Research Report

VOLUNTARY SMILING CHANGES REGIONAL BRAIN ACTIVITY

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Abstract—*We used measures of regional brain electrical activity to show that not all smiles are the same. Only one form of smiling produced the physiological pattern associated with enjoyment. Our finding helps to explain why investigators who treated all smiles as the same found smiles to be ubiquitous, occurring when people are unhappy as well as happy. Also, our finding that voluntarily making two different kinds of smiles generated the same two patterns of regional brain activity as was found when these smiles occur involuntarily suggests that it is possible to generate deliberately some of the physiological change which occurs during spontaneous positive affect.*

This report deals with three issues which have been the subject of dispute in cultural anthropology, social psychology, and psychophysiology. The first, whether smiles occur with negative as well as positive emotions, is part of an old but continuing argument about the universality of facial expressions of emotion (see Ekman, 1989, for a recent review). The second, whether voluntarily performing a set of facial muscular movements generates the physiological changes which accompany emotions, is of more recent vintage (Ekman, Levenson, & Friesen, 1983) and is relevant to understanding how emotions are brought about (Ekman, 1992). The third, whether physiological activity is differentiated only for the extent but not the type of emotion aroused, is another old argument, dating back to Cannon, Bard, and more recently Schacter and Singer (see Levenson, 1992, for a recent review).

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In the last century, the French neurologist Duchenne de Boulogne observed (1862/1990): "The emotion of frank joy is expressed on the face by the combined contraction of the *zygomatic major* muscle, and the *orbicularis oculi*. The first obeys the will but the second is only put in play by the sweet emotions of the soul . . ." (p. 126). Despite the attention Darwin (1872) gave to Duchenne's distinction, most behavioral scientists ignored it, instead treating smiles as a single behavioral category. Consequently, smiles were reported to occur with both negative and positive emotions, supporting the claims of cultural relativists that this and other expressions are socially learned and culturally variable, their meaning totally dependent on the knowledge of the context in which they occur (Lutz & White, 1986).

A further refinement of Duchenne's distinction (Ekman, Friesen, & O'Sullivan, 1988) specified more precisely which part of the *orbicularis oculi* muscle is active during enjoyment. An earlier study (Ekman, Roper, & Hager, 1980) found that most people can voluntarily contract the inner part of the muscle (*pars medialis*), which is most evident in a tightened and raised lower eyelid, while few people can voluntarily contract the outer portion of the muscle (*pars lateralis*), which raises the cheeks and produces crow's-feet wrinkles. (Hereafter, we refer to those smiles produced by the action of both *zygomatic major* and *orbicularis oculi, pars lateralis*, as having *Duchenne's marker*, and use the phrase *other smile* to refer to action of *zygomatic major* without *orbicularis oculi, pars lateralis*.)

When subjects concealed negative emotions aroused by watching an amputation film, and instead tried to appear as if they were feeling pleasant, they exhibited few smiles with Duchenne's marker but many instances of other smiles (Ekman et al., 1988). Conversely, when subjects watched amusing films, there were many Duchenne-marker smiles and few other smiles. More than a dozen other studies have shown that smiles with Duchenne's marker occur more often than other forms of smiling when people experience enjoyment. Three criteria were used to establish that subjects were experiencing enjoyment: the social context in which a smile was emitted (e.g., an infant approached by the mother as compared with approached by a stranger [Fox & Davidson, 1988]); the type of people who showed the smiling (e.g., happily vs. unhappily married couples [J. Gottman, personal communication, June 1992]); and association with other emotional responses (e.g., correlation with subjective reports of positive responses [Ekman, Davidson, & Friesen, 1990]).

Our study is the first experimental test of Duchenne's hypothesis, directly manipulating the absence and presence of the outer portion of the eye muscle in smiling. This manipulation was achieved by asking subjects to voluntarily contract different sets of facial muscles. Other experiments (Levenson, Ekman, & Friesen, 1990) have found different patterns of autonomic nervous system activity occurred when subjects followed instructions to produce different facial expressions, but did not compare different forms of smiling. Our study is the first to examine physiological changes generated when Duchenne-marker smiles and other smiles are produced deliberately, and the first to examine electroencephalogram (EEG) measures of regional brain activity when subjects make faces deliberately.

Regional brain activity has been examined with more traditional tasks used to arouse emotion, such as viewing pleasant and unpleasant films (Davidson, Ekman, Saron, Senulis, & Friesen, 1990), remembering or imagining emotional events (Bennett, Davidson, & Saron, 1981), and responding to reward and punishment contingencies (Sobotka, Davidson, & Senulis, 1992). The anterior regions of the two hemispheres of the brain have been found to be differentially involved in certain positive and negative emotions (Davidson & Tomarken, 1989). In particular, experimentally aroused, approach-related positive affect has been found to be associated with left-sided anterior activation, while withdrawal-related negative affect has been found to be associated with right-sided anterior activation.

Our examination of whether there are similar differences between smiles with Duchenne's marker and other smiles not only provides a crucial test of Duchenne's distinction, but also focuses attention on the issue of whether some of the physiological patterns generated when emotions occur involuntarily can also be generated by voluntarily making a set of facial movements. In light of previous data on relations between anterior activation asymmetries and emotion, we specifically hypothesized that when subjects produce a smile containing Duchenne's marker, it will be accompanied by a pattern of anterior brain asymmetry that has been found previously in spontaneous enjoyment, that is, greater left-sided anterior activation, compared with the voluntary production of other smiles.

METHODS

Forty-five undergraduates from introductory psychology classes at the University of Wisconsin were recruited to fulfill part of a course requirement. These subjects were screened individually to determine their ability to control their facial muscles voluntarily using a procedure that required moving certain facial muscles singly and in combination (but not making full facial configurations). The screening procedure included examining ability to contract the *zygomatic major* and the *orbicularis oculi* muscles. Thirty-two individuals demonstrated good voluntary control and agreed to participate in the experiment, but 5 of them could not find time to return for the experimental session. (It should be noted that to have such a large percentage of subjects able to contract *orbicularis oculi, pars lateralis,* is quite unusual. More typically, we have found [Ekman et al., 1980; Levenson et al., 1990] that only a minority can make this facial action voluntarily.) Twelve of the 27 remaining subjects were excluded because of artifacts in the EEG records due to gross movements in either the Duchenne-marker smile or the other smile (8 subjects), or in both trials (4 subjects). An equipment failure made the data from one other subject not usable. Fourteen subjects remained, 8 females and 6 males.

Each subject sat alone in a small room. An experimenter applied electrodes for the measurement of EEG. The subject was told that a coach seated in another room would see his or her face on a television monitor and would give instructions over an intercom. The experiment began with baseline recordings, followed by nine trials, each of which utilized a different configuration of facial muscles. We report here only the findings on the two trials which involved smiling activity and one other trial that was used for control purposes (see below). The instructions for the smile with Duchenne's marker first told the subject to "raise your cheeks," and then told the subject to "part your lips and let your lip corners come up." For the other smile, only the second instruction was given. Once the coach determined that the instructed expression was present, the subject was told to maintain the expression for 20 s. The order of these two trials varied across subjects.

EEG was recorded from the left and right mid-frontal (F3, F4), lateral frontal (F7, F8), anterior temporal (T3, T4), central (C3, C4), posterior temporal (T5, T6), parietal (P3, P4), and occipital (O1, O2) regions. In addition, EEG was recorded from the external canthus to the suborbit of one eye so that data confounded by eye movements could be removed. All channels were referenced to linked ears using a lycra, stretchable cap. Linked ears was used as a reference because of its good psychometric properties (Tomarken, Davidson, Wheeler, & Kinney, 1992) and use in other recent studies on brain electrical activity and emotion (Davidson & Tomarken, 1989). Three recent studies have found that linking the ears does not affect the magnitude of observed asymmetry (Andino et al., 1990; Miller, Lutzenberger, & Elbert, 1991; Senulis & Davidson, 1989).

All impedances were below 5K ohms, with the two ear leads within 500 ohms of one another. The EEG was amplified with a Grass Model 12 Neurodata System, with the bandpass between 0.01 and 300 Hz. The output of the amplifiers was low-pass filtered at 150 Hz (36 db/octave roll-off) to prevent aliasing. The filtered, amplified signals were digitized at 250 samples per second.

RESULTS

The EEG data were inspected visually for the presence of eye movement and gross movement artifact, and portions containing such artifact were removed prior to analysis. When artifact was present, data from all channels were removed. The EEG was Fourier transformed, and power density in the alpha band was extracted. We also examined power in other frequency bands, but consistent with a large body of previous evidence (Davidson, Ekman, et al., 1990; Ekman et al., 1990), the asymmetrical difference we report was present only in the alpha band. In addition, power in the frequency band from 75 to 125 Hz was computed to provide an estimate of muscle activity. The data in the alpha band were residualized to remove the contribution of muscle activity, separately for each channel (see Davidson, 1988, for a description of the use of an electromyographic, EMG, band to correct EEG power). Finally, they were log-transformed to normalize the distributions. Log-transformation of power values is a standard procedure and results in the best deskewing of the observed values (Davidson, Chapman, Chapman, & Henriques, 1990).

Differences between smiles with Duchenne's marker and other smiles in regional brain activity were evaluated by computing analyses of variance with expression type and hemisphere as repeated-measures factors, separately on the data from each region. In the four anterior scalp regions (lateral frontal, mid-frontal, anterior temporal, and central), the two smile types showed significant or near-significant differences in overall activation, with the smiles with Duchenne's marker producing more activation (i.e., less alpha power) than other smiles in each region (lateral frontal: $p < .06$; mid-frontal: $p < .02$; anterior temporal: $p < .02$; central: $p < .06$). The smiles did not differ in posterior brain activity recorded at the same points in time.

In addition to the difference in overall anterior activation between smile types, we observed a significant Expression

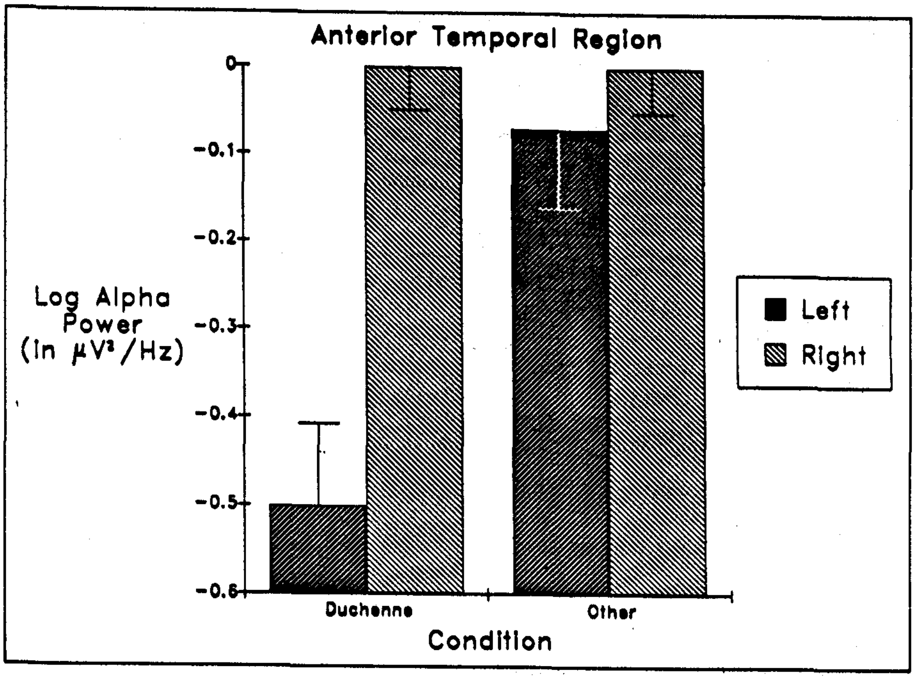

Fig. 1. Mean log-transformed alpha power in the left (T3) and right (T4) anterior temporal regions during the voluntary production of Duchenne and other smiles. Alpha power values have been residualized to remove the contribution of power in the EMG band (see text). Error bars represent standard error of the mean.

Type × Hemisphere interaction, $F(1, 13) = 5.58$, $p = .03$ (Fig. 1). This interaction is a function of the smiles with Duchenne's marker producing more left-sided anterior temporal activation (i.e., less alpha power) compared with other smiles, $t(14) = 2.78$, $p < .02$. When the data were examined for individual subjects, 12 of 14 subjects showed the asymmetrical difference in the anterior temporal region in the direction of prediction. No difference was observed in the right temporal region ($p > .20$). The central region lying over the motor strip showed no asymmetrical differentiation between the two types of smiling ($p > .75$).

Since the two smiles differed in the number of muscles that the subject was required to contract, it was possible that this alone—the effort involved in contracting two muscles in the smile with Duchenne's marker, as compared with one muscle in the other smile—might have been responsible for the difference in EEG asymmetry we found.[1] Two types of evidence argue against such an interpretation of our findings.

First, Levenson et al. (1990) observed that the number of muscles involved in a voluntary facial action could not explain the different patterns of autonomic nervous system activity they found, nor could ratings the subjects made immediately after each trial as to how difficult it was to make each face. Based on those findings, we also asked our subjects to rate difficulty after each trial on a scale from zero (no difficulty) to 8 (extreme difficulty). Although the other smile was rated slightly less difficult ($M = 1.71$) than the smile with Duchenne's marker ($M = 2.21$), this difference was not significant, $t(13) = 1.03$.

Second, we examined the EEG activity that occurred in another trial in which the subjects had to contract five muscles, a set of muscles which are contracted in spontaneous anger expressions. If the difference in EEG asymmetry between the two types of smiles was simply a function of the increased effort required to contract more muscles, we should expect that the anger configuration with five muscles should also differ from the other smiles (one muscle) and probably from the smile with Duchenne's marker (two muscles). Indeed, the anger face was rated as more difficult to make ($M = 4.86$) than the Duchenne-marker smile, $t(13) = 6.60$, $p < .0001$, or the other smile, $t(13) = 6.90$, $p < .0001$.

Differences in EEG activity among these three facial configurations were evaluated by computing an analysis of variance with expression type (Duchenne-marker smile, other smile, anger configuration) and hemisphere, using data from the anterior temporal leads, which is where the effect for the two smile types was obtained. There was a significant Expression Type × Hemisphere interaction, $F(2, 24) = 3.46$, $p = .05$ (Greenhouse-Geiser corrected). The difference between the anger configuration and the other smile was not significant when these two expressions were compared directly, $F < 1.0$. When we compared the anger configuration and the Duchenne-marker smile directly, the interaction of Expression Type × Hemisphere was significant, $F(1, 17) = 7.78$, $p = .01$. In anger, the means for the left ($-.21$) and right ($-.23$) anterior temporal regions were virtually the same, in contrast to the Duchenne-marker smile, for which marked left-sided activation was observed. Thus, these data suggest that the recruitment of additional muscles in the voluntary production of facial expressions is not responsible for the difference we observed between the two forms of smiling.

DISCUSSION

Our findings provide further support for Duchenne's hypothesis and are consistent with many other findings which have shown that the smile of enjoyment differs in subtle ways from other forms of smiling. By no longer treating smiles as a unitary class of behavior, investigators should be able to obtain a more accurate index of emotional state, and to resolve earlier contradictory observations that people smile in unpleasant as well as pleasant circumstances. Although these two forms of smiling are very similar in appearance, a recent study has found that they provide signal value to observers since subjects were able to distinguish Duchenne's smile from other smiles without the aid of slowed or repeated viewing, especially

1. An anonymous reviewer raised the question of whether effort could produce the decreased alpha in the Duchenne-marker smile.

when the smile was not broad, making the activity of the *orbicularis oculi, pars medialis,* noticeable (Frank, Ekman, & Friesen, 1993).

Our results are consistent with a large body of research (which did not focus on facial expression) showing more left anterior activation in certain positive emotions as compared with negative emotions (Davidson, 1992). These results are also consistent with the three prior studies that did distinguish between Duchenne-marker smiles and other forms of smiling in measuring regional brain activity. In a study of 10-month-old infants (Fox & Davidson, 1988), greater activation was found in the left frontal than the right frontal region for Duchenne-marker smiles as compared with other forms of smiling. In a study of college students (Ekman et al., 1990), more left-sided frontal and anterior temporal activation was observed during Duchenne-marker smiles than during other forms of smiling. Precisely the same pattern was observed in the present study. In a companion study, we (Davidson, Ekman, et al., 1990) found that the Duchenne-marker smile was associated with more left-sided frontal and anterior temporal activation than an involuntarily produced negative facial expression. The frontal differentiation between expressions may occur only when emotion is brought about in more typical fashion, not simply by performing a motor act, as in the current experiment.

All of these studies examined spontaneous emotional behavior—the response of infants to the approach of mother or stranger and the response of college students to watching nature films when they thought they are alone, unobserved. In both instances, it seems reasonable to presume that the facial expressions were likely to be involuntary. Our finding that voluntarily performing these facial muscular movements produced a similar pattern of regional brain activity suggests that at least some of the physiological changes are specific to emotion, not to how the emotion is brought about.

It is remarkable that the EEG findings were similar for voluntary and spontaneous forms of smiling, despite the fact that these performances differed in duration. Spontaneous smiles typically last only a few seconds (Frank et al., 1993), while we required our subjects to hold the muscular contraction for 20 s. Clearly, it is the morphology of facial muscular movement, not the duration of the movement, and not how the movement is generated, that is responsible for the comparability in the patterns of EEG activity found in voluntary and spontaneous forms of smiling.

Our finding of similar patterns of physiological activity for spontaneous emotional expression compared with voluntarily performed facial expression is consistent with preliminary findings (Levenson, Carstensen, Friesen, & Ekman, 1991) showing similar patterns of autonomic nervous system activity when subjects deliberately made the expressions associated with negative emotions and when those subjects remembered and reported reexperiencing past emotions. While emotions are generally experienced as happening to the individual, our results suggest it may be possible for an individual to choose when to generate some of the physiological changes that occur during a spontaneous emotion—by simply making a facial expression.

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