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Electromyograms as Measures of Extent and Affectivity of Information Processing

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ABSTRACT: *Advances in psychophysiological method and theory have made it possible and fruitful to study the physiological response components that accompany particular types of information-processing activity. This article surveys these advances, briefly tracing the development of psychophysiology. A review of a program of research using the electromyogram to augment the study of processing depth and affectivity illustrates the principles and utility of psychophysiology. Implications for the study of mental processes in cognitive/experimental and social psychology are discussed.*

The thesis of this article is that "mental processes" are accompanied by focal sites of muscular activity, typically at sites in the musculature involved during the "acting out" of one's thoughts, and that the amplitude of somatic responses decreases as the distance of measurement from these focal sites increases. The implication of this thesis is that electromyographic (EMG) responses provide a powerful supplement to the verbal and more overtly behavioral (e.g., chronometric) responses that are used in studies of covert information processing. The purposes of the present article are to (a) trace briefly the evolution of the area of psychophysiology, out of which grew interest in, resistance to, and then evidence for the utility of the electromyogram in studies of mental processes; (b) outline briefly the evidence for and theoretical accounts of the notion that particular mental processes are accompanied by somato-visceral patterns of activity; and (c) illustrate the procedures for and theoretical benefits of monitoring covert bodily responses (specifically, skeletomuscular responses) in research on the extent and affectivity of ongoing information processing.

Early Psychophysiology

The earliest writings to address the relationships between psychological and physiological phenomena are probably those of the ancient Greeks (e.g., about 500 B.C. in Plato's *Theatetus*; cf. McGuigan, 1978, chap. 2; Mesulum & Perry, 1972). Empirical research on these relationships is still fairly recent, having begun only about 100 years ago (e.g., see Angell & Thompson, 1899, and Sechenov, 1878/1947, for reviews of some of the early work). The early work by psychophysiologists was hindered by seemingly insurmountable technical limitations in measuring physiological responses (e.g., Berger, 1929/1976; Féré, 1888/1976; Thorson, 1925). When satisfactory analog measurements of bodily responses were obtained, the pioneering psychophysiologists still faced the problem of quantifying and analyzing their masses of data. Perhaps surprisingly, psychophysiological research continued through these difficult times, apparently sustained by the potential contribution of the approach, its wide range of application, occasional technological and procedural developments, and the dedication of its advocates. Not so surprising given the insensitive observational procedures then available to psychophysiologists, most of the early studies involved anything but subtle experimental treatments (Darrow, 1929, for instance, once used an unexpected gunshot as an eliciting stimulus), and major, unidirectional changes in physiological activity were typically obtained.

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In the 1940s, advances in electronics provided standardized and economical methods with which to investigate psychophysiological processes. The most important stimulus to the growth of psychophysiology was the widespread introduction of the oscillograph (polygraph), which provided a means for researchers to measure a variety of subtle bioelectrical and physical responses that occur in a person's body. These technological advances were accompanied by innovations in statistics and data processing, which facilitated the collection, quantification, and analysis of psychophysiological data.

The field of psychophysiology grew quickly and in even more diverse directions from that point through today. The reliance on increasingly sophisticated equipment has continued.[1] In addition, subjects are now being treated in a manner designed to minimize their apprehension concerning participation in "electrophysiological" research (cf. McGuigan, 1979). Moreover, the experimental treatments to which subjects are now exposed are not nearly as blatant (and traumatic) as in previous years, and the number and sensitivity of the dependent measures obtained have increased. Together, these developments have contributed to the recurrent observation of psychophysiological specificity and patterning (cf. Davidson, 1978; Schwartz, 1975).

As a consequence of this modern diversity, characterizing the *general* field of psychophysiology requires appropriately diffuse language: Something like "the scientific study by nonsurgical means of the interrelationship between psychological processes and physiological systems in humans" sets empirical boundaries wide enough to encompass relevant research in which bodily responses have served as independent as well as dependent variables (e.g., Cacioppo, 1979), but not so wide as to obfuscate distinctions between psychophysiology and physiological psychology. More important, the breadth and complexity of the issues addressed in psychophysiological research have led to its application in each of the subareas of psychology.

In the present article, we focus on the psychophysiological procedures for investigating "mental" processes and demonstrate the utility of these procedures for examining theoretical issues in two subareas of psychology—cognitive/experimental and social psychology. The approach in this endeavor is to wed psychophysiology with these two subareas of psychology in order to (a) gain insights into basic psychological processes (e.g., as studied by social and cognitive/experimental psychologists) by scrutinizing covert bodily reactions and (b) advance psychophysiological theory by capitalizing on the extant models in the subareas of psychology. There is an inherent danger in this approach, since advancements along each front presume sometimes dubiously that positions are secure along the other. This danger, inherent in all psychological research, is lessened to the extent that movements along both fronts are viewed cautiously until converging lines of evidence for or against the guiding constructs are obtained using other (e.g., chronometric, verbal) procedures.

Evidence for Somato-Visceral Patterns During Information Processing

The first century of research on the psychophysiology of mental processes covered perception, nocturnal dreams, imagination, learning, and problem solving, most of which, at one time or another, were used to elicit responses in the skeletomuscular, visceral, and central nervous systems. A characteristic finding, in part due to the nature of the independent and dependent variables employed, was that physiological responding increased relative to baseline levels when people performed motor and mental tasks (e.g., Clites, 1936; Freeman, 1930; Golla, 1921). As a result, several elaborate theories regarding task performance and arousal (in one of its many forms) were developed (e.g., Duffy, 1957; Lindsley, 1952; Malmo, 1957).

PRINCIPLES OF SPECIFICITY

There were notable exceptions, however, to the focus on and evidence for the dominant notion of general physiological arousal. Darrow (1929), for instance, measured multiple physiological responses simultaneously while subjects performed a host of tasks (e.g., mental arithmetic, attending to weak stimulation). Darrow observed that the notion of general arousal, though an evident accoutrement of some tasks, failed to account for much of the variance in physiological responding. A quarter of a century later, Ax (1953) conducted

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[1] As an anonymous reviewer of this article noted, the recent advances in built-in digital integrators, and we might add in microcomputers and software, have made what was once a monumental task now simple enough for psychologists to accomplish with relative ease.

a seminal experiment on "the physiological differentiation between fear and anger in humans." In his experiment, Ax (a) demonstrated distinctive patterns of somato-visceral reaction during emotion, (b) obtained low correlations among the physiological reactions for each emotion (though the intercorrelations were slightly higher for anger than for fear), and (c) found greater between-subject than within-subject variance in physiological reactions (suggesting that people may have distinctive modes of responding physiologically). Schwartz, Weinberger, and Singer (1979) have recently replicated and extended this work.

Shortly after the appearance of Ax's report, the Laceys (Lacey, 1959, 1967; Lacey & Lacey, 1958) martialed an influential attack on arousal theories, arguing that there are multiple psychologically important factors that influence the various physiological responses at each moment in time. Two principles identified by the Laceys are individual response stereotypy and stimulus response stereotypy. *Individual response stereotypy* refers to the tendency for the same individual to display the same profile of physiological responses regardless of the situation or stimulus, whereas *stimulus response stereotypy* refers to the tendency for a situation or stimulus to elicit a common pattern or profile of responses from people in general.

Schwartz and his colleagues (e.g., Schwartz, 1975; Schwartz, Ahern, & Brown, 1979; Schwartz, Brown, & Ahern, 1980; Schwartz et al., 1978) have found support, using EMG measures of muscle activity in the human face, for Darwin's (1872/1904) suggestion that distinctive facial expressions are linked to different emotions. For instance, Schwartz, Fair, Salt, Mandel, and Klerman (1976b) found that clinically depressed subjects displayed unique patterns of facial EMG activity when they imagined pleasant versus unpleasant experiences. Nondepressed subjects displayed patterns similar to those produced by the depressed subjects, but the pattern accompanying pleasant imagery was accentuated and the pattern accompanying unpleasant imagery attenuated in the normal subjects. Furthermore, when the subjects were asked to imagine their typical day, normal subjects displayed a pattern similar to that evinced while they imagined a pleasant experience, whereas depressed subjects displayed a pattern similar to that exhibited while they imagined an unpleasant experience (see also Cacioppo & Petty, 1981a; Schwartz, Fair, Salt, Mandel, & Klerman, 1976a).

Recently, Lang (1979) has proposed a bio-informational theory of (emotional) imagery, in which he states

> that imaginal activities are accompanied by efferent outflow, that specific patterns of visceral and somato-motor activity are associated with the kind of processing and the specific content of cognitive events . . . that the image structure includes a motor program, and furthermore, that it is a prototype of overt behavioral expression. (p. 495)

Lang's views regarding the skeletomuscular system are especially pertinent here, as they too bespeak the utility of EMG measures in studies of information processing.[2]

Lang's views account well for a number of early studies on imagination in addition to the more recent work on emotional imagery (e.g., Lang, Kozak, Miller, Levin, & McLean, 1980). Shaw (1940), for example, found that the amplitude of preferred-arm EMG increased as subjects lifted heavier and heavier weights; this same general trend held when subjects *imagined* lifting the weights. Similarly, Jacobson (1930a, 1930b) instructed subjects to imagine performing a variety of tasks that involved the use of the right arm (e.g., throwing a ball, pulling on socks). Jacobson observed increased right-arm EMG activity when subjects imagined how it would feel to perform these actions, relative to EMG levels in the right arm during baseline and control conditions (e.g., when subjects were instructed to imagine performing the actions left-handed—see also Jacobson, 1931).

A more general principle is necessary, however, to account also for verbal learning and verbal behavior. A suggestive beginning of such a principle was outlined by Davis (1939). Davis (1937, 1938, 1939) conducted a program of research on the relationship between "mental work" (e.g., mental arithmetic, memorizing nonsense syllables, memorizing poetry, etc.) and EMG activity at various sites (i.e., on arms and legs). Davis posited the *prin-*

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[2] Lang's proposal that the extent to which an emotional image captures efferent activity influences the extent to which the imagined response is predisposed is reminiscent of James's (1890/1905) suggestion, based on introspective procedures, that the "Will" (i.e., a central idea or image) triggers the waiting musculature:

> We may then lay it down for certain that every representation of a movement awakens in some degree the actual movement which is its object; and awakens it in a maximum degree whenever it is not kept from doing so by an antagonistic representation present simultaneously to the mind. . . . We do not have a sensation or a thought and then have to *add* something dynamic to get a movement. (pp. 526–527)

See Greenwald (1970; Greenwald, Note 1) for an elaboration of James's ideomotor principle.

ciple of focus of muscular responses, which holds that each task which a subject performs is accompanied by a focus of muscular activity, typically in relevant motor areas,[3] and that the amplitude of somatic responses during the task decreases as the distance of measurement from this focus increases. Davis's principle of focus of muscular responses does not, however, predict where a focal point might be located.

A descendant of Davis's postulate which possesses greater explanatory and predictive power is that (1) there are foci of skeletal muscles in which changes characterize particular psychological processes (e.g., linguistic processing); (2) inhibitory as well as excitatory changes in skeletomuscular activity can characterize psychological processes; (3) the changes in skeletomuscular responding are patterned temporally as well as spatially; (4) the changes in skeletomuscular responding become less evident as the distance of measurement from a focal point increases; and (5) foci can be identified a priori by (a) analyzing the overt reactions that previously characterized the particular psychological process of interest but that dropped out with practice or (b) observing the sites in the musculature that are involved during the "acting out" of one's thoughts (e.g., reading aloud and writing indicate the presence of covert linguistic processing). These principles, which we summarily refer to as the *model of skeletomuscular patterning*, account not only for the observations garnered in Davis's program of research but also for the early work by Shaw (1938, 1940), Jacobson (1930a, 1930b, 1931), and others on EMG patterns as a function of the type and content of imagined activity, the work on temporal relations among psychophysiological responses (cf. McGuigan, 1978; McGuigan & Boness, 1975), and the especially pertinent work linking silent language processing to changes in EMG activity of the speech and writing-arm musculature (see reviews by Garrity, 1977; McGuigan, 1970, 1978; Sokolov, 1972).[4]

AN APPLICATION

We became interested in the principle of skeletomuscular patterning when searching for a means to address a controversy that arose in social psychology. The controversy concerned whether recipients of a persuasive message (e.g., advertisements, editorials, political speeches) think about and elaborate on topic-relevant information (e.g., message arguments) when yielding to or resisting a communicator's recommendation. The evidence we have outlined above for peripheral physiological response patterning in general and for skeletomuscular patterning in particular seemed to bode well for our chances of finding psychophysiological procedures for assessing the extent and affectivity of ongoing information processing, assessments that would provide an empirical solution to the controversy. We next describe several experiments that we conducted to determine the value and nuances of using EMG measures of speech-related and non-speech-related muscles to measure the extent (or "depth") of processing. In a subsequent section, we describe the set of EMG measures and procedures we employed to assess the extent and affectivity of subjects' ongoing information processing as they awaited and monitored a personally involving persuasive communication. We conclude by commenting on the utility of employing psychophysiological principles and procedures to facilitate theoretical advancement in psychology.

Assessing the Extent of Associative (Linguistic) Processing During Encoding

There are interesting parallels between the notions from social psychology regarding the extent to which message recipients vigilantly process topic-relevant information and the notions from experimental psychology regarding the levels of human information processing (cf. Craik & Lockhart, 1972; Petty & Cacioppo, 1981a, chap. 9). According to Craik and Lockhart's "levels of processing" framework, the durability of the memorial trace and the mode of representation of a stimulus are determined by the "level" at which the stimulus is processed. Research since the introduction of Craik and Lockhart's model has been directed at determining the theoretical distinctions between

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[3] For instance, Davis (1939) found increased EMG activity focused in the right arm when subjects performed mental arithmetic, whereas he found no differences in EMG activity in the right and left arms when subjects memorized nonsense syllables. Davis noted that subjects reported a strong tendency to want to write during the former but not the latter task; he speculated that the focus of muscular activity during the latter task was someplace on the body other than the measured sites, such as on the speech musculature.

[4] It should be evident that we are specifically concerned in the present article with *peripheral* physiological measures of information processing. Although we do not discuss here the research on electrocortical measures of information processing, we should point out that significant advances have recently been made in identifying information-processing stages using the evoked cortical response. The interested reader might consult recent reviews by Craik and Blankstein (1975), Donchin (1979), and Callaway, Tueting, and Koslow (1978).

"deep" versus "shallow" processing. Whereas Craik and Lockhart initially proposed that encoding operations could be ordered at mutually exclusive levels along a depth-of-processing continuum, as a function of the feature that was analyzed (e.g., semantic, orthographic), research now suggests that deep versus shallow processing (or encoding) results from (a) more extensive analyses of a feature of the stimulus (e.g., identifying more associations to a stimulus) or (b) analyses of multiple features (e.g., phonetic, associative) of a stimulus either simultaneously or sequentially (cf. Cermak & Craik, 1978). According to our elaboration-likelihood model of attitude change, specifiable conditions determine the extent to which people elaborate cognitively on topic-relevant information. When the elaboration likelihood is high, the nature of the cognitive responses that are produced exerts a strong influence on attitude change. When the elaboration likelihood is low, however, attitude change is influenced more by factors pertaining to the context than by the content of relevant evidence (e.g., the credibility of a communicator in contrast to the cogency of his or her message arguments; Cacioppo & Petty, 1980b; Petty & Cacioppo, 1979b, 1981b). Finally, the changes in attitudes are less enduring when the elaboration likelihood of the situation that spawned them is low rather than high (cf. Petty & Cacioppo, 1981a). Thus, both formulations posit that the extent of associative processing has predictable memorial consequences.

The behavioral measures of associative processing in social-psychological versus experimental research have differed, but the measures of each area have nevertheless been the object of some concern and criticism (cf. Baddeley, 1978; Miller & Baron, 1973; T. O. Nelson, 1977). We sought, therefore, to determine the utility and limitations of using EMG measures of speech- and non-speech-related muscles to gauge the extent of ongoing linguistic processing, a measure that would have utility in both paradigms. Both speech- and non-speech-related EMG responses are necessary to measure, of course, since only changes from prestimulus levels in the former that are not found in the latter reflect the *unique* involvement of the speech musculature in response to a stimulus and, hence, suggest the presence of silent language processing (McGuigan, 1970).

TABLE 1
Examples of the Orienting Tasks

Task	Cue question
Volume discrimination	Is the following word spoken louder than this question?
Rhyme	Does the following word rhyme with ______?
Association	Is the following word similar in meaning to ______?
Evaluation	Is the following word good?
Self-reference	Is the following word self-descriptive?

We decided to use the orienting-task paradigm from research in cognitive psychology on encoding operations (e.g., Craik & Tulving, 1975) in the initial studies. We did this to minimize other sources of variance between and within treatments—for example, confounding subject, stimulus, or response characteristics with extent of processing or relying on fortuitous matching of the sampling interval for physiological measurement with the presence of the desired differences in extent of processing (see D. L. Nelson, 1978, and Rogers, 1977, for discussions regarding the difficulties involved in controlling people's "mental operations" using experimental instructions). In the orienting-task paradigm, a subject is instructed by a cue question to focus on a specific feature of a stimulus (e.g., a trait adjective) in order to solve a problem (posed by the cue question). Several examples of these tasks are displayed in Table 1. Subjects focus on other features of the stimulus, too, of course, sometimes concurrent with their instructed inspection of it (Pavio, 1971), but the exigencies of the task shape the encoding process sufficiently to yield predicted differences on verbal learning and verbal behavior (cf. Craik, 1979; D. L. Nelson, 1978). Interestingly, however, if the stimulus is available for inspection following completion of the instructed orienting task, subjects continue to examine the stimulus along a variety of dimensions (e.g., Cacioppo & Petty, 1980a; Rogers 1977). Hence, if the subject is allowed to examine and think about the stimulus for too long (e.g., several seconds) after completing the task, there is a converging of mental operations that masks the subtle differences in covert information processing which were effected by the task instructions. Accordingly, behavioral (Rogers, 1977) and electrophysiological (Kadlac, Note 2) differences as a function of orienting task are no longer apparent. Hence, subjects in our research were not given much time to examine or think about the target adjective once they indicated their response to a cue question.

A more demanding research issue involves specifying the degree of correspondence between the extent of a particular covert operation and the intensity of an electrophysiological pattern. Correlational approaches are unsatisfactory because the subtle bodily patterns that *are* observed account for only a small proportion of the total variance, so correlations are invariably low. This might be expected, since the body has numerous demands placed on it besides performing the experimental task. Alternatively, advances in assessing correspondence can be made by varying experimentally the extent of covert information processing along some (e.g., the depth-of-processing) dimension, while determining whether the magnitude of the physiological response varies concomitantly (e.g., Ahern & Beatty, 1979). Employing an experimental approach using the orienting-task (or depth-of-processing) paradigm not only allowed us to better control the factors that might be contributing to the obtained electrophysiological data, but it allowed us in subsequent studies to explore the degree of parallelism between the extent of information processing and physiological patterning by experimentally varying the former across a wide range of possible levels while monitoring the latter.

SKELETOMUSCULAR PATTERNS AS A FUNCTION OF ORIENTING TASK

When people consider whether or not a word is self-descriptive, they are more likely to remember the word than when they attend primarily to a structural feature of the word, such as whether it is printed in uppercase letters (e.g., Rogers, Kuiper, & Kirker, 1977). This effect is theoretically due to the more distinctive and elaborate linguistic analyses that are required to perform the former task. The notion is that a stimulus is made more "memorable" by linking a large number of distinctive associations, or pathways, to it. That this notion is common to a number of models of memory (cf. Cermak & Craik, 1978) suggests that it is sufficiently secure to guide our search for identifiable patterns of skeletomuscular response.

In our first experiment (Cacioppo & Petty, 1979c), eight men and eight women saw a cue question, which asked them to determine either whether a word was self-descriptive (a self-reference task) or whether a word was printed in uppercase letters (an orthographic task). After presenting each cue question, we presented orthogonally a trait adjective that was printed either in uppercase or in lowercase letters and that was either self-descriptive or not at all self-descriptive.[5] Subjects had to determine the meaning of the word and compare it with their self-concept to solve the self-reference task, whereas they had only to inspect the general appearance of the letters to solve the orthographic task. In both instances, subjects were instructed to wait until the removal of the trait adjective to respond, which they did by pressing one of two buttons to indicate *yes* or *no*.

The self-reference task necessitates tying more linguistic associations to the trait adjective than does the orthographic task. According to the model of skeletomuscular patterning, we expected that the EMG activity of the speech muscles would be greater during the self-reference than during the orthographic task. This differentiation was *not* expected to emerge generally in the musculature; rather, we expected the changes in the general level of tension to mirror the motoric or biologic requirements of the task. Lip (task-relevant) and nonpreferred forearm (task-irrelevant) EMG responses were monitored during the experiment to evaluate these hypotheses.

In addition, cue questions and trait adjectives were paired so that subjects responded *yes* to half the questions and *no* to the other half (see Footnote 5). We reasoned that judging a trait adjective as undescriptive would especially evoke linguistic processing, since this judgment means that a person discovers a mismatch between the implications of the trait adjective and the cluster of memorial items categorized as the self. Accordingly, we expected the somatic responses from the speech musculature to be most evident in this condition.

The EMG measures were obtained by placing small disk electrodes or "sensors" in pairs over the nonpreferred forearm and adjacent to the lips (see Figure 5 on p. 452). Since the EMG in immobile subjects is small, amplification and filtering are necessary to obtain a clear signal of the action potentials that lead to muscular tension and contraction. In our studies, each EMG measure was rectified (i.e., the absolute value of the signal was obtained) and integrated, which provides an index of the total EMG output (i.e., muscular activity) over a given period of time at a particular site (see Hassett, 1978, chap. 8, for a simple discussion of the EMG response).

The data from this study are displayed in Fig-

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[5] We were able to anticipate whether a particular subject considered a trait adjective as self-descriptive or not by referring to a pretest given to all subjects one week earlier. In this pretest, subjects rated the self-descriptiveness of each of 120 trait adjectives.

ures 1 and 2. We should note that we replicated previous research in experimental psychology showing that more durable semantic-memory traces result when an adjective is the object of a self-reference rather than the object of an orthographic orienting task (e.g., Rogers et al., 1977). The new finding is that the task-relevant physiological (i.e., lip EMG) responses parallel this difference between the tasks. Lip EMG responses during the processing interval were greater when the preceding question cued subjects to analyze the trait word's self-descriptiveness than when it cued them to analyze the word's orthographic features (see Figure 1).

It is important that semantic-encoding efficacy was *not* differentiated by task-*irrelevant* skeletomuscular responses. In Figure 1, it is evident that the EMG responses over the nonpreferred forearm were unaffected by the type of problem-solving process required by the task. We did find that the magnitude of general somatic activity increased across the intervals of the trial and peaked when the subject pressed one of the two buttons. Together, these observations support the suggestion that *general* somatic activity reflects the motoric rather than the cognitive aspects of a task.

In Figure 2 we have illustrated the effects of the type of decision (*yes* versus *no*) on skeletomuscular activity. As expected, the EMG response near the lips was largest when the trait adjective was judged to be nondescriptive. Also as expected, the EMG response over the nonpreferred forearm (a task-irrelevant muscular site) was unaffected by this manipulation of covert information processing.

A MORE STRINGENT TEST

These data are consistent with the notion that the extent of associative processing is accompanied by localized changes in speech-related skeletomuscular activity. Nonetheless, we repeated this study, making a number of changes in the procedure to rule out alternative explanations for our observations (Cacioppo & Petty, in press).

First, we used five rather than two tasks to vary the intensity of associative processing. These tasks are listed in Table 1, where they are ordered in accordance with their effectiveness in producing durable semantic-memory traces. (Recognition confidence was measured at the end of the experiment to validate this ordering of the tasks.)

Second, each cue question was preceded by a variable-length prestimulus interval so that EMG responses for each task could be contrasted against a moving baseline rather than a fixed initial baseline. This procedure is preferable because it takes into account changes in baseline over time.

Third, we employed aural rather than visual presentations of the cue questions and trait adjectives. This increased our control of the cognitive effects of the experimental stimuli, since each trait adjective was "present" only for the length of time

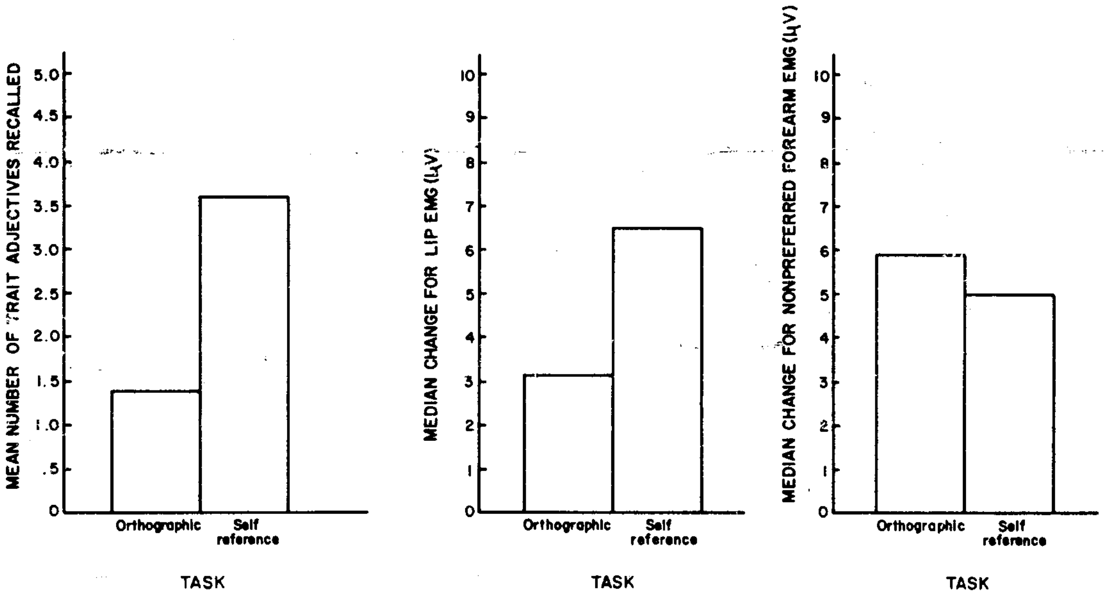

Figure 1. Mean recall performance (left panel) and median change from an initial baseline for electromyographic (EMG) activity during the processing interval for lip (middle panel) and nonpreferred forearm (right panel) as a function of orienting task. (Adapted from Cacioppo and Petty, 1979c.)

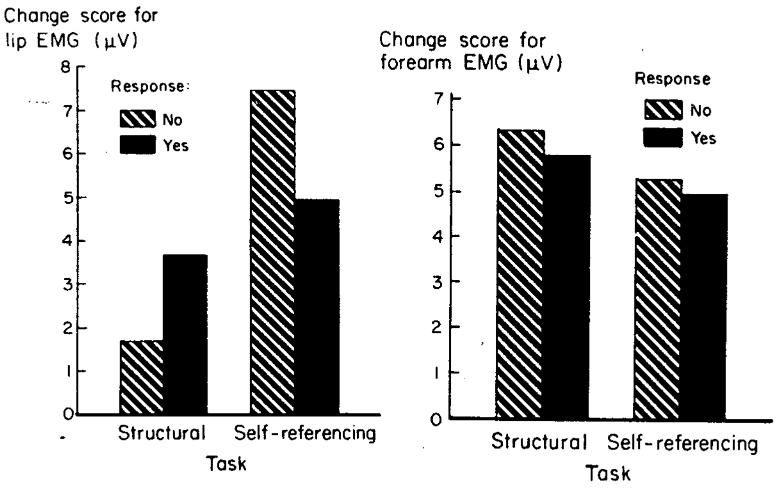

Figure 2. Median change from baseline for electromyographic (EMG) activity from the lip (left panel) and nonpreferred forearm (right panel) as a function of orienting task and decision. (From "Lip and Nonpreferred Forearm EMG Activity as a Function of Orienting Task" by John T. Cacioppo and Richard E. Petty, *Journal of Biological Psychology*, 1979, *9*, 103–113. Copyright 1979 by James V. McConnell. Reprinted by permission.)

it took to announce the word. The presentation of the target adjective, therefore, was constant across tasks regardless of the length of time it took subjects to perform the tasks. This procedure also removed the possibility that subjects might "read" the words when implicative questions were asked but "inspect a single letter" when questions about sensory features of the stimulus were asked.

Fourth, rather than arbitrarily designating a fixed time interval following onset of the trait adjective as the "processing interval," we initiated recording for this interval at the onset of the trait adjective, and we terminated the interval when the subject responded by pressing one of the two buttons to indicate *yes* or *no*. More durable memory traces are formed by complex semantic tasks than by sensorial tasks, even after taking into consideration the fact that the former usually take longer to perform (e.g., Rogers et al., 1977). This suggested to us that there should be higher magnitude somatic responses in the speech muscles during the semantic than during the sensorial tasks. However, the procedure of using a fixed time interval, as in the previous study, would not provide a strong test of this hypothesis, since the semantic relative to the sensorial task may have been associated not with more concentrated or higher levels of EMG output during the actual processing interval, but with a longer but equally high level of EMG output. By analyzing the EMG responses that were evinced while subjects performed the tasks (rather than during a fixed interval of time), we were able to test whether or not the semantic task led to more concentrated lip EMG activity.

Finally, we varied the likableness of the trait adjectives to explore the effects of mild variations in stimulus affectivity on speech and general muscle activity. The manipulation of stimulus affectivity was exploratory; but in accordance with the principle of skeletomuscular patterning, we did not expect to be able to distinguish stimulus affectivity using the present set of EMG measures.[6]

The results revealed first that, as expected, the self-reference and evaluation tasks led to the longest decision latencies and the most durable memory traces for the trait adjective, whereas volume discrimination and rhyme resulted in the shortest latencies and the least durable traces.

In Figure 3, we have graphed our finding that the magnitude of the lip EMG responses during encoding paralleled encoding efficacy. These data are in accord with the outcome of the previous study (Cacioppo & Petty, 1979c). We were puz-

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[6] Nonpreferred rather than preferred forearm EMG was measured because the learned association between writing and language processing leads to the expectation that the latter but not the former will yield patterns of EMG activity similar to those obtained from lip EMG measures (cf. McGuigan, 1970). In retrospect, it might also have been interesting in this study to have recorded EMG from facial placements, to determine whether the pattern of activity recorded would be influenced by the likability of the trait adjectives (cf. Schwartz et al., 1976b).

zled, however, by the *decrease* in lip EMG activity for some of the tasks in the present study (see Figure 3). Postexperimental discussions with our subjects suggested to us that they were talking to themselves during the prestimulus intervals—ruminating about the last trial and trying to anticipate the nature of the next task or the next trait adjective. It is possible, then, that the encoding operations for some tasks actually involved *less* associative processing than was stimulated by the brief pauses between tasks!

It can also be seen that the EMG responses over the nonpreferred forearm were unrelated to the type of encoding task performed. It is unlikely that this measure was insensitive because, as in the previous study, it increased across the intervals of a trial and was maximal when a voluntary motor response was emitted. (This increase in EMG activity was not found for the speech muscles.)

Last, as expected, stimulus affectivity had no effect on lip or nonpreferred forearm EMG activity. We return to this observation later in the article.

Collectively, these data illustrate several of the principles we discussed earlier. First, multiple influences appear to operate on each physiological response at any moment in time. General adjustments in the tonus of the skeletomuscular system that match the demands of a task may be one of these influences, but certainly they are not the only or necessarily the predominant influence. The differential responsiveness of lip EMG activity during encoding speaks for the existence of subtle and focused modulations of task-relevant physiological activity that reflect particular aspects of covert information processing; that is, there are forms of stimulus specificity (by which we mean the tendency for environmental exigencies to elicit a common pattern or profile of responses from various people) that harbor information about those hard-to-examine processes serving verbal learning and verbal behavior. For instance, we observed that only the EMG responses localized over muscles involved in language (e.g., the lips) reflected the differential linguistic requirements of the tasks. Moreover, these localized skeletomuscular responses were selective with respect to what types of covert information processing they accompanied. The analyses that were restricted to the period in which subjects worked toward solving a problem indicated that covert speech-related EMG responses generally reflected the extent to which the problem solving involved associative (linguistic) processing. Finally, we found that the skeletomuscular responses over the speech muscles were insensitive to the emotional tone of the processing

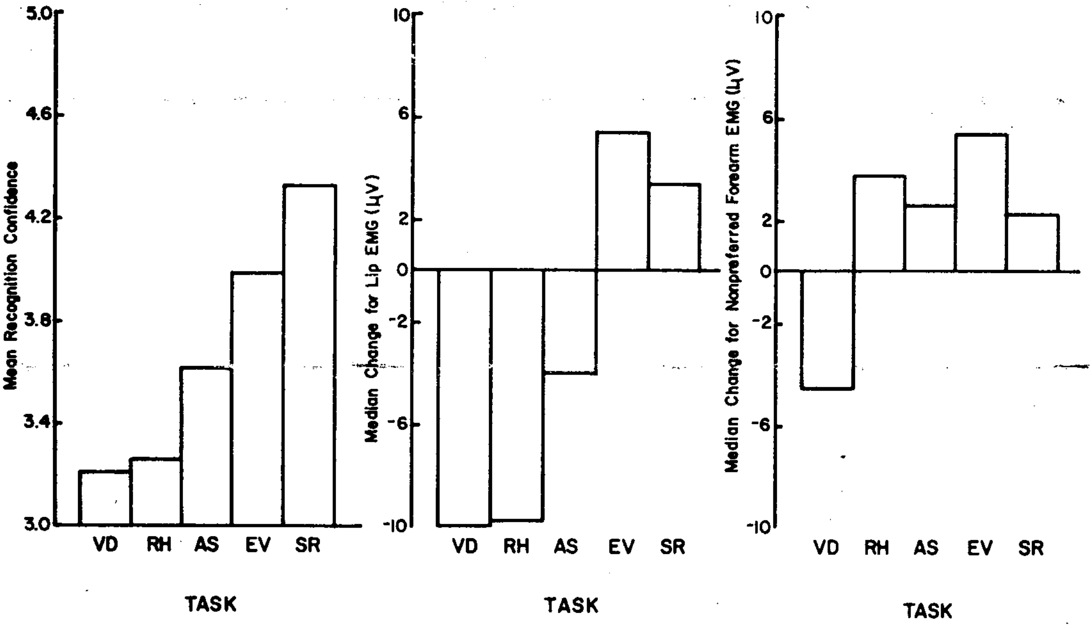

Figure 3. Mean recognition confidence (left panel) and median change from prestimulus levels for electromyographic (EMG) activity during the processing interval for lip (middle panel) and nonpreferred forearm (right panel) as a function of orienting task (VD = volume discrimination; RH = rhyme; AS = association; EV = evaluation; and SR = self-reference). (Adapted from Cacioppo and Petty, in press.)

(i.e., the likability of the adjectives). These EMG placements apparently reflected the extent but not the affectivity of ongoing information processing.

Assessing the Extent of People's Idiosyncratic Thoughts About a Persuasive Appeal

Recent work on persuasion has highlighted the manner in which people process the information contained in personally involving persuasive communications (see Petty, Ostrom, & Brock, 1981). According to this view, the thoughts generated about an advocacy (e.g., increasing taxes) can vary from complete inattention or sensorial analyses of the message presentation (e.g., the accent or speed of speech) to careful, deliberate, and extensive examination of the central issues, principles, and personal implications involved in endorsing the advocacy. This dimension is similar in many respects to the associative-processing dimension we discussed earlier. For instance, moderate repetition of a message, which provides recipients with greater opportunities to process the message arguments, elicits a more complete elaboration of the message arguments (Cacioppo & Petty, 1979b). In general, when individuals are motivated and able to think deeply about a recommendation (i.e., high elaboration likelihood), they generate new associations, implications, and arguments pertinent to the attitude issue. Some of these "cognitive responses" favor the advocated position, whereas some disfavor it. According to the view that people are (covertly) active participants in persuasion, the nature of these thoughts is an important determinant of attitude change (cf. Petty & Cacioppo, 1981a, chap. 8).

Of course, examination of and elaboration on the central issues of an advocacy are effortful and are not elicited by every persuasive communication to which people are exposed. When accepting a recommendation has trivial outcomes, people do not think extensively about topic-relevant information; rather, they respond to persuasion cues (e.g., source credibility) and with habitual sequences (e.g., gender roles). As the long-term personal consequences of endorsing an attitudinal position increase, however, thoughts and attitudes become increasingly determined by the attributes and implications of the attitude stimulus and decreasingly influenced by habitual modes of responding or contextual factors (Cacioppo & Petty, 1980b; Petty & Cacioppo, 1979a, 1979b, 1981b). In other words, people are more and more likely to become covertly active participants in persuasion as the intrapersonal consequences of endorsing an attitudinal position increase.

This view can be contrasted with the view of people as passive recipients of persuasive communications (e.g., Hovland, Janis, & Kelley, 1953; cf. McGuire, 1968). According to this perspective, people are persuaded by nonthinking habits, emotional reactions, and simple learning of the message arguments (e.g., Baron, Baron, & Miller, 1973; Langer, Blank, & Chanowitz, 1978; Romer, 1979).

The notion that people are covertly active participants in persuasion has proved to be a useful heuristic for attitude research (cf. Cialdini, Petty, & Cacioppo, 1981; Perloff & Brock, 1980; Petty et al., 1981), but what direct evidence is there that people *actually* think and behave in this manner? Heretofore, people were asked to list their thoughts about an issue after hearing a message advocating a position that was contrary to their initial attitude (Brock, 1967; Greenwald, 1968). When asked to do this, people tended to list arguments against the recommended position. Indeed, contemporary research using the thought-listing procedure has shown that people tend to list topic-relevant thoughts rather than message arguments or irrelevant thoughts and that when the elaboration likelihood of recipients is high, the topic-relevant thoughts appear to mediate attitude change (see Cacioppo & Petty, 1981b, and Petty & Cacioppo, 1981a, for reviews of this research). Still, the thought-listing procedure has been criticized for placing post hoc demands on people to report rational(izing) thoughts for their new attitudes. Miller and Baron (1973), for instance, contend that requesting people to list their thoughts produces listings of thoughts that do not occur prior to the instruction; that is, they assert that the thought-listing technique is a reactive measure of idiosyncratic cognitive responses to persuasion.

Truly cogent evidence that people covertly and spontaneously think about the advocacy and its implications would require a direct, concomitant measure of associative processing. This seemed a particularly suitable situation for applying psychophysiological principles and methodology to help resolve a theoretical controversy. Specifically, the localized somatic responses over the speech muscles held promise in this regard, since their magnitude had been linked to silent language processing. If people are covertly thinking about the issues, then we should observe larger EMG responses focused over the speech muscles.

Three issues must be considered, however, before the test of this hypothesis can be meaningful. First, suppose there are larger EMG responses over the speech muscles during than before a persuasive message. Would the larger EMG responses be due to people's passively comprehending, rehearsing, and encoding the message arguments or to their actively thinking about and elaborating on the message arguments and issues relevant to the advocacy? There is no way to tell. The problem is avoided entirely, however, by comparing the EMG responses before versus after the *forewarning* of the topic and position of a persuasive message.

Second, what type of forewarning is needed to elicit a person's participation in the form of topic-relevant thinking even before the message is presented? Neutral and nonthreatening advocacies, those that appear to have no consequences or few important ramifications for a person, should not evoke any especially concentrated preparation for the message. On the other hand, we would expect people forewarned of an impending communication that constitutes an attack on an important set of beliefs to engage actively in topic-relevant thinking even before the onset of the message (cf. Petty & Cacioppo, 1977).

Third, simply applying principles and procedures from cognitive psychophysiology to a specific question in a unique paradigm can be a risky, if not misleading, venture. Hence, we conducted an initial experiment to validate the assumption that the EMG responses over the speech muscles index the intensity of cognitive-response processes in persuasion. In this experiment (Cacioppo & Petty, 1979a, Experiment 1), subjects were told the topic and position of an upcoming editorial and were instructed to think about the issue. In this way, we forced subjects to do what we expected they would do in any case—generate topic-relevant cognitive responses while awaiting the persuasive message. But only if these instructions were followed by larger magnitude EMG responses localized over the speech muscles could we feel confident that speech EMG would provide an index of cognitive-response processes in persuasion.

We also manipulated the size of the threat posed by the impending advocacy by varying how contrary it was to subjects' initial attitudes. This provided a test of the sensitivity of covert oral EMG responses to the *emotional tone* of the postulated internal conversation. We monitored speech (lip, chin, and throat) and nonspeech (back) EMG activity during the prewarning (baseline) and postwarning ("collect thoughts") epochs, and after the latter epoch we asked subjects to list everything they had been thinking about.[7]

Analyses of the thought listings revealed that as discrepancy increased, anticipatory counterargumentation increased and generation of favorable thoughts and agreement decreased. However, total thought production during the collect-thoughts interval, as measured by the number of thoughts listed, was the same for the various levels of discrepancy.

Skeletomuscular responses during the collect-thoughts versus prewarning epoch revealed that speech EMG activity increased while nonspeech EMG activity remained constant and quiescent (see Figure 4). This pattern of skeletomuscular response was the same regardless of the emotional tone of the stimulus, which, by reckoning of the thought listings and attitude measures, was manipulated as planned. This suggests, consistent with the previous experiment, that the level of skeletomuscular responding localized over the speech muscles reflects the extent rather than the emotional tone of associative (linguistic) processing. Moreover, these data are in complete accord with the principles of skeletomuscular patterning we reviewed above.

We conducted a second experiment to determine whether concentrated topic-relevant thinking would occur *spontaneously* when people anticipated hearing a communication attacking an important set of beliefs (Cacioppo & Petty, 1979a, Experiment 2). As in the previous study, subjects were told the topic and position of an impending (counterattitudinal and personally involving) editorial. But rather than ask subjects to collect or list their thoughts after this forewarning, we simply monitored changes from basal levels in skeletomuscular activity. Two other groups of subjects were tested to rule out a number of possible artifacts (e.g., any instruction might cause people to repeat the instruction silently to themselves until onset of the message). Subjects in one of the additional groups were told the topic and position of an impending editorial that was consistent with their prior attitudes (i.e., proattitudinal), and subjects in the remaining group were forewarned only that they would hear a message.

Several findings of the study are noteworthy at

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[7] A variety of speech-related muscle sites were monitored to collect convergent data that silent language processing was being assessed. Measures of tongue EMG, preferred forearm EMG, and so on would have done just as well.

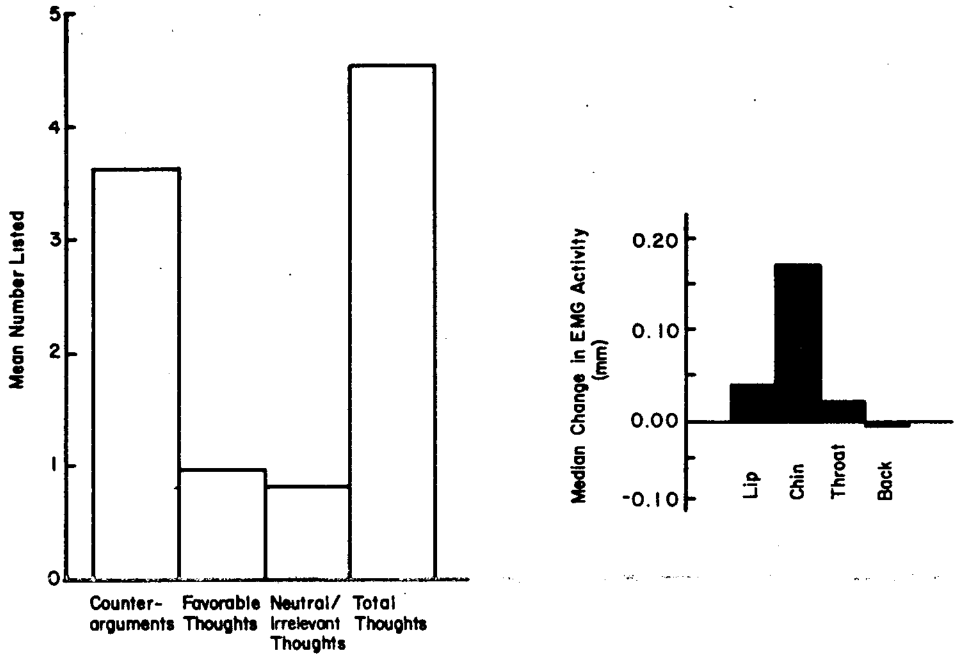

Figure 4. Mean cognitive responses following the "collect thoughts" interval (left panel) and median changes in electromyographic (EMG) activity from prewarning to the "collect thoughts" interval (right panel). (Adapted from Cacioppo and Petty, 1979a.)

this point. First, subjects who were expecting a proattitudinal (nonthreatening) or unidentified (neutral) message failed to display reliable increases in speech EMG activity during the postwarning-premessage interval; subjects who were expecting a counterattitudinal message displayed increases in speech EMG activity during this interval, just as people in the previous experiment did when they were told to collect their thoughts on the issue; and consistent with previous research that has linked speech EMG activity to silent language processing, *all* subjects, regardless of the type of advocacy, exhibited heightened speech EMG activity during the message presentation. Together, these data suggest that speech EMG activity reflected the extent of associative processing equally well for the various groups of subjects and, more important, that people spontaneously produced more concentrated or extensive associative processing following a forewarning when they expected the communication to attack their position on a personally important issue.

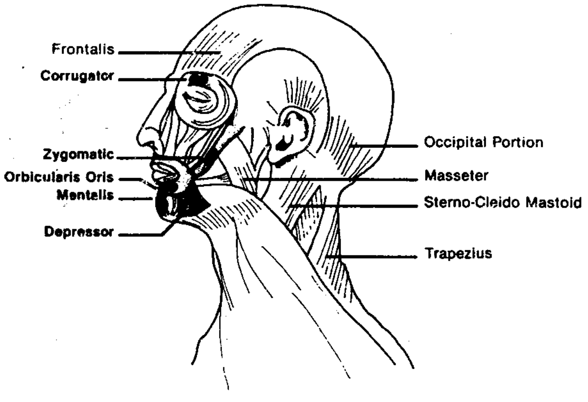

Figure 5. A set of electromyographic (EMG) electrode placements used for assessing expressive movements in the face.

Assessing the Affectivity of Ongoing Information Processing

In addition to the skeletomuscular responses over the speech muscles, we recorded EMG responses over three muscle groups in the face—the corrugator, zygomatic, and depressor regions (see Figure 5). The purpose of recording these EMG responses was to obtain a measure of the subtle and phasic expressions of emotion emitted by subjects as they awaited and monitored a communication.

The selection of these particular sites for monitoring skeletomuscular patterns of emotion was not serendipitous, but followed directly from the early observations of Darwin (1872/1904), the contemporary research and theory of Tomkins (1962, 1963), Izard (1971, 1976), and Ekman and Friesen (1975), and the important electromyographic work of Schwartz and his colleagues (e.g., Schwartz, Ahern, & Brown, 1979; Schwartz et al., 1976b, 1978). As was noted previously, empirical research has generally supported Darwin's initial observation that distinctive facial expressions are linked to different emotions (see Cacioppo & Petty, 1979d, for a recent review of this literature). Ekman (1972), for instance, documented across a wide variety of cultures the existence of unique facial expressions for six distinct emotions. Moreover, Schwartz and his colleagues have demonstrated the usefulness of monitoring EMG activity at the corrugator, zygomatic, and depressor muscle sites in studies of emotional imagery. For instance, Schwartz et al. (1976b) asked people to imagine positive or negative events in their lives. Results revealed that people generally showed more EMG activity in the depressor and zygomatic muscles and less EMG activity in the corrugator muscles when imagining happy as compared with sad events.

We reasoned that measures of EMG activity over these muscle sites might yield a pattern of skeletomuscular response that would distinguish positive from negative reactions to a persuasive communication. The results of our corrugator, zygomatic, and depressor EMG measurements were consistent with this reasoning and suggested that the associative processing which followed the forewarning (as measured by speech EMG) pertained at least in part to the advocacy (i.e., it was topic-relevant thinking).

Looking first at the pattern of EMG activity evinced in the face during the message presentation, which we have graphed in the right panel of Figure 6, one can see that the counterattitudinal message evoked a different pattern of response than the proattitudinal and neutral messages. As it turned out, the proattitudinal and neutral messages were rated on semantic differential attitude scales as being equally favorable, though both were rated as much more favorable than the counterattitudinal message. It is interesting to note, given these subjective ratings, that the patterns of EMG activity were similar during the neutral and proattitudinal messages but distinguished these messages from the counterattitudinal message.

Next, recall the evidence from the oral EMG measure that associative processing became more concentrated during the postwarning–premessage interval when people anticipated hearing a counterattitudinal (but not a proattitudinal or unidentified) message. In the left panel of Figure 6, we have illustrated the EMG patterns of covert facial expressions evinced during the postwarning–premessage interval. Corrugator responses, which are especially large during unpleasant emotional imagery and distinctive across emotional states (cf. Schwartz et al., 1978), were larger during this interval when people anticipated hearing the counterattitudinal rather than the proattitudinal message. Third, looking at the patterns of skeletomuscular response evinced during the postwarning–premessage versus message intervals, one can see that the profiles for the counterattitudinal condition are especially similar in form, though as might be expected, the pattern of EMG activity was magnified when the message was presented.

To reiterate, people anticipated and heard a proattitudinal, a counterattitudinal, or a neutral communication. They evaluated more positively and generated more favorable thoughts about, and fewer counterarguments to, the pro- than the counterattitudinal advocacy, but rated similarly the neutral and proattitudinal advocacies. Incipient speech muscle activity increased following the forewarning of an involving counterattitudinal advocacy, and it increased for all conditions during the message. Profiles of subtle facial muscle changes generally reflected the affective nature of the cognitive responding before and during the message, particularly for the counterattitudinal advocacy. These data provide evidence that recipients of persuasive communications are active information processors when topic involvement is high.

Further Implications

These data also illustrate (a) the utility and means of monitoring covert bodily responses (specifically, skeletomuscular responses) in research on the *extent* and *affectivity* of ongoing information processing, (b) the possibility of tapping simultaneously cognitive and affective processes *within the same individual* by using multiple sets of EMG measures, and (c) the application of the *model of skeletomuscular patterning* in studies of mental processes.

The promise of the model of skeletomuscular patterning appears to be just as great for the study of a number of other issues in psychology. Consider the study of emotion. The early theories of affect and emotion cast people's thoughts and attributions as subsequent to the arousal of an emotion (e.g., Cannon, 1927; James, 1884). Almost 20 years ago, however, Schachter and Singer (1962) published their influential article in which they proposed that people's inference processes *fashion* the emotion they experience. Recently, Schachter and Singer's position has been attacked (Marshall & Zimbardo, 1979; Maslach, 1979; cf. Schachter & Singer, 1979),

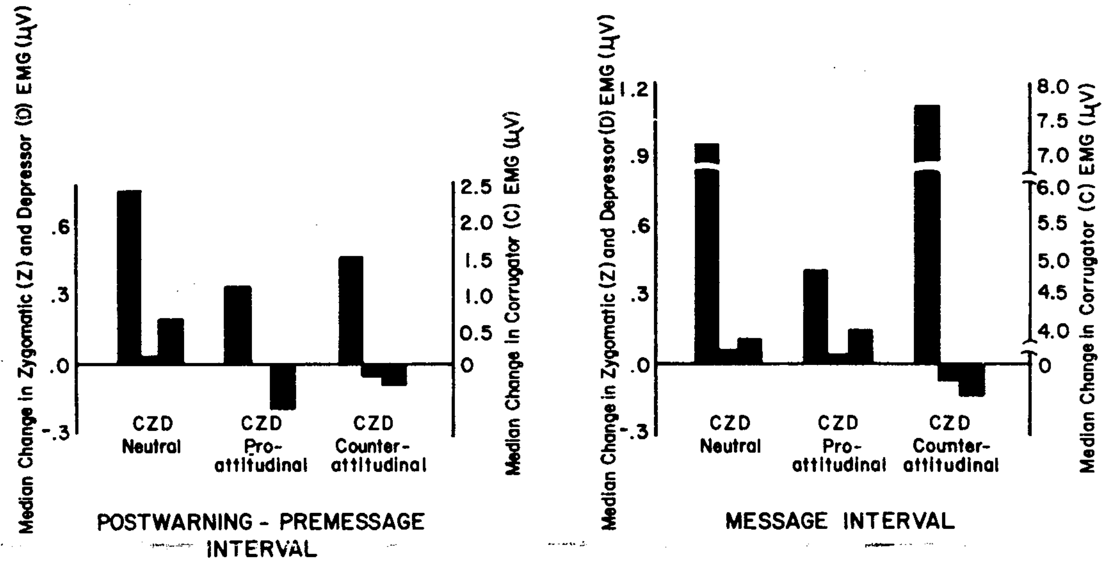

Figure 6. Median change from prewarning baseline for corrugator (C), zygomatic (Z), and depressor (D) electromyographic (EMG) activity during the postwarning–premessage (left panel) and message (right panel) intervals. The data are displayed separately for subjects in the neutral, proattitudinal, and counterattitudinal groups. (Adapted from Cacioppo and Petty, 1979a.)

and strong suggestions have appeared that overt affective responses can be unrelated to the prior cognitive processes initiated by the stimulus (Kunst-Wilson & Zajonc, 1980; Moreland & Zajonc, 1977; Wilson, 1979; but see also Birnbaum & Mellers, 1979; Grush, 1979). Using the sets of EMG measures described above, it may be possible to trace not only the extent and affectivity of people's reactions to stimulus exposures but also the *temporal relations* between the cognitive–affective reactions.[8]

The present survey of research highlights the information about mental processes that can be gleaned by examining the covert responses of the human body. But, clearly, multiple exigencies are served by our bodies and brains, and the meaning of physiological responses must be interpreted in the context of accompanying physiological activity and the environmental demands placed upon the organism. Corresponding caveats apply to the interpretation of overt behavior as well. We have focused in this article on patterns of skeletomuscular response because they are the doorways to the neuromuscular paths that interface the brain to the external environment. This focus was meant to demonstrate the use of psychophysiology in explorations of basic psychological processes within two subareas of psychology rather than to define its utility and domain.

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[8] The interested reader might wish to consult McGuigan and Boness (1975) for a description of a procedure by which temporal relations among psychophysiological responses might be assessed. The article by Schwartz, Davidson, and Maer (1975) is also of interest, as they inferred patterns of cognitive and affective processing from patterns of lateral eye movements in a study of hemispheric asymmetry.

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