Facial Expression and Imagery in Depression: An Electromyographic Study

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When subjects are instructed to self-generate happy, sad, and angry imagery, discrete patterns of facial muscle activity can be detected using electromyographic (EMG) procedures. Prior research from this laboratory suggests that depressed subjects show attenuated facial EMG patterns during imagery conditions, particularly during happy imagery. In the present experiment, 12 depressed subjects and 12 matched normals were requested to generate happy and sad imagery, first with the instruction to simply "think" about the imagery, and then to self-regulate the affective state by "reexperiencing the feelings" associated with the imagery. Continuous recordings of facial EMG were obtained from the corrugator, zygomatic major, depressor anguli oris, and mentalis muscle regions. It was hypothesized that (a) these muscle sites would reliably differentiate between happy and sad imagery, (b) the instruction to self-generate the affective feeling state would produce greater EMG differences than the "think" instructions, and (c) the "think" instructions would be a more sensitive indicator of the difference between depressed and nondepressed subjects, especially for happy imagery. All three hypotheses were confirmed. The application of facial electromyography to the assessment of normal and clinical mood states, and the role of facial muscle patterning in the subjective experience of emotion, are discussed.

INTRODUCTION

One of the many facets of clinical depression that has received little scientific scrutiny is facial expression. Although typically the clinician is taught to attend to many nonverbal indices of emotion, including posture, tone of voice, and facial expression (1), the significance of these data for research on affective disorders has only recently been recognized. Interestingly, just over 100 years ago, Darwin (2) reported his classic observations in *The Expression of the Emotions in Man and Animals*. Drawing on the anatomical and physiological data then available, notably from Bell (3) and Duchenne (4), Darwin hypothesized that not only could emotions be differentiated by the facial expressions exhibited, but also that these patterns of muscle responding were in large part innate and therefore universal. Included in this treatise is a detailed discussion of melancholia and grief, and his classification is reminiscent of the present distinction between agitated and retarded depression:

"Persons suffering from excessive grief often seek relief by violent and almost frantic movements . . . but when their suffering

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is somewhat mitigated, yet prolonged, they no longer wish for action but remain motionless and passive, or may occasionally rock themselves to and fro. The circulation becomes languid, the face pale; the muscles flaccid; the eyelids droop; the head hangs on the contracted chest; the lips, cheeks and features are lengthened; and the face of a person who hears bad news is said to fall" (Darwin, 1872, p. 176).

There are numerous reasons why facial expression has not been systematically studied in affective disorders; two central factors involve replicability and reliability of measurement. As discussed in detail by Ekman and colleagues (5), when a few key studies in the 1930's failed to replicate cross-cultural stability of facial recognition, research was essentially halted. However, using more sophisticated stimulus and rating prccedures, Ekman et al. (5) and Izard (6) have documented that at least six different overt facial expressions are universally observed and labeled cross-culturally as distinct emotions: happy, sad, anger, fear, surprise, and disgust. Ekman has continued to develop his procedures for scoring overt facial expression (7). Izard (8) has applied these observations to the assessment of subjective experience by differentiating fundamental emotions and patterns of emotions (in anxiety and depression) with his Differential Emotion Scale (DES).

Another approach to the assessment of facial expression is to directly record the dynamic patterns of facial muscle activity. One goal in the present research is to develop objective psychophysiological procedures for evaluating the subtle changes in affect produced by antidepressant and antianxiety drugs. Visual rating techniques, although quite adequate for assessing large magnitude facial adjustments, are not as well suited for the measurement of small facial adjustments, particularly those occurring quickly in time. Based on the early findings of Jacobson (9) involving subtle electromyographic (EMG) patterning during imagery, and the body of research on depression emphasizing chronic patterns of muscle tension in depressed subjects that were not readily visible to the naked eye (10), we reasoned that direct recording of patterns of facial muscles via electromyography could provide a continuous and highly sensitive measure of facial expression, not only of the overt face, but also of "covert" facial expressions as well.

In a previous experiment, we recorded facial EMG from the corrugator and frontalis muscle regions of the eyebrow and forehead, and the depressor and masseter muscle regions of the mouth and jaw (11). The data indicated that it was possible to discriminate when subjects were self-generating happy, sad, or angry thoughts and feelings, even when no differences were readily apparent in the overt face. Furthermore, when depressed subjects were compared to nondepressed subjects, the data indicated that the depressed subjects showed attenuated facial EMG patterns for happy imagery, and slightly accentuated facial EMG patterns during sad imagery. Interestingly, the largest difference between the groups was in a condition originally included as a control imagery period. Subjects were asked to simply think about what they do in a typical day, from the time they awoke until the time they went to sleep, with no requirement to also generate an affective state. The results showed that the depressed subjects generated a small sad pattern in their facial EMG, while the nondepressed subjects generated a miniature happy pattern.

The present experiment was conducted to replicate and extend these findings, using matched samples and two different muscle placements. To ascertain whether the improved differentiation for typical day imagery was determined in part by the lack of an instructional requirement to self-generate an emotional state associated with the imagery, two different instructional conditions were employed in this study. One required that the subject simply generate the imagery without any requirement to also self-regulate the corresponding affective state ("think" condition); the second required that the subject generate the imagery and also attempt to reexperience the feelings associated with the imagery ("feel" condition). Altogether, three hypotheses were made: (1) for the group as a whole, facial EMG would differentiate between happy and sad imagery, (2) the "feel" instructions would lead to greater facial EMG differentiation between happy and sad imagery than "think" instructions, and (3) depressed subjects would show attenuated EMG patterns, particularly during the "think" happy conditions.

METHOD

Subjects:

Twelve depressed subjects and 12 nondepressed subjects matched for age and sex were studied. The depressed subjects were recruited through a clinic and the nondepressed subjects were recruited from an ad in a local newspaper and paid for their participation. Inclusion criteria for the depressed group were a score of 56 or above on the Zung Self-Rating Depression Scale (12), a diagnosis of clinical depression, an ability to tolerate the acoustic chamber, and considered to be appropriate for a trial of antidepressant medication. Subjects were excluded from the study if there were concomitant major medical problems, any suicidal ideation or history, or if there were contraindications for the use of a tricyclic antidepressant. Most of the depressed subjects, as reflected in the high Zung scores, had some endogenous features, notably sleep disturbance, weight loss, and some inability to perform at work because of anergia. All of these subjects were medication-free at the time they started the study.

The nondepressed subjects had scores below 50 on the Zung and were in good health. Each group was comprised of 2 males and 10 females. The mean scores on the Zung, the Taylor Manifest Anxiety Scale (13), and ages for the two groups are shown in Table 1.

TABLE 1. Mean Scores for Each Group

	Age	Zung	Taylor
Depressed $N=12$	37.5	70.2	33.1
Normals $N=12$	38.3	38.8	11.2

Experimental Design

The experiment consisted of two happy imagery periods and two sad imagery periods, each separated by rest trials of 30 sec. All conditions were performed with eyes closed. Each affect was examined under two instructions, for convenience referred to as "think" and "feel," making a 2 × 2 within-subject design. Sample instructions for each are given below.

"Think": "What I'd like you to do is to sit back with your eyes closed and think about that particular thing. As you're recalling the situation if you find that it makes you feel (happy /sad) again, then allow yourself to feel that way. If you find that recalling doesn't make you feel anything, don't worry. All I'm interested in is that you recall and continue to think about the situation for the next couple of minutes."

"Feel": "What I want you to do is to sit back with your eyes closed and think about that particular thing. While you're thinking about it, try to reexperience the feeling, try to *make* yourself feel (happy /sad) for a couple of minutes."

Although the order of happy and sad conditions was counterbalanced across subjects, both "think" conditions always preceded the "feel" conditions. Because the order of the instructional variable was

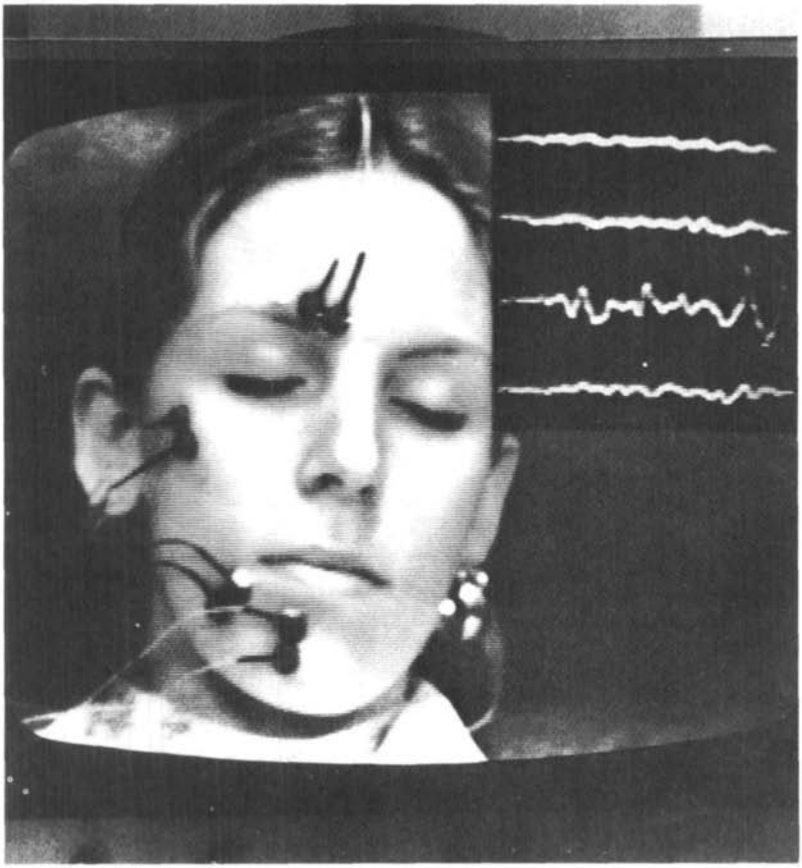

Fig. 1. Photograph of the videoscreen showing placement of the four pairs of EMG electrodes and, superimposed electronically next to the face, the oscilloscope tracings of the amplified electromyographic activity from the four facial regions.

not counterbalanced, this could make it more difficult to obtain a "think" versus "feel" effect due to habituation. However, since it was less clear regarding what effects the reverse order might have (e.g., practice effects leading to improved imagery generation seemed unlikely), and given the relatively small N, it was decided to allow potential habituation effects to attenuate the predicted think/feel comparison by maintaining a fixed order. Thus, although significant think/feel effects were obtained, caution must be exercised in interpreting the magnitude of these effects.

Physiological Recording Procedures

Miniature Beckman Ag/AgC electrodes were placed adjacent to each other in pairs with interelectrode resistance reduced to less than 3000Ω. The four muscles selected for study were the corrugator, zygomatic, depressor anguli oris, and mentalis on the right side of the face. It is conceivable that a right-sided placement, particularly for the lower face, may not have been optimal for detecting facial patterns associated with emotion. Recent research indicates that the right hemisphere may play a special role in emotion (14), including affect generated by imagery (15).

It must be noted that since surface electrodes are being used here, caution must be exercised in interpreting the activity from a given site as emmanating solely from that muscle. Although for convenience we will speak of "depressor" activity, for example, it should be recognized that activity from adjacent muscles such as the orbicularis oris may be contributing to the recorded EMG. This qualifies the anatomical generalizations of the data (16), but it does not eliminate the validity of using the procedure as a sensitive empirical tool.

The EMG is amplified by four Grass Wideband AC amplifiers (7P511) set at 7.5 μV/mm, and then each channel is individually rectified and summed by four Grass 7P10 integrators. The integrated EMG is written out on the polygraph as a resetting ramp function with a full scale pen deflection of 40 mm (1 mm = 45 μV). Raw EMG is also displayed on a four-trace Tektronix oscilloscope to observe single motor unit firings and to monitor for artifacts. Simultaneous recording of the overt facial expression and the raw EMG from the oscilloscope is made on video tape with the aid of a Panasonic Special Effects Generator and video tape recorder. This makes it possible to observe the subject's overt facial expression and the underlying raw facial EMG at the same time. Figure 1 illustrates the positioning of electrodes and the video display.

Procedure

After the electrodes were attached, subjects were seated in a sound-proof room and reclined in a lounge chair with eyes closed. The experimenter read all instructions from the adjoining equipment room. After each imagery condition, subjects reported the intensity of the emotion experienced on a five-point scale.

Subjects were told that the purpose of the research was to investigate patterns of physiological processes in imagery and emotion. Additional electrodes placed on the arms (for heart rate) and nonpreferred hand (for skin resistance) served to reduce focus on the face itself. In the previous study (11), subjects were specifically told that the purpose of the research was to monitor muscle activity over much of the body (with additional electrodes placed on the head and legs as well). Although it could be hypothesized that the obtrusive nature of the facial electrodes heightens facial responding (by increasing subject attention to the face), it could also be the case that the electrodes act to attenuate responding, since the electrodes restrict movement. Employing multiple recording sites in addition to the face and using instructions aimed at reducing movement and attention to the face increases the probability that the facial EMG patterning observed during affective imagery is not an atypical phenomenon.

At the conclusion of the recording procedure, subjects filled out a modified version of the Differential Emotion Scale (8), using 10 categories, three-word descriptions each. This instrument was used to assess the effectiveness of the instructional manipulations in terms of self-report and the relationship of self-perceived affect to changes in facial EMG patterns.

Data Reduction and Analysis

The EMG was scored from the paper records in 30-sec periods and summed over 1.5 min. Difference scores relative to rest were then computed. Rest scores were derived separately for the think and feel conditions, using the mean of pre- and postrest scores surrounding each condition. Since the distribution of difference scores was not always normal, two-tailed nonparametric procedures (17) were used. Wilcoxon Matched-Pairs Signed-Ranks tests were performed within subject groups and comparisons across groups were made using Mann Whitney U Tests. The data are analyzed for the total sample, then separately within each group, followed by comparisons between groups.

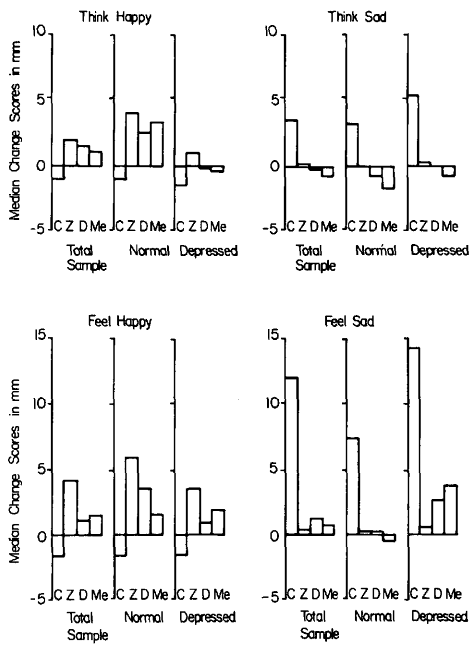

Fig. 2. Median change from resting baseline for muscle activity from the corrugator (C), zygomatic (Z), depressor anguli oris (D), and mentalis (Me) facial regions during the two imagery (happy, sad) and instructional (think, feel) conditions. Data are displayed separately for the total sample (N=24), the normal group (N=12), and the depressed group (N=12). A 1mm change score equals 45 μV /30 sec.

RESULTS

Total Sample

Figure 2 presents the EMG change scores for each muscle, for each condition, for the total sample (N = 24), and for the two groups separately. Table 2 presents the P values for (a) change from baseline (b) separate comparisons of happy versus sad and think versus feel, and (c) direct comparisons of happy versus sad with think versus feel. These analyses are performed for the total sample, each of the groups separately, and comparisons across the two groups.

In Fig. 2, looking first at the total sample, it is clear that happy imagery during both "think" and "feel" instructions consistently generates a different pattern from

TABLE 2. P Values for the Corrugator (C), Zygomatic (Z), Depressor (D), and Mentalis (Me) Regions. (a) Change from Baseline; (b) Separate Comparisons of Happy versus Sad and Think Versus Feel, and (c) Direct Comparisons of Happy versus Sad with Think versus Feel. Analyses Are Presented for the Total Sample (T), Each of the Groups Separately (N=Normals; D=Depressed), and Comparisons across the Groups (N vs. D) P Values Reflect Wilcoxon Test Comparisons within Each Group and Mann Whitney Comparisons between Groups

	Think happy				Feel happy				Think sad				Feel sad			
(a)	C	Z	D	Me	C	Z	D	Me	C	Z	D	Me	C	Z	D	Me
T		<0.01	<0.05		<0.06	<0.01	<0.05	<0.07	<0.01				<0.01			
N		<0.01	<0.01	<0.05	<0.01	<0.01	<0.05	<0.10	<0.05				<0.01			
D						<0.01			<0.05				<0.01			<0.05
N vs. D		0.02	0.05	0.01												<0.07

	Think (happy-sad)				Feel (happy-sad)				Happy (think-feel)				Sad (think-feel)			
(b)	C	Z	D	Me	C	Z	D	Me	C	Z	D	Me	C	Z	D	Me
T	<0.01	<0.01	<0.05	<0.05	<0.01	<0.01				<0.01			<0.01			
N	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			<0.05			<0.01			
D	<0.08				<0.01	<0.05				=0.05			=0.05			
N vs. D		<0.02	<0.02	<0.05		<0.06	<0.05									

	Think (happy-sad)-Feel (happy-sad)			
(c)	C	Z	D	Me
T	<0.01	<0.02		
N	<0.01			<0.10
D		<0.10		
N vs. D				

sad imagery. Visual inspection reveals that during happy imagery there is a decrease in corrugator below resting levels and a simultaneous increase in depressor. In addition, happiness is associated with an increase in zygomatic and an increase in mentalis. Sad imagery produces a different pattern, with increases in corrugator activity above baseline, little change in depressor, and little effect on either zygomatic or mentalis activity. The results for corrugator and depressor in both happy and sad imagery replicate our previous findings (11).

Examination of the P values reveals that the difference between happy versus sad is reliable for all four muscles during the "think" condition, but the depressor and mentalis fail to reach significance during the "feel" conditions. This would suggest that the zygomatic and corrugator are the most sensitive of these four muscles to these two imagery conditions. This conclusion is supported by examining the "think" versus "feel" tests separately for happy and sad imagery. The P values illustrate that the zygomatic is sensitive to instructional differences in happy imagery, whereas the corrugator is sensitive to instructional differences in sad imagery. It should be noted that this particular effect is reliable for each group separately. Since the zygomatic is activated during the smile whereas the corrugator is activated during sadness and grief (2,6), these findings during imagery make anatomical sense.

The sensitivity of the zygomatic and corrugator to happy and sad imagery is also reflected in the P values comparing happy versus sad differences for "think" versus "feel." These data indicate that the "feel" instruction result in larger happy/sad differences than the "think" instruction, but that this occurs primarily in the corrugator and zygomatic.

Depressed Versus Nondepressed

Turning to comparisons between the depressed and nondepressed subjects, it is immediately apparent from the curves that nondepressed subjects generate large and reliable EMG changes for happy imagery (7 of 8 P values for change from baseline are significant for the "think" and "feel" happy conditions), whereas the depressed subjects produce only one reliable EMG change during happy, and this is for the zygomatic in "feel" happy. A Fisher Exact Test on this distribution of P values is significant at the 0.01 level and replicates our previous findings (11). It is more important, however, that comparisons between the two groups yield three significant effects for the "think" conditions, whereas none of the comparisons between groups for the "feel" happy condition reach significance. These data suggest that when specifically requested to do so, depressed patients have some ability to self-regulate a happy psychophysiological state. However, in the absence of this external instructional demand, depressed subjects do not *spontaneously* generate a reliably happy pattern, as do nondepressed subjects.

The difference between depressed and nondepressed subjects in EMG is also seen in the P values comparing happy versus sad separately for the "think" and "feel" conditions. While the nondepressed subjects generate four P values of 0.02, 0.01, 0.01, and 0.01 for the four muscles in the "think" conditions, the depressed subjects show only one significant effect ($P < 0.08$) for the corrugator. It can also be seen that with the addition of the "feel" instruction, the depressed subjects now generate reliable happy/sad differences in corrugator ($P < 0.01$) and zygomatic ($P < 0.05$). A Fisher Exact Test reveals a significant difference between the two groups in their distribution of effects ($P < 0.05$).

Looking at the sad conditions alone, the only significant difference between groups is the mentalis ($P < 0.07$); this is meager support for the notion that depressed subjects are more prone to generate facial patterns for sadness. In an earlier study (11), only the frontalis reliably differentiated between depressed and nondepressed subjects during sad imagery, and the magnitude of this effect was also small. A conservative statement would be that the primary difference between the groups, using these muscles, is found in generating *positive* imagery when there is no instructional requirement to also self-regulate the associated affective state.

Self-Reports

Table 3 presents the mean emotion ratings made both immediately after each condition and as assessed at the end of the session on the DES. Mann Whitney U tests show that these self-reports also differentiate between the two groups under the happy conditions, but not the sad. That is, the nondepressed rate themselves as having felt more happy than the depressed group, but not more sad.

TABLE 3. Mean Postimagery Rating for Each Group and Comparison between Groups

	Post imagery ratings			
	Think		Feel	
	Happy	Sad	Happy	Sad
N	3.75	3.38	3.83	3.58
D	2.42	2.96	2.79	3.42
N vs. D	U=37	U=60.5	U=27.5	U=63
	P<0.05	NS	*P*<0.02	NS
	DES ratings			
	Think		Feel	
	Happy	Sad	Happy	Sad
N	4.08	3.84	3.75	3.75
D	2.75	3.08	2.50	3.58
N vs. D	U=17.5	U=43.5	U=17.5	U=65
	P<0.002	NS	*P*<0.002	NS

DISCUSSION

The three main hypotheses outlined in the introduction were supported by the data. First, it was demonstrated that facial EMG can reliably differentiate between periods when subjects were imagining happy scenes and when they were imagining sad scenes. Of the four muscle regions monitored in this study, the zygomatic was found to be particularly sensitive to happy imagery, and the corrugator was especially sensitive to sad imagery. In a recent experiment recording from a total of 12 different sites on the face, Fair and Schwartz (18) have found that the zygomatic and corrugator placements continue to be particularly sensitive muscles for tapping happy and sad affect, respectively. This probably reflects the fact that anatomically the zygomatic is engaged in the production of a smile whereas the corrugator is activated in the production of a frown (2, 6).

Second, it was demonstrated that instructions to reexperience the feelings associated with the imagery result in larger facial EMG patterns than those observed when subjects are instructed to simply generate the imagery (without the additional requirement that they also self-regulate an emotional state). Consistent with anatomical considerations, this intensity variable, manipulated via instructions, expresses itself primarily in the zygomatic for happy imagery, and in the corrugator for sad imagery. However, since the instructional variable was not counterbalanced in the present experiment, the conclusion must be seen as tentative.

Finally, it was found that subjects diagnosed as clinically depressed show attenuation of the facial EMG pattern associated with happy imagery, but this primarily occurs under conditions that do not require the subjects to reexperience the prior feelings. The distinction between the generation of imagery versus the activation or regulation of other more visceral and skeletal processes is important. It recognizes the neuropsychological differences between specific cortical processes and their integration with subcortical and limbic processes (19).

The fact that depressed subjects show attenuated facial EMG patterns during the generation of happy imagery, but that this attenuation can be reversed to some extent by further cognitive demands, illustrates the potential that imagery may play in therapeutically modifying the depressive mood (20). To the extent that depressed people fail to generate positive facial expressions, they also reduce the total amount of patterned proprioceptive feedback associated with a positive affective state. Recent theories of emotion (6, 21) suggest that the experience of emotion is based, in part, on the specific *pattern* of feedback resulting from the facial and bodily expressions of emotion. It is tempting to speculate that, in light of the fact that imagery does elicit covert patterns of facial muscle activity and that these patterns can be accentuated when the person attempts to self-regulate the specific emotion, it might be of value to teach depressed patients to recognize that they are failing to generate a positive patterned skeletal state and then train them to self-regulate this pattern as a means of reversing their depressed mood. There may be some biological truth to the old saying "put on a happy face," although this will of course require further investigation. The concept of self-regulation of specific *patterns* of physiological responses as a means of altering cognitive and affective states is discussed further by Schwartz (22, 23).

Altogether, the present data provide additional support for the hypothesis that facial electromyography can be useful in the assessment of normal and clinical mood states (11). However, it remains to be demonstrated whether these procedures can be applied to more complex differentiations such as between anxiety and depression and their combination. Although the use of electromyographic procedures appears to have value in accurately quantifying subtle facial patterns occurring over time, this need not imply that it is the only procedure for examining facial expression, particularly in a clinical population. Visual scoring procedures are being developed that can be employed in clinical settings (7). On the other hand, with the advent of portable equipment for quantifying EMG (originally developed for biofeedback research), it is now feasible to collect electromyographic data in a clinical setting. Although the major advantage of visual observation procedures is that they are unobtrusive and require minimal equipment, it is not possible to use visual analysis for accurately summing subtle changes occurring over time in specific muscle regions, particularly those occurring quickly in time. Ideally, the specific research needs will dictate which method is preferable.

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REFERENCES

1. Hamilton M: A rating scale for depression. J Neurol Neurosurg Psychiatry 23:56–62, 1960
2. Darwin C: The Expression of the Emotions in Man and Animals. Chicago, University of Chicago Press, 1965 (originally published 1872)
3. Bell C: Anatomy and Philosophy of Expression. London, Longmans, Green, ed. 3, 1844
4. Duchenne GB: Mechanisme de la Physonomie Humaine. Paris, Bailliere, ed. 8, 1862
5. Ekman P, Friesen W, Ellsworth P: Emotion in the Human Face. New York, Pergamon Press, 1972
6. Izard C: The Face of Emotion. New York, Appleton-Century-Crofts, 1971
7. Ekman P, Friesen W: Unmasking the Face. New York, Prentice-Hall, 1975.
8. Izard C: Patterns of Emotions. New York, Academic Press, 1972
9. Jacobson E: Progressive Relaxation. Chicago, University of Chicago Press, 1938
10. Whatmore GB, Ellis RM: Some neurophysiologic aspects of depressed states. Arch Gen Psychiatry 1:70–80, 1959
11. Schwartz GE, Fair PL, Salt P, Mandel M, Klerman GL: Facial muscle patterning to affective imagery in depressed and nondepressed subjects. Science 192:489–491, 1976
12. Zung WWK: A self-rating depression scale. Arch Gen Psychiatry 12:63–70, 1965
13. Taylor JA: Personality scale of manifest anxiety. J Abnorm Soc Psychol 48:285–290, 1953
14. Schwartz GE, Davidson RJ, Maer F: Right hemisphere lateralization for emotion in the human brain: interactions with cognition. Science 190:286–288, 1975
15. Davidson RJ, Schwartz GE: Patterns of cerebral lateralization during cardiac biofeedback versus the self-regulation of emotion: sex differences. Psychophysiology 13:62–68, 1976
16. Basmajian JV: Muscles Alive. Baltimore, Williams and Wilkins, 1967
17. Siegel S: Nonparametric Statistics. New York, McGraw-Hill, 1967
18. Fair PL, Schwartz GE: Facial muscle patterning to affective imagery and the voluntary expression of emotion. Psychophysiology (abs.) (in press)
19. Luria AR: The Working Brain. New York, Basic Books, 1973
20. Singer JL, Imagery and Daydream Methods in Psychotherapy and Behavior Modification. New York, Academic Press, 1974
21. Tomkins SS: Affect, Imagery, Consciousness (2 vols.). New York, Springer, 1962, 1963
22. Schwartz GE: Biofeedback, self-regulation, and the patterning of physiological processes. Am Sci 63:314–324, 1975
23. Schwartz GE: Self-regulation of response patterning: implications for psychophysiological research and therapy. Biofeedback Self-Reg 1:7–30, 1976