaze, pupil dilation, voice and speech utterances, and body movements. For the purposes of this article, however, we consider only facial expressions of emotion and the influence of volition and consciousness on them. We offer these as a starting point for a better integration of psychological and neurological perspectives.

THE FACIAL MUSCULATURE AND THE NEURAL PATHS LEADING TO IT

The Facial Musculature

The face contains over 40 anatomically separate muscles, most of which are attached on one side to bone, and on the other side to facial skin or fascia. Most facial muscles do not move bone and ligaments; Rinn (1984) has suggested that they are specialized for communication and expression. A small group of muscles (e.g., temporalis, masseter) do move skeletal structures and are involved in facial acts such as chewing as well as expression. These two general groups of muscles use different neural tracts (Rinn, 1984) and have somewhat different evolutionary origins (Redican, 1982). Finally, the face is one of the few areas in the body that includes muscles that are unattached to bone on either side (e.g., orbicularis oris, orbicularis oculi).

Most facial muscles contract as a single, functional unit. Some muscles, however, contract only in combination with other anatomically separate muscles (e.g., the corrugator muscle group). Others have different functional contractions even though they are part of the same anatomic unit. The frontalis muscle, for example, can be moved only in the middle of the face, raising the inner corners of the eyebrows, or in its outer portions, raising the outer corners of the brows. When the entire brow is raised, both the inner and the outer portions of the frontalis muscle are jointly contracted. Facial measurement systems should rely, therefore, on functional rather than structural anatomy [e.g., Ekman & Friesen's, 1978, Facial Action Coding Systems (FACS)].

The face contains over 40 functional muscle units, each producing a different appearance change. In addition each functional action unit (or AU in Ekman & Friesen's, 1978, terminology) can be innervated to different degrees of intensity or laterality and with different timing characteristics (i.e., onset, apex, and offset). The large number of AUs, along with their timing and intensity capabilities, allows for a rich and complex behavioral repertoire, involving literally thousands of expression combinations.

The Facial Nerve

Within the nervous system, upper motor neurons (UMNs) carry impulses from motor centers in the brain to the brain stem or spinal cord. Lower motor neurons (LMNs) carry the impulses from the brain stem or spinal cord to the muscles themselves. Two cranial nerves—the fifth and seventh—house the LMN tracts that innervate the facial muscles. Their functions are quite different.

The fifth cranial nerve (the trigeminal nerve) innervates the temporalis, masseter, and the internal and external pterygoid muscles, which manipulate the jaw in chewing movements. In contrast, LMNs emanating from the seventh cranial nerve (the facial nerve) do not move skeletal structures; they primarily innervate muscles attached to facial skin and fascia. Because these muscles produce facial expressions per se, the (seventh) facial nerve has received the most attention.

The facial nerve has three separate parts, only one of which concerns us here. Each is apparently controlled by three different brain stem nuclei that contribute fibers to the facial nucleic tract. One, the superior salivatory nucleus, innervates the lacrimal and salivary glands. Another, the nucleus solitarius, contributes sensory fibers that carry taste information from the tongue. The third includes fibers innervating the facial muscles and begins in a small cluster of cell bodies located in the brain stem at the level of the pons. This cluster comprises the motor nucleus of the facial nerve.

The motor nucleus of the facial nerve originates in the facial nucleus and runs via the bony facial canal in the temporal bone through the parotid gland (van Gelder & van Gelder, 1990). There is considerable interindividual variation in the course of the peripheral branches of the facial nerve, and in the specific muscles innervated by each branch. The main trunk of the nerve divides first into an upper and lower branch, known as the temporofacial and cervicofacial divisions, respectively, shortly after emerging on the face just in front of the ear. The cervicofacial division further subdivides into three branches—the buccal, mandibular, and cervical branches, all of which innervate muscles in the lower face. The temporofacial division further subdivides into the zygomatic and temporal branches, which innervate muscles in the middle and upper face. Although smaller branches exist, these five are primarily responsible for most visible facial expressions.

Adjacent branches communicate with each other through a network called the pes anserinus or parotid plexus. Individuals vary in the exact nature of these connections, however, making valid, cross-individual description of the neural control of specific muscles quite difficult (Harker & McCabe, 1977).

Innervation of the Facial Nerve

The facial nerve receives impulses from multiple brain areas, including the pyramidal (with its corticobulbar and corticospinal components) and extrapyramidal tracts. These include direct and indirect corticobulbar pathways to the facial nucleus (Brodal, 1981; Noback & Demarest, 1975), direct fibers from the contralateral red nucleus, and connections from several areas of the limbic system. In addition, despite the anatomical independence of different brain areas, many areas most likely share functional interdependence. The influence of the basal ganglia on facial motility, for example, is exerted via the premotor and motor areas of the cortex, rather than by descending projections to the brain stem itself.[2] Also, both the limbic and the extrapyramidal systems include large areas of the neocortex, and are not necessarily subcortical. Neural connections to the facial nerve are discussed in much more detail elsewhere (e.g., Kuypers, 1987; LeDoux, 1987; Rinn, 1984), and interested readers are referred to these sources.

The Neural Control of Facial Expressions: The Voluntary–Involuntary Distinction

The neuroanatomical distinction between voluntary and involuntary facial expressions is a well-established principle of clinical neurology (Monrad-Krohn, 1924, 1927; Karnosh, 1945; Dejong, 1979; DeMyer, 1980; Tschiassny, 1953). This distinction can be considered a starting point in our understanding of the underlying neural control of facial expressions of emotion. Voluntary facial expressions are thought to emanate from the cortical motor strip and course to the facial nucleus through the pyramidal tract (i.e., the corticobulbar projections); impulses for involuntary facial expressions result from innervations along the extrapyramidal tract (Rinn, 1984).

Rinn (1984) cites four lines of evidence supporting the neuroanatomical distinction between voluntary and involuntary expressions. One is based on observations of patients with injury to the motor strip or the corticobulbar projections, resulting in facial hemiparalysis; typically, such patients cannot contract the facial muscles on command, but can produce spontaneous expressions. Another is based on observations of patients with lesions in the extrapyramidal system, especially the basal ganglia; these patients can move their facial muscles on command, but lose all spontaneous movements. The third comes from observations based on a surgical procedure known as facial nerve anastomosis, which involves the splicing of the spinal accessory nerve that supplies the shoulder onto a severed motor root of the facial nerve; these patients can regain volitional control over facial movements, but spontaneous emotional expressions will not recover on the affected side. The fourth comes from observations of nonemotional involuntary laughing and/or weeping seen in patients exhibiting symptoms of pseudobulbar palsy, which results from lesions in the corticobulbar pathways. These expressions are virtually indistinguishable from those of normal laughing or crying, with the exception that patients often report no emotional experience, or an incompatible experience, to the expression. Pseudobulbar patients also exhibit some voluntary facial paralysis.

Hemispheric Specialization

Another line of research has examined hemispheric specialization in the production of facial expressions of emotion, based primarily on asymmetries in facial

[2] This was suggested by one of the reviewers.

expression. Although facial asymmetries were studied as early as the 1930s (Wolff, 1933), this line of research gained prominence only later (see Hager, 1982, and Thompson, 1985, for reviews). Several studies (e.g., Campbell, 1978; Sackheim, Gur, & Saucy, 1978) have tested facial asymmetries via facial perception by observers, typically involving the manipulation of posed, still-photo expressions of emotion (usually through the production of chimeric images—left–left, right–right, and left–right images of the face), and then subsequent presentation to observers for ratings. Other studies (e.g., Borod & Caron, 1980; Chaurasia & Goswami, 1975; Ekman, Hagar, & Friesen, 1981; Lynn & Lynn, 1938, 1943; Schwartz, Ahern, & Brown, 1979) have actually measured facial symmetry by coding facial movements or facial EMG.

Several studies have reported a left-face superiority in expression (e.g., Sackheim et al., 1978; Borod & Caron, 1980; etc.), implicating greater right hemispheric lateralization of emotion. Despite the apparent widespread acceptance of this finding, it has been challenged lately, on the basis of the voluntary–involuntary distinction. That is, most studies demonstrating left-face dominance have examined either posed expressions or expressions generated during a face-to-face conversation. The former is clearly under voluntary control; the latter is believed to be usually modified by volitional control. If lateralized neural tracts are involved in voluntary expressions, this would explain why voluntary facial expressions are asymmetrical. Subcortically mediated expressions, that is, "spontaneous" emotional expressions, may not be asymmetrical.

A few studies have examined spontaneous facial behaviors recorded when subjects were unaware that they were being observed (Ekman et al., 1981; Lynn & Lynn, 1938, 1943). In these studies, the expressions were nearly symmetrical, and when asymmetries did occur, they occurred with equal frequency on the right face as they did on the left. More recently, Gazzaniga and Smylie (1991) reported that facial expressions of emotion produced by their sample of split brain patients were symmetrical and that either hemisphere could generate the spontaneous expressions. Mammucari, Caltagirone, Ekman, Friesen, Gainotti, Pizzamiglio, and Zoccolotti (1988) also reported no differences in the symmetry of spontaneous facial expressions of emotion between right- and left-brain-damaged patients.

Several other studies challenge the notion that posed facial expressions of emotion are lateralized. Caltagirone, Ekman, Friesen, Gainotti, Mammucari, Pizzamiglio, and Zuccolotti (1989), for example, reported no differences in the symmetry of posed emotional expressions in their sample of left- and right-brain-damaged subjects. Pizzamiglio, Caltagirone, Mammucari, Ekman, and Friesen (1987) reported no differences in the symmetry of imitated facial movements in their left- vs right-brain-damaged subjects. These researchers suggest that the control of facial expressions of emotion may actually be diffused symmetrically across the cortex, rather than localized on any one side.

Rinn (1984) suggests that the findings showing right hemisphere lateralization for emotion may actually be due to a left hemispheric superiority in the *inhibition* of emotion. Several writers have suggested that the frontal cortex inhibits subcortical arousal mechanisms (Lindsley, 1951; Luria & Homskaya, 1970; Tucker, 1970). The role of language, a heavily cortical process, in the regulation of behavior in general has been cited by many researchers (e.g., Luria, 1973; Vygotsky, 1934). Its role in emotion control is implicated in the case of cognitive defense mechanisms (although the evidence for defense mechanisms is controversial). Rinn (1984) suggests that the left hemisphere, due to its linguistic and propositional thought capacities, is better equipped to inhibit emotional episodes, resulting in better inhibition of the right face and subsequently greater expression in the left face.

Thus, our understanding of hemispheric differences in the neural control of facial expressions of emotion has changed in recent years and suggests a much more complicated picture than the previous right-brain superiority hypothesis. While advances in our understanding of brain functioning will undoubtedly continue to occur (e.g., making distinctions among different regions within a hemisphere[3]), we turn our discussion now to a broader understanding of the nature of volition and consciousness in the production of facial expressions of emotion.

CURRENT PERSPECTIVES ON VOLITION AND CONSCIOUSNESS IN THE EXPRESSION OF EMOTION

In addition to improvements in our understanding of the neurophysiology of facial expressions, we now know more about the *psychology* of facial expressions as well. Psychological characteristics of emotional expressions are presumably linked to neurophysiological activities, so that neurophysiological and psychological aspects are compatible and need to be integrated.

In this section, we outline some issues concerning volition and consciousness in the production of facial expressions of emotion that we feel have not been well addressed. To be sure, other authors have raised similar issues (e.g., Bryden & Ley, 1983; Hager, 1982; Rinn, 1984; Thompson, 1985). We do not intend to ignore or replace these previous discussions. We acknowledge some overlap and offer these in the spirit of complementing previous attempts at integration and theory building.

Emotional Expressions in Relation to Other Facial Behaviors

1. Facial expressions of emotion comprise only one of several types of facial actions, and different facial actions need to be recognized. As a signal system, the face conveys multiple messages in multiple contexts. Ekman (1978) classified the repertoire of facial behaviors into such categories as "illustrators" (behaviors that punctuate speech), "emblems" (behaviors that carry meaning by themselves), "regulators" (behaviors that regulate the flow of conversation), and "adaptors" (behaviors that allow for regulation of one's own body), in addition to "emotion." Facial expressions *of emotion* are only one type of facial behavior.

Comparative research across cultures conducted over two decades ago (Ekman, 1972; Ekman & Friesen, 1971; Ekman, Sorenson, & Friesen, 1969; Izard, 1971) and replicated in many studies since (see Matsumoto, Wallbott, & Scherer, 1989, for a review) has shown convincingly that only a small set of facial behav-

[3] This was suggested by one of the reviewers.

iors depict emotion universally (anger, disgust, fear, happiness, sadness, and surprise). Other studies (e.g., Ekman, 1972; Ekman, Friesen, & Ancoli, 1980) have shown that these expressions do occur when subjects report these discrete feelings. More recently, Ekman and Friesen (1986) have also provided evidence for the universality of a contempt expression.

That facial expressions of emotion are only a subset of the facial behaviors has important consequences for the study of their neuropsychological control. Some studies do not make distinctions between emotion signals and nonemotional facial behaviors (e.g., Kolb & Milner, 1981; Borod & Koff, 1983; Borod, Koff, Perlman Lorch, & Nicholas, 1985; Borod & Caron, 1980). Comparing nonemotional poses (e.g., winking, blinking, blowing, etc.) to spontaneous, uninhibited facial expressions of emotion confounds the comparison with the type of expression being compared. Clearly, winking and blinking, which are indeed facial *behaviors*, are not the optimal analog to compare spontaneous facial expressions of emotion.

2. Facial expressions of emotion are highly specific in their patterning, and adequate steps must be taken in order to validate their occurrence. The facial configurations for each of the universal emotions are quite distinct from each other. For example, the universal expression of sadness involves the movement of the inner frontalis muscle, a slight pushing of the mentalis, and a slight movement of the triangularis. This configuration may or may not be accompanied by activation of the corrugator muscle group; a slight innervation of orbicularis oculi, pars orbitalis; a slight innervation of orbicularis oculi, pars palpebralis; or a downward glancing of the eyes. The addition of any other muscle, the subtraction of those mandatory, not optional ones above, or changes in relative intensity would distort the message of sadness.

Care must be taken to directly measure the facial muscle movements so as to verify the validity of the expression. We have the criteria by which this validity can be established (i.e., comparing the expressions that did occur with the facial muscle configurations of the universal emotions). Unfortunately, with only a few exceptions (e.g., Ekman et al., 1981), this procedure is rarely handled adequately, thus leaving open the possibility of confounding expression type (i.e., emotion vs nonemotion) with laterality.

3. Separate facial areas and specific facial muscles must be given equal and independent consideration, rather than treating the face as an undifferentiated gestalt. Many studies, particularly those testing hemispheric laterality of emotional expression, have compared posed emotional expressions with more spontaneous expressions. Typically, however, little distinction is made between different face regions. UMN pathways to the facial nerve and subsequently to the facial muscles are contralaterally projected to the lower face, with increasing bilateral influence to the mid- and upper-face areas. Thus, one would expect different degrees of asymmetry in different areas of the face in posed facial expressions.

Unfortunately, data from judgment studies (e.g., Sackheim et al., 1978) involving the entire face as stimulus (e.g., chimeric images) cannot test differing degrees of asymmetry depending on facial region, because judging the entire face precludes comparison of specific facial areas. Facial measurement on specific facial muscle movements in the posed expressions may be the first step in examining this possibility (e.g., Ekman & Friesen's FACS, 1978). The availability of both older and newer sets of photos of posed emotions enables this question to be answered relatively easily on already posed expressions (Ekman & Friesen's Pictures of Facial Affect—PFA, 1976; (Matsumoto & Ekman's Japanese and Caucasian Facial Expressions of Emotion—JACFEE, 1988). The use of FACS on videorecorded posing attempts would also address this question. (Hager, 1982, discusses other drawbacks to global judgment data in facial asymmetry research.) Increased interest in different brain regions within a hemisphere in studies of hemispheric specialization represent a similar development on the neurophysiological side.

There is considerable interindividual variation in the degree of voluntary control of the facial muscles. These differences have potential ramifications for their underlying neurological control mechanisms. Whether or not these individual differences are simply related to differences in the size of the motor strip representations of these muscles, or whether they suggest the existence of different neural pathways, remains to be seen. Conclusions suggesting that voluntary emotional expressions are mediated solely by innervations along direct, corticobulbar pathways may overgeneralize a limited aspect of the neural circuitry. The separation of the different facial areas, and the use of facial muscle combinations that are related to emotion, may be necessary in refining our neurological distinctions between voluntary and involuntary facial expressions of emotion.

4. Researchers need to examine a full range of emotional expressions, rather than singling out only one or two, in order to make generalizations concerning the entire class of facial expressions of emotion. While the smile continues to be the most frequently studied expression, researchers have included other emotional expressions as well, such as sadness (e.g., Cacioppo & Petty, 1981; Moscovitch & Olds, 1982; Rubin & Rubin, 1980), anger (Rubin & Rubin, 1980), and fear (Moscovitch & Olds, 1982). The inclusion of emotional signals other than the smile is absolutely necessary in examining the neuropsychological control of facial expressions of emotion. Different emotional expressions may have different neural control mechanisms and pathways; the basic fact that the facial emotions use different facial muscles in different areas of the face makes this a likely possibility that cannot be explored by limiting research to only a few emotions or faces.

The Voluntary–Involuntary Distinction

1. The voluntary–involuntary distinction is not adequate in characterizing the repertoire of facial expressions of emotion and may actually be misleading. A number of authors (e.g., Buck, 1984; Ekman, 1984; Fridlund, 1990) have expressed concern that the voluntary–involuntary distinction does not capture adequately the complexity of human facial expressions of emotion. Other descriptors have included the spontaneous–posed or spontaneous–deliberate distinctions. We contend that distinctions that dichotomize facial expressions are not adequate in characterizing their actual use. Our concerns are based on our knowledge of display rules and expression automaticity.

Display rules are culturally based rules governing the modification of expressions, depending on social circumstances (Ekman & Friesen, 1969). Display rules are learned behavior norms, which provide guidelines to individuals for appropriate use of their facial expressions in various social situations. Display rules combine with the facial prototypes of universal emotions and can amplify, deamplify, neutralize, or mask one's true feelings. Since Friesen's (1972) original cross-cultural study of them, display rules have been studied quite extensively in developmental research (e.g., see Lewis & Saarni, 1985) and more recently again cross-culturally (Matsumoto, 1990).

Display rules are learned early in life and are functional by mid- to late-childhood. By adulthood, they are usually learned so well that people can engage in display rule modified behaviors automatically, without much conscious thought. Automatic display rule modified facial behaviors, however, still differ from automatic, yet unmodified facial expressions in that the latter are not affected by learned rules. Thus, characterizing expressions simply as "spontaneous" is inadequate because "spontaneous" implies "automatic," and automatic expressions may or may not be altered by extensively practiced display rules.

Yet another type of distinction needs to be recognized. In many situations, people need to consciously manage their facial behaviors because of the particular characteristics of the circumstances. These situations involve the use of display rule affected behaviors that are not automatic, but that require an interaction between volitional and unmodified expression. These occur often in normal social interaction or conversation, where one may ponder, however briefly, the acceptability or appropriateness of one's emotional reactions and adjust behavior accordingly.

We suggest a three-dimensional scheme with which to characterize facial expressions. One dimension involves the degree of modification or mediation by learned display rules and can range from no modification at all to total modification. A second dimension involves the degree of learning and rehearsal involved in the modification, ranging from totally unlearned responses to totally learned and automatic responses.. A third dimension involves the degree of conscious, volitional effort needed to produce the expression.

These dimensions would help us to understand better the differences among different expressions. Posed expressions produced on command, for example, involve no display rule mediation, no previous learning, but a high degree of conscious effort. Spontaneous expressions that occur within a display rule laden social context would involve a high degree of display rule mediation, a high degree of learning and rehearsal, but minimal conscious effort. Spontaneous expressions can also occur without display rule modification and would involve no learning and no conscious effort. Still, these two examples of spontaneous expressions should involve different patterns of neural activation because of differences in learning and conscious volition.

Given the different ways display rules, learning, and volition interact with expression, the voluntary–involuntary dichotomy is not adequate in characterizing the use of facial expressions of emotion. While some studies have included the use of "posed expressions produced upon request or command," we know of no studies that have made a distinction among the remaining three types of "spontaneous" expressions (i.e., automatic with no modification by learned display rules, automatic but involving learned display rules with no conscious effort, and automatic with some modification with some conscious effort). Some studies (e.g., Chaurasia & Goswami, 1975; Lynn & Lynn, 1938; Ekman et al., 1981, study 1; Heller & Levy, 1981; Moscovitch & Olds, 1982) have elicited "spontaneous" expressions in conversations between experimenters and subjects, which are situations that could be mediated by display rules, at some level of consciousness. Situations involving the individual testing of subjects do not solve this problem entirely, as discussed below.

Integrating our knowledge of display rules with the voluntary–involuntary distinction has important ramifications for understanding the neural control of facial expressions. Display rules may be organized cortically (Rinn, 1984). The improved ability to regulate socially one's facial expressions of emotion, which occurs in mid- to late-childhood, appears to be related to the completion of frontal lobe development. The distinctions in facial behavior with and without display rules described above suggest at the very least that the cortical (i.e., pyramidal) motor system frequently works with subcortical systems. Thus, some facial expressions may involve more cortical influences, others more subcortical influences, and still others with influences from only one of these tracts. Because of this, we need to turn our efforts to examining the relative contributions of both neural tracts to the different types of facial behaviors outlined above.

If we adopt this posture, however, a challenge that remains is the assessment of the three dimensions described above in characterizing facial expressions. One simple way that we can begin this type of assessment is to obtain detailed knowledge, through interview, concerning an "expression and display rule history." If experimental sessions are videotaped, subjects can also review their own tapes and make quantitative ratings along the three dimensions in reference to expressions that occur during the sessions. While these suggestions are quite rudimentary, they are a first step in the direction of better characterizations of facial expressions that occur in the lab.

2. *Most adult expressions involve some degree of display rules*. This point was made by Tomkins (1982), who suggested that the emotions we experience and express as adults are really different from what he would consider biologically and psychologically authentic innate affect. All societies, Tomkins maintains, exercise control over the unrestrained, free expression of emotion. Strict control over affect is instituted very early on, although there may be large variations between societies and among classes within societies in the exact nature and mechanisms of this control.

This line of reasoning again raises questions about the nature of "spontaneous" emotional expressions assessed in the past. Because many spontaneous expressions observed in the laboratory may actually involve some degree of display rule mediation, clear-cut inferences concerning the underlying neurology may be difficult.

In its most extreme sense, this line of reasoning raises serious doubts concerning our ability to elicit "true," unfettered, unmodulated expressions of emotion. If Tomkins' (1982) ideas concerning "backed-up affect" are indeed true, for example, then the very nature of human adult emotional expressions may preclude the possibility of examining emotional expressions free of cortically mediated control. Even in situations where it would appear that display rules are *not* operative, a display rule dictating no modification of the original emotional response may actually have been learned and operational. Brodal's (1981) finding that emotional smiles were more exaggerated on the paralyzed side in patients with cortical motor strip lesions is certainly suggestive of release of inhibition by the ever-present influence of corticobulbar connections.

Children are probably less influenced by cultural display rules, and the "backing-up" of affect Tomkins describes. They may give us important clues to the relative contributions of cortical and subcortical areas in the neurological control of facial expressions. For example, infants born with no brain structures higher than the midbrain show some normal facial expressions, such as crying and disgust (Guyton, 1976; Steiner, 1973). Congenitally blind children display a full range of spontaneous facial expressions of emotion, which cannot be explained by visual learning or imitation (Freedman, 1964; Goodenough, 1932; Thompson, 1941). Perhaps more refined measurements of their emotional expressions will give us important clues to the underlying neural control.

3. Display rule effects need to be incorporated, not ignored. Some studies have attempted to deal with the issue of possible display rule control (and the implied cortical interference) by testing subjects individually and videorecording their facial reactions without their apparent awareness (e.g., Ekman et al., 1981). While this is a step in the right direction, it is still open to qualification because display rules can operate habitually when one is alone. The mere fact that no one else is present when facial behaviors are recorded is not sufficient to control for possible habitual display rule effects.

There is, however, a larger methodological, and theoretical, issue. Eliminating the possible effects of cortically mediated display rules ignores the complexity of their probable neural influences on facial expressions. Instead, we should find ways of *incorporating,* not ignoring, these influences. The adoption of a more detailed picture of the interaction between spontaneity, automaticity, deliberateness, and display rules, as outlined above, is a step in this direction. The inclusion of detailed and repeated measurements of the same subjects over time, with extensive interviewing about the degree to which consciously mediated display rules were operative, may also help. If we accept the interactive nature of the neural control of facial expressions, we need to find methods that are sensitive to multiple sources of control.

The Special Case of Smiles

1. Smiles serve multiple functions and have multiple meanings, including other than genuine positive emotion. The smile is the simplest emotional expression in terms of signal characteristics and is often studied. At the same time, the smile is perhaps one of the most complex expressions in terms of signal value and message. The smile is used in a variety of ways [see Ekman & Friesen, 1982, for a review, and Ekman's (1985) description of 18 different types of smiles].

There are many social situations that require one to look pleasant, even though one does not truly feel this way; smiles are used to simulate these feelings. Smiles also convey other socially relevant messages, such as appeasement to a superior or acceptance and understanding to friends. Smiles accent other emotions; by cooccurring with negative emotions, for example, smiles soften messages, commenting on one's acceptance of a situation, or the fact that one is OK despite the negative feelings. Smiles can also mask other emotions, concealing one's true feelings such as anger or sadness. Of course, smiles can also denote true, felt happiness.

Each use of the smile implicates different neural pathways. Smiles denoting true, genuine, and uninhibited feelings of happiness may involve more subcortical rather than cortical pathways, while smiles that result from deliberate facial action with no feelings of happiness may involve more cortical control. The addition of nonemotional, social messages also implicates other brain areas in the production of the smile.

Most studies that include smiles do not make these distinctions among its multiple functions. It is necessary to do so. The laboratory situation is further complicated because smiles may arise because of embarrassment or some other emotional reaction to the experimental situation. Clearly, researchers who incorporate smiles in their studies need to ascertain which of the many different smiles they have elicited, in order to ascertain the relationship between neurology and expression.

2. The facial muscles associated with different uses of the smile differ. The facial muscles associated with genuine, felt happiness are different from those associated with other smiles. Genuine, felt happiness involves the innervation of two muscles—zygomatic major and orbicularis oculi; other smiles usually appear only with zygomatic major. When a smile is cooccurring with another emotion, it will include the zygomatic major, with or without orbicularis oculi, in conjunction with the facial muscles associated with the other emotion. There are considerable differences in the signal values of these smiles (Ekman & Friesen, 1982) and in their electrocortical activity (Ekman, Davidson, & Friesen, 1990).

That different facial muscles are involved in different types of smiles suggests a more complex picture of the underlying neurology than the simple pyramidal–extrapyramidal tract distinction. For example, smiles that involve messages of social appropriateness may require a combination of "spontaneous" and learned pathways in the neural tracts leading up to the facial nerve. The resulting output (i.e., activation of zygomatic major only) may occur because of a lack of innervation of the orbicularis, or its cortical suppression, or both. Different social uses of the smile may involve differing degrees of inhibition or stimulation of the orbicularis, implicating a rich but complex system of combinatorial neural influences on the facial nerve.

The Elicitation and Subjective Experience of Emotion

1. Emotions can be elicited in a variety of ways, each suggesting the existence of different neural pathways to the face. LeDoux (1987) presents a careful review of the literature concerning the neural circuitry associated with conditioned emotional reactions in animals, involving the elicitation of emotion via different sensory modalities. The evidence he provides implicates the amygdala as the possible site of integration of emotional information across the senses.

Still, the bulk of this work has been done with animals, and much more is necessary. Emotion elicitation in humans presents an especially complex case, given the multiple ways that emotion can be elicited. The most common technique used in laboratory settings with humans involves the presentation of emotion-eliciting stimuli, usually on video or slides, and recording or observation of the facial reactions. Although emotions can be elicited validly and reliably in this way (see Matsumoto, Ekman, & Fridlund, 1991, for a fuller discussion), emotions are elicited in other ways. Another popular method, for example, involves imagery, a technique often used in the study of facial expressions via EMG (see Fridlund, 1990; Schwartz et al., 1979). Emotions can also be elicited via auditory channels involving either language or paralinguistic stimuli (e.g., tone of voice, speech rate). And, emotion is often aroused by a combination of these channels. When emotion is aroused by any of these techniques, facial expressions may or may not occur, and these may or may not be influenced by display rules. The combination of imagery, vision, hearing, memory, social situation, and display rules provides for a relatively complex interaction among the neural substrates associated with the production of facial expression. Research using animals to suggest the importance of the amygdala as an integration center may lend a useful model for the possible circuitry in humans.

2. The neural contributions of facial expressions of emotion on consciousness and subjective emotional experience need to be explored. Most studies view facial expressions of emotion as output (or "readout" devices) (see Buck, 1984), that is, as endpoints in the emotion process. In accordance with such a view, researchers typically explore almost exclusively the neural circuitry leading up to facial innervation during an emotion process, with facial muscle movement as the terminal point.

But the face may not be the endpoint in the emotion process. The "facial feedback hypothesis" (Tomkins, 1962, 1963), for example, suggests that peripheral feedback from the facial muscles, possibly back to the limbic system, contributes to the regulation of subjective experience. Although there are "strong" and "weak" versions of this hypothesis (discussed extensively elsewhere, e.g., Izard, 1990; Laird, 1984; Matsumoto, 1987; Winton, 1986), the hypothesis states that emotional expression intensifies subjective emotional response; the suppression of expression, on the other hand, lessens the experience. In this view, facial expressions of emotion are important contributors, not endpoints, to subjective experience.

Although not designed to test facial feedback effects, Ekman, Levenson, and Friesen's (1983) study on ANS reactivity to posed emotional expressions raises some important questions. Subjects were asked to pose the universal emotions, as several ANS indices were measured. Each expression produced a different ANS patterning. While the exact paths are unclear, some neural pattern must account for the effects of facial activity on physiological responses or subjective experience.

This putative feedback system, however, has yet to be explored. Are there neural tracts leading from the facial musculature or facial skin that carry neural information back to an "integration center" after an expression has been produced? Or, does the neural feedback occur earlier in the facial innervation process? When the facial nerve is stimulated, for example, that may itself be what is fed back to its source, contributing to emotional experience. In this case, the firing of the facial muscles per se would not be the source of feedback; instead, it would be the *neural activation* of the facial muscles that is fed back. Studying emotion elicitation and subjective experience in patients with lesions in the distal facial nerve tracts would address this possibility, as would studies of patients with spinal lesions or neuromuscular blocking agents.

CONCLUSIONS

Our understanding of emotions in general, and of facial expressions in particular, has advanced considerably in the last two decades. Our acceptance of emotion as an important and integral part of human functioning is due in large part to the recognition of its universality and to an abundance of studies of emotion in several major subfields of psychology. Clearly, our understanding of emotion and emotional expression, especially concerning the multiple messages conveyed by facial expressions, the complexity of the facial musculature, the use of display rules, emotion elicitation, and facial measurement, is better today than ever.

We suggest that advances in our theoretical understanding of the roles and effects of volition and consciousness in emotion and the production of facial expressions be integrated with advances in our comprehension of the neuroanatomy and neurophysiological control of facial expressions. In no way do we discount the research conducted to date; indeed, we have cited much information from this literature. Rather, our intention is to suggest an *integration* of two seemingly disparate and sometimes unconnected literatures. If we are to make inroads into furthering our understanding of this complex neuropsychological process, then we must attack the problem exactly at that level of complexity, and nothing less.

Some of these "new" ways can occur through a combination of already existing technologies. Procedures for testing brain lesion patients, for instance, may incorporate a wider variety of measures of facial expression, elicited in different contexts, across more emotions, with more extensive follow-up interviews and post-testing. Studies involving nonpatient samples can take more steps to determine how the individuals in the study interpreted the social situation surrounding the emotion elicitation, in an attempt to better characterize the role of display rules in the production of the elicited expressions. Better facial measurement techniques can be used to explore symmetry of independent facial actions. The tools to enact many of these procedures already exist and provide us with the methodology necessary to incorporate the integration on an empirical level.

The advent of new and developing technologies offers yet more exciting possibilities. Methods for measuring brain structure as well as function are continually improving. Although techniques such as CAT scans, PET scans, and MRI have existed for years now, improvements in their spatial and temporal resolution are providing us with the ability to measure brain function not possible even a few years ago. Scientists interested in the neuropsychology of emotional expression will soon begin to combine these technological advances with an improved understanding of the psychology of expression to produce results that we can only imagine today. The complexity of the face, emotion, and the brain challenge us to achieve this integration of concept and method.

ACKNOWLEDGMENTS

The writing of this article was supported in part by a research grant from the National Institute of Mental Health (MH 42749-01), by a Faculty Affirmative Action Award, and a grant from the California State University Research, Scholarship, and Professional Development program. We thank Masami Kobayashi, Deborah Krupp, Bill Roberts, and Michelle Weissman for their assistance in the production of this article, and in our general research program. We also acknowledge the support and contributions of Paul Eskildsen to our thinking on integration in psychology.

REFERENCES

Borod, J., & Caron, H. (1980). Facedness and emotions related to lateral dominance, sex and expression type. *Neuropsychologia*, **18**, 237–241.

Borod, J., & Koff, E. (1983). Hemiface mobility and facial expression asymmetry. *Cortex*, **19**, 327–332.

Borod, J., Koff, E., Perlman Lorch, M., & Nicholas, M. (1985). Channels of emotional expression in patients with unilateral brain damage. *Archives of Neurology*, **42**, 345–348.

Brodal, A. (1981). *Neurological anatomy: In relation to clinical medicine*. New York: Oxford Univ. Press.

Bryden, M. P., & Ley, R. G. (1983). Right-hemispheric involvement in the perception and expression of emotion in normal humans. In K. M. Heilman & P. Satz (Eds.), *Neuropsychology of human emotion*. New York: Guilford Press.

Buck, R. (1984). *The communication of emotion*. New York: Guilford Press.

Cacioppo, J. T., & Petty, R. E. (1981). Lateral asymmetry in the expression of cognition and emotion. *Journal of Experimental Psychology: Human Perception and Performance*, **7**, 333–341.

Caltagirone, C., Ekman, P., Friesen, W., Gainotti, G., Mammucari, A., Pizzamiglio, L., & Zuccolotti, P. (1989). Posed emotional expression in unilateral brain damaged patients. *Cortex*, **25**, 653–663.

Campbell, R. (1978). Asymmetries in interpreting and expressing a posed facial expression. *Cortex*, **14**, 327–342.

Chaurasia, B., & Goswami, H. (1975). Functional asymmetry in the face. *Acta Anatomica*, **91**, 154–160.

Dejong, R. N. (1979). *The neurological examination*. Hagerstown, MD: Harper & Row.

DeMeyer, W. (1980). *Technique of the neurological examination*. New York: McGraw–HIll.

Ekman, P. (1972). Universals and cultural differences in facial expression of emotion. In J. Cole (Ed.), *Nebraska Symposium on Motivation* (Vol. 19). Lincoln: Univ. of Nebraska Press.

Ekman, P. (1978). Facial signs: Facts, fantasies, and possibilities. In T. Sebeok (Ed.), *Sight, sound, and scents* (pp. 124–156). Bloomington, IN: Indiana Univ. Press.

Ekman, P. (1984). Emotion and the nature of expression. In K. Scherer & P. Ekman (Eds.), *Approaches to emotion*. Hillsdale, NJ: Erlbaum.

Ekman, P., Davidson, R., & Friesen, W. (1990). The Duchenne smile: Emotional expression and brain physiology II. *Journal of Personality and Social Psychology*, 58(2), 342–353.

Ekman, P., & Friesen, W. (1969). Nonverbal leakage and clues to deception. *Psychiatry*, **32**, 88–106.

Ekman, P., & Friesen, W. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, **17**, 124–129.

Ekman, P., & Friesen, W. (1976). *Pictures of facial affect (PFA)*. Palo Alto: Consulting Psychologists Press.

Ekman, P., & Friesen, W. (1978). *Facial action coding system: A technique for the measurement of facial movement*. Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., & Friesen, W. (1982). Felt, false, and miserable smiles. *Journal of Nonverbal Behavior*, **6**, 238–252.

Ekman, P., & Friesen, W. (1986). A new pan-cultural expression of emotion. *Motivation and Emotion*, **10**, 159–168.

Ekman, P., Friesen, W. V., & Ancoli, S. (1980). Facial signs of emotional experience. *Journal of Personality and Social Psychology*, **39**, 1125–1134.

Ekman, P., Hagar, J., & Friesen, W. (1981). The symmetry of emotional and deliberate facial actions. *Psychophysiology*, **18**, 101–106.

Ekman, P., Sorenson, E. R., & Friesen, W. (1969). Pan-cultural elements in facial displays of emotion. *Science*, **164**, 86–88.

Ekman, P., Levenson, R., & Friesen, W. (1983). Autonomic nervous system activity distinguishes among emotions. *Science*, **221**, 1208–1210.

Freedman, D. G. (1964). Smiling in blind infants and the issue of innate vs. acquired. *Journal of Child Psychology and Psychiatry*, **5**, 171–184.

Fridlund, A. J. (1990). Evolution and facial action of reflex, social motive, and paralanguage. *Biological Psychology*, **32**, 3–100.

Friesen, W. (1972). *Cultural differences in facial expressions in a social situation: An experimental test of the concept of display rules*. Unpublished doctoral dissertation, University of California, San Francisco, CA.

Gazzaniga, M. S., & Smylie, C. S. (1991). Hemispheric mechanisms controlling voluntary and spontaneous facial expressions. *Journal of Cognitive Neuroscience*, **2**(2), 239–245.

Goodenough, F. L. (1932). Expression of the emotions in a blind–deaf child. *Journal of Abnormal and Social Psychology*, **27**, 328–333.

Guyton, A. C. (1976). *Organ physiology: Structure and function of the nervous system*. Philadelphia: Saunders.

Hager, J. (1982). Asymmetries in facial expressions. In P. Ekman (Ed.), *Emotion in the human face*. Cambridge: Cambridge Univ. Press.

Harker, L. A., & McCabe, B. F. (1977). Surgical anatomy of the facial nerve. In L. R. Rubin (Ed.), *Reanimation of the paralyzed face: New approaches*. St. Louis, MO: Mosby.

Heller, W., & Levy, J. (1981). Perception and expression of emotion in right handers and left handers. *Neuropsychologia*, **19**, 363–372.

Izard, C. (1971) *The face of emotion*. New York: Appleton–Century–Crofts.

Izard, C. (1990). Facial expressions and the regulation of emotions. *Journal of Personality and Social Psychology*, **58**, 487–498.

Karnosh, L. J. (1945). Amimia or emotional paralysis of the face. *Diseases of the Nervous System*, **6**, 106–108.

Kolb, B., & Milner, B. (1981). Observations on spontaneous facial expression after focal cerebral excisions and after intracarotid injection of sodium amytal. *Neuropsychologia*, **19**, 505–514.

Kuypers, G. J. M. (1987). Anatomy of the descending pathways. In S. R. Geiger (Ed.), *Handbook of physiology* (Vol II, Part I). Bethesda, MD: American Physiological Society.

Laird, J. (1984). The real role of facial response in the experience of emotion: A reply to Tourangeau and Ellsworth and others. *Journal of Personality and Social Psychology*, **47**, 909–917.

LeDoux, J. E. (1987). Emotion. In S. R. Geiger (Ed.), *Handbook of physiology* (Vol. V, Part I). Bethesda, MD: Amerian Physiological Society.

Lewis, M., & Saarni, C. (1985). *The socialization of emotions*. New York: Plenum.

Lindsley, D. (1951). Emotion in S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley.

Luria, A. R. (1973). *The working brain*. New York: Basic Books.

Luria, A. R., & Homskaya, E. D. (1970). Frontal lobes and the regulation of arousal processes. In D. I. Mostofsky (Ed.), *Attention: Contemporary theory and analysis*. New York: Appleton–Century–Crofts.

Lynn, J., & Lynn, D. (1938). Face–hand laterality in relation to personality. *Journal of Abnormal and Social Psychology*, **24**, 291–322.

Lynn, J., & Lynn, D. (1943). Smile and hand dominance in relation to basic modes of adaptation. *Journal of Abnormal and Social Psychology*, **38**, 250–276.

Mammucari, A., Caltagirone, C., Ekman, P., Friesen, W., Gainotti, G., Pizzamiglio, L., & Zoccolotti, P. (1988). Spontaneous facial expression of emotions in brain-damaged patients. *Cortex*, **24**, 521–533.

Matsumoto, D. (1987). The role of facial response in the experience of emotions: More methodological problems and a meta-analysis. *Journal of Personality and Social Psychology*, **52**, 769–774.

Matsumoto, D. (1990). Cultural similarities and differences in display rules. *Motivation and Emotion*, **14**, 195–214.

Matsumoto, D., & Ekman, P. (1988). *Japanese and Caucasian Facial Expressions of Emotion (JACFEE)*. Slides available from David Matsumoto, Department of Psychology, San Francisco State University, 1600 Holloway Avenue, San Francisco, CA 94132.

Matsumoto, D., Ekman, P., & Fridlund, A. J. (1991). Analyzing nonverbal behavior. In P. Dowrick (Ed.), *A practical guide to video in the behavioral sciences*. New York: Dorland.

Matsumoto, D., Wallbott, H., & Scherer, K. (1989). Emotion and intercultural communication. In W. Gudykunst & M. Asantes (Eds.), *Handbook of intercultural and international communication*. Beverly Hills, CA: Sage.

Monrad-Krohn, G. H. (1924). On the dissociation of voluntary and emotional innervation in facial paralysis of central origin. *Brain*, 47, 22–35.

Monrad-Krohn, G. H. (1927). A few remarks on the question of the dissociation between voluntary and emotional innervation in peripheral facial paralysis. *Acta Psychiatrica et Neurologica*, **3**, 33–39.

Moscovitch, M., & Olds, J. (1982). Asymmetries in spontaneous facial expressions and their possible relation to hemispheric specialization. *Neuropsychologia*, **20**, 71–81.

Noback, C. R., & Demarest, R. J. (1975). *The human nervous system: Basic principles of neurobiology* (second ed.). New York: McGraw–Hill.

Pizzamiglio, L., Caltagirone, C., Mammucari, A., Ekman, P., & Friesen, W. (1987). Imitation of facial movements in brain damaged patients. *Cortex*, **23**, 207–221.

Redican, W. K. (1982). An evolutionary perspective on human facial displays. In P. Ekman (Ed.), *Emotion in the human face* (Second ed.). New York: Cambridge Univ. Press.

Rinn, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin*, **95**, 52–77.

Rubin, D., & Rubin, R. (1980). Differences in asymmetry of facial expression between left- and right-handed children. *Neuropsychologia*, **18**, 373–377.

Sackheim, H., Gur, R., & Saucy, M. (1978). Emotions are expressed more intensely on the left side of the face. *Science*, **202**, 434–444.

Schwartz, G., Ahern, G., & Brown, S. (1979). Lateralized facial muscle response to positive and negative emotional stimuli. *Psychophysiology*, **16**, 561–571.

Steiner, J. E. (1973). The gustofacial response: Observation on normal and anencephalic newborn infants. In J. F. Bosma (Ed.), *Fourth symposium on oral sensation and perception*. Bethesda, MD: U.S. Department of Health.

Thompson, J. (1941). Development of facial expression of emotion in blind and seeing children. *Archives of Psychology*, 39, 1–47.

Thompson, J. (1985). Neuroanatomy, hemisphericity and facial asymmetry. *Neuropsychologia*, 20, 699–701.

Tomkins, S. S. (1962). *Affect, imagery, and consciousness* (Vol. 1). New York: Springer.

Tomkins, S. S. (1963). *Affect, imagery, and consciousness* (Vol. 2). New York: Springer.

Tomkins, S. S. (1982). *Affect theory*. In P. Ekman (Ed.), *Emotion in the human face*. Cambridge: Cambridge Univ. Press.

Tschiassny, K. (1953). Eight syndromes of facial paralysis and their significance in locating the lesion. *Annals of Otology, Rhinology, and Laryngology*, 62, 677–691.

Tucker, I. F. (1970). *Adjustment: Models and mechanisms*. New York: Academic Press.

van Gelder, R. S., & van Gelder, L. (1990). Facial expression and speech: Neuroanatomical considerations. *International Journal of Psychology*, 25, 141–155.

Vygotsky, L. S. (1934). *Thought and language*. Cambridge, MA: MIT Press.

Winton, W. (1986). The role of facial response in self-reports of emotion: A critique of Laird. *Journal of Personality and Social Psychology*, 50, 808–812.

Wolff, W. (1933). The experimental study of forms of expression. *Journal of Personality*, 2, 168–176.

Received January 1, 1993