Psychological Assessment:
A Journal of Consulting and Clinical Psychology
1991, Vol. 3, No. 3, 321–336

1040-3590/91/$3.00

Psychophysiological Approaches to the Evaluation of Psychotherapeutic Process and Outcome, 1991: Contributions From Social Psychophysiology

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In 1959 John Lacey envisioned psychophysiological assessments as providing an objective means for evaluating psychotherapeutic process and outcome. Lacey also identified several problems in relating physiological assessments of psychological processes and states that he argued would need to be resolved first. The problems raised by Lacey and his cohorts shaped a generation of research by psychophysiologists, who shed light on autonomic organization and assessment but who also, in turn, moved away from the study of social and molar psychological processes and states. In this article, issues raised in Lacey's classic article are considered in light of the past 32 years of research. Progress is reviewed, and implications for interpreting psychophysiological indicants of psychotherapeutic process and outcome are considered. Evidence is also reviewed that demonstrates that the social environment is more than a powerful determinant of psychophysiological response; it can also moderate psychophysiological and brain–behavior relationships. We suggest that in the future, factors and processes derived from the social environment will need to be incorporated for Lacey's original vision to be realized.

A third of a century ago, John Lacey (1959) published an influential review entitled "Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome." Lacey surveyed process and outcome research in which somatovisceral measures were used, and he outlined fundamental problems in these assessments. Although Lacey was generally optimistic about the potential for contributions, he was pessimistic about the extant psychophysiological approaches for evaluating psychotherapeutic process and outcome:

> If . . . autonomic and skeletal–motor responses are to be utilized to maximum advantage in the study of psychotherapeutic process, some attention will have to be given to some rather serious problems, and some theoretical re-organization may be desirable, or at least heuristic (Lacey, 1959, p. 179).

In this article, we will survey progress made over the past 32 years on psychophysiological assessments of behavioral processes and outcomes. Because this survey is necessarily selective, we will focus on the specific problems in psychophysiological assessments emphasized by Lacey (1959), and we will examine the implications of related principles in social psychophysiology for the interpretation of psychophysiological measures in clinical process and outcome research. Important advances that have emerged from the field of clinical psychophysiology are summarized by Lang (1971, 1985), Barlow (1988), Turpin (1989), and Zahn (1986), and in the other articles in this issue's special series on psychophysiology.

Preparation of this manuscript was supported by National Science Foundation Grant BNS-8818557/8940915.

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Psychophysiological Evaluations of Psychotherapeutic Process and Outcome, 1959

Lacey (1959) envisioned four substantive uses of psychophysiological assessment in psychotherapy research. First, physiological events might mark subtle and otherwise not-easily-detectable changes in affect or arousal in the course of a therapeutic interview. Second, physiological events might reveal conflict areas and their interrelationships somewhat in advance (or in the absence) of their emergence in the verbal exchange. Third, physiological responses as a function of psychotherapeutic techniques and therapist behaviors may provide clues to the differential effectiveness of therapists and techniques. Finally, physiological events might provide an objective means of evaluating changes that purportedly occur during psychotherapy. These uses have been amplified and expanded over the past 32 years. Haynes, Falkin, and Sexton-Radek (1989), for instance, have listed the following five factors contributing to the increase in psychophysiological assessments in behavior therapy: (a) many behavior disorders involve the dysfunction of physiological systems; (b) there can be complex interactions (and incoherences) among the behavioral, cognitive, and physiological components of behavioral disorders; (c) given that behavior disorders are complexly and multiply determined, psychophysiological assessments can help identify when or for whom physiological interventions might be appropriate; (d) behavior therapies often have as one of their goals the alteration of physiological processes; and (e) advances in electronics, digital computers, and digital signal processing have made psychophysiological analyses less arcane. Additionally, advances in telemetry and ambulatory monitoring have made psychophysiological assessments less restrictive.

A sizable body of literature had already accrued by 1959 on somatovisceral activity as a function of therapeutic (or quasitherapeutic) process, therapeutic effectiveness, and therapist behaviors. Among the processes purportedly illuminated by physiological measurement were tension, emotion, conflict, and social relations (e.g., status, permissiveness, empathy), and Lacey (1959), presaging Zahn (1986), observed that psychophysiological measures appeared more robust in studies of psychotherapeutic process than in studies of psychotherapeutic outcome. Lacey further summarized the impression created by this early literature as follows:

> Autonomic and skeletal-motor responses are sensitive indicators, even in the hurly-burly of the interview situation. They are objective. They reveal significant correlations with affect, describe the total effect of a single interview, the variation within interviews, and the long-term course of therapy (Lacey, 1959, p. 172).

However, Lacey went on to argue that a critical analysis of the literature revealed this impression to be infirm. The psychophysiological literature on therapeutic outcomes was inconsistent, and Lacey identified statistical and methodological problems that plagued many of these early investigations (see below). In addition, Lacey observed that increases in physiological tension were commonly interpreted as signifying increases in psychological tension, conflict identification, or a heightening of affect, anxiety, or hostility, whereas decreases in physiological response were interpreted as marking decreases in psychological tension, catharsis, conflict resolution, or reductions in affect, anxiety, or hostility. This theoretical framework, Lacey argued, was overly simplistic, was contradicted by low or negative intercorrelations among autonomic responses, and thus contributed to the impression that psychophysiological relationships were unreliable. He concluded that fundamental theoretical, methodological, and statistical problems needed to be resolved before psychophysiological assessments could truly contribute to psychotherapy research:

> The "meaning" of the somatic response must be *interpreted* in terms of the transactions of the individual with his environment, and in terms which involve judgments, or at least statements, of "molar" psychological states and behavior . . . In the present state of our knowledge, and in light of our inability to control or evaluate a vast number of relevant psychological, intrapersonal, and interpersonal variables, I do not believe a substantive use of somatic response as an index of change, or of success, in psychotherapy is justified (Lacey, 1959, p. 178, italics in original).

For the field of psychophysiology, this shift toward research on the detection and quantification of physiological functions, and on the relationship of these psychophysiological functions to elementary neurophysiological (e.g., the cortical effects of the baroreceptor reflex) and behavioral processes (e.g., "acceptance" vs. "rejection of the environment"), resulted in important advances in technique (e.g., Martin & Venables, 1980; Venables & Martin, 1967), theory (e.g., Cacioppo & Tassinary, 1990b; Coles, Donchin, & Porges, 1986; Greenfield & Sternbach, 1972), and application (e.g., Gentry, 1984; Matthews et al., 1986). It also reduced the attention paid by psychophysiologists to social and molar psychological processes and states, however (Cacioppo, 1982).

Psychophysiological approaches can contribute to the establishment of an efficacious nosology, to the identification of the psychological and biological mechanisms underlying behavioral disorders, and to the development and selection of effective treatment and prevention methods (Zahn, 1986). Progress toward these goals can be hindered, however, if social and contextual factors are ignored. This is because social factors (e.g., mere presence, attachment, status, social support, modeling, attitudes) can have powerful additive and *interactive* (e.g., moderating, gating) effects on psychophysiological relationships. Given the existence of interactive effects, the context in which psychophysiological data are observed can have important implications for the interpretation and clinical significance of psychophysiological data.

Ironically, one of the consequences of Lacey's (1959) perspicacious review was that social factors tended to be held constant in psychophysiological studies to avoid the potentially powerful effects they might exert on physiological responding. Although this strategy is clearly sensible in any given study, holding social factors constant across conditions is not equivalent to eliminating their effects from psychophysiological inquiries. To illustrate, consider two hypothetical studies on the physiological effects of discussing sexual problems with a therapist. Assume further that the methods and measures used in these studies are identical, that social factors such as the rapport with the therapist are held constant within each study, and that the demeanor (e.g., apparent permissiveness) of the therapist is varied across these studies. If factors such as the apparent permissiveness of the therapist moderate physiological activity during the discussion of sexual problems, as an early study by Dittes (1957) has suggested, then the physiological effects of discussing sexual problems can appear inconsistent or unreliable across studies even if each of these social psychophysiological relationships is highly reliable. Thus, holding social factors constant can facilitate the interpretation of physiological measures in a given study or paradigm, but can undermine psychophysiological contributions to the assessment, treatment, and understanding of behavioral disorders by creating the erroneous impression that psychophysiological data are unreliable when (a) social factors are not maintained at comparable levels across studies or paradigms, and (b) the interactive effects of these factors across studies or paradigms are not recognized.

Do psychophysiological laboratories really differ in any substantive way? To explore this issue, we surveyed authors from psychophysiology laboratories worldwide (Cacioppo, Rourke, Marshall-Goodell, Tassinary, & Baron, 1990). Results revealed variability in features as fundamental as whether subjects were obviously or surreptitiously surveilled during experiments—a factor which itself has been shown to affect autonomic reactivity differentially across target organs (Cacioppo et al., 1990; Moore & Baron, 1983). We will return to these and related issues below. We begin, however, by reviewing the problems emphasized by Lacey (1959) as limiting psychophysiological contributions to clinical psychology and by summarizing recent work on these problems. Our coverage of this research is illustrative rather than comprehensive. For additional information, interested readers may wish to consult Coles, Donchin, and Porges (1986), Gale and Edwards (1983), Martin and Venables (1980), and Cacioppo and Tassinary (1990c).

Psychophysiological Indicators: Problems and Progress

Lacey (1959) articulated four problems in the manner in which psychophysiological measures were being used to index psychotherapeutic process or outcome: (a) defining dimensions of psychophysiological activity, (b) defining what constitutes a response in time-varying physiological functions, (c) low or negative intercorrelations among physiological measures within and across situations, and (d) individual differences in physiological functions. Before turning to these problems, however, we need to introduce terminology and a perspective that we will be using throughout the remainder of this article.

Briefly, psychological operations, diagnostic categories, or "events" and physiological events can be modeled as distinct sets (domains) of elements (Cacioppo & Tassinary, 1990b). Psychological events constitute one set (Set Ψ), and physiological events constitute another (Set Φ). Elements within the psychological and physiological sets will be denoted simply by Ψ and Φ, respectively. A major component of the psychophysiological enterprise, including diagnostic differentiation and the physiological evaluation of psychotherapeutic process and outcome, can therefore be restated as $\Psi = f(\Phi)$. In the following sections, we will examine Lacey's (1959) specification of Φ and its implications for clinical assessments and for the evaluation of psychotherapeutic processes and outcomes.

Dimensions of Psychophysiological Activity

Lacey distinguished between what he suggested were three dimensions of autonomic activity: (a) *autonomic tension,* the current status (i.e., level) of a physiological function in the units of measurement appropriate to that function; (b) *autonomic lability,* the momentary displacement of a level of a physiological function in response to some imposed stimulus, and (c) *spontaneous autonomic activity,* the momentary displacement of a level of a physiological function because of internal rather than externally imposed stimuli. The suggestion that these concepts reflected separate dimensions of autonomic activity was based on evidence showing that measures of autonomic tension, lability, and spontaneous activity were correlated weakly or nonsignificantly.

Lacey's (1959) observations were made during a period when interpretations of psychophysiological data were guided by arousal theory, which posits a common underlying excitatory mechanism that acts on all effectors to rally bodily resources during strong emotional/behavioral states. Because of the putative operation of this general arousal mechanism, measures of psychophysiological activity were expected to covary closely within individuals. Lacey's suggestion that there were empirically distinct dimensions of autonomic activity, therefore, was significant.

The dimensions of autonomic tension, autonomic lability, and spontaneous autonomic activity, although a significant advance 32 years ago, are neither orthogonal nor exhaustive. However, these three dimensions of autonomic activity can be reconceptualized in terms of a more general three-dimensional psychophysiological response space in which one dimension represents the antecedent of the physiological event (event-related/spontaneous), a second dimension represents the features of the environmental setting along which physiological activity varies (discrete/contextual), and a third represents the time course of the physiological response (tonic/phasic). The first two dimensions represent properties of the evocative condition, whereas the third dimension represents a feature of the physiological activity observed in the particular condition. This three-dimensional psychophysiological response space is depicted in Figure 1. The three dimensions of autonomic activity identified by Lacey (1959) represent special case instantiations within this more general response space and do not nearly exhaust the kinds of psychophysiological functions that can be observed. Note, too, that the stimulus dimension ranging from discrete to contextual has previously been ignored, with response variation attributable to this dimension appearing in the error term of psychophysiological assessments.

The physiological activity involved in behavioral disorders has been categorized usefully along a dimension representing (a) the temporal relationship between external events and physiological responses and (b) the time course of the target physiological event or events. Along the former dimension, *event-related* activity is characterized by a stable temporal relationship between a stimulus (e.g., environmental event) and physiological activity, and *spontaneous* activity refers to physiological events that occur in the absence of a designated or identified stimulus. The orthogonal dimension of time course ranges from *tonic* activity, which refers to the current status (level) of a physiological function, to *phasic* activity, which refers to a relatively momentary displacement of the physiological function. Thus, Raine and Venables (1987) found that psychopathic antisocials exhibited a larger amplitude P3 component in the event-related brain potential to a warning stimulus than did matched controls, and Carruthers (1981) reviewed evidence that heart rates were elevated before a public speech in speakers generally and in speech phobics in particular. Both the P3 component and heart rate are event-related because there is a clear and replicable temporal relationship between the presentation of the stimulus and the physiological response. The P3 observed following the warning tone varies as a function of a discrete stimulus and is a phasic response, whereas the elevation in heart rate observed in public speakers varies as a function of more contextual features of the environment and is a relatively tonic reaction.

The effects of social and contextual stimuli in psychophysiological response have tended to be misclassified as spontaneous activity because a discrete antecedent could not be identified. The framework outlined in Figure 1 may help remedy this problem. Specifically, the third dimension of psychophysiological response space depicted in Figure 1 represents the feature or features of the environment that covary with the observed psychophysiological activity. When physiological activity varies as a function of a discrete feature, as might occur if a spider were presented to an arachnophobic, then the psychophysiological response would be represented within the front-right portion of the psychophysiological response space in Figure 1. When psychophysiological activity varies as a function of more manifold contextual features, such as an unfamiliar laboratory environment or diffuse extralaboratory stressors (e.g., loneliness, exam week), then the psychophysiological activity would be identified with contextual rather than discrete environmental events, and would fall along the left-rear portion of the psychophysiological response space. Thus, medical students who show depressed immune functioning during examination periods (see review by Kennedy, Kiecolt-Glaser, & Glaser, 1990) are not dis-

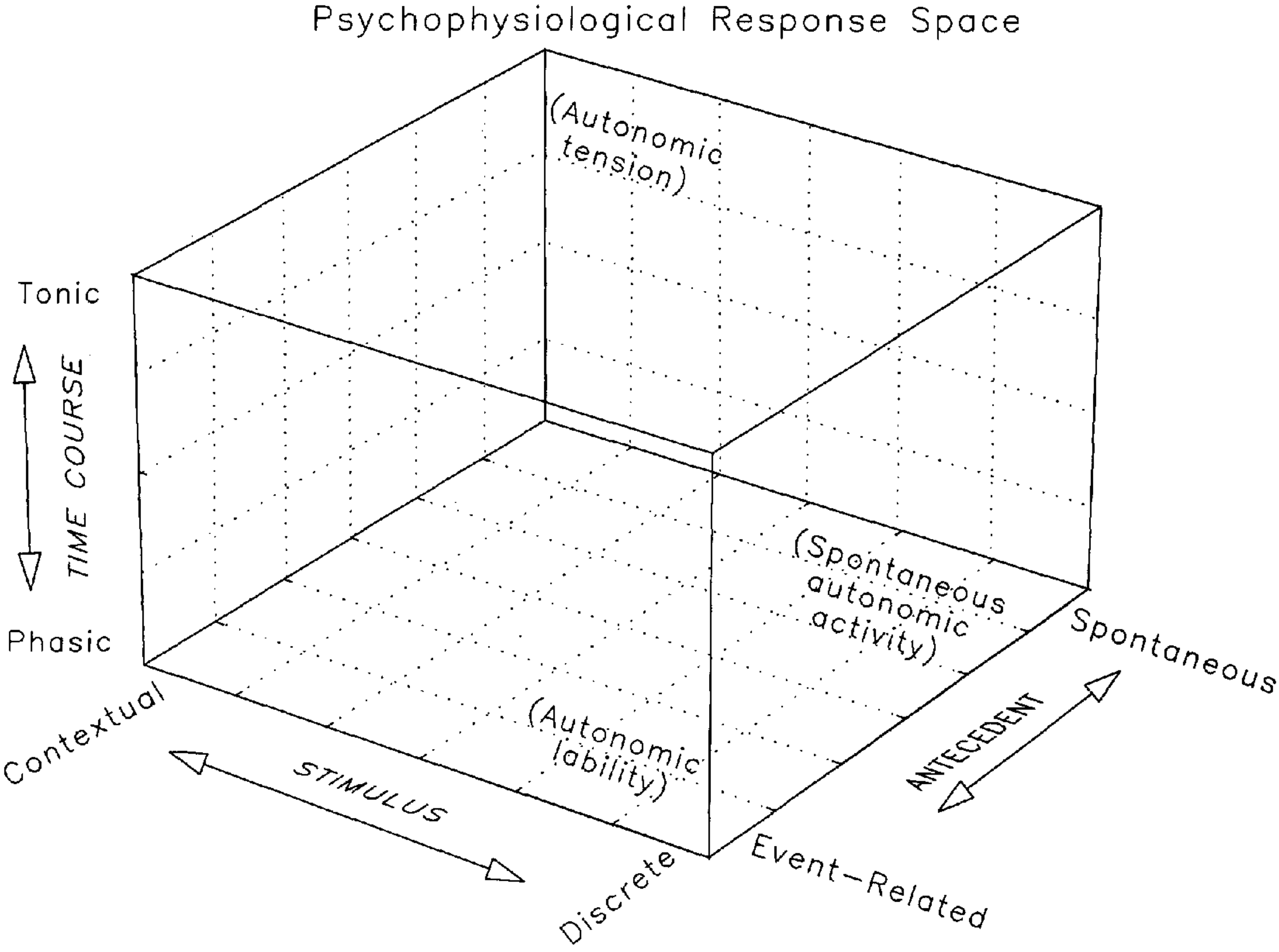

Figure 1. Dimensions of psychophysiological response space. (One dimension represents the antecedent of the physiological event [event-related/spontaneous], a second dimension represents the nature of the stimulus [discrete/contextual], and a third represents the time course of the physiological event [tonic/phasic]. Each of the pairs of terms in this figure represents endpoints on a continuum rather than narrowly and absolutely defined categories of activity. The two dimensions bordering the bottom plane represent properties of the evocative condition, whereas the dimension along the vertical axis represents a property of the observed physiological activity. The three "dimensions" of psychophysiological activity identified by Lacey, 1959, are depicted within this psychophysiological response space. Note that this three-dimensional response space is not limited to autonomic events, but rather applies to physiological events generally.)

playing spontaneous activity, but rather are exhibiting physiological activity evoked by a definable social context. The moderating effect of testing environments on orienting responses (Saiers, Richardson, & Campbell, 1990) and of sociodemographic factors on psychophysiological activity (Anderson & McNeilly, this issue) can also be conceptualized as variations along this third dimension.

As Lacey (1959) foresaw, the identification of the dimensions of physiological activity can contribute to the interpretation of pretreatment assessments, the selection or structure of psychophysiological interventions, and the evaluation of psychophysiological data regarding treatment process and outcome. First, because the physiological responses represented by one portion of the psychophysiological response space depicted in Figure 1 may not be redundant with the physiological responses manifest in another portion of this space, classifying physiological activity along these dimensions can improve the apparent "reliability" of psychophysiological results. Second, dimensional information about the observed psychophysiological response can help identify the psychological and biological mechanism underlying the response and associated behavioral disorders. Third, these dimensional features of physiological activity (e.g., time course) can be helpful in defining the pattern of activation. We will return to these points below. For the moment, it is clear that lumping event-related/spontaneous, or discrete/contextual, or tonic/phasic physiological activity together can mask systematic variance in psychophysiological functions.

Response Definition in Psychophysiology

Psychophysiological procedures are used in pretreatment assessments to index an individual's dispositional reactivity (e.g., cardiovascular reactivity), an individual's reactivity to stressors generally (e.g., anxiety reactions), and an individual's reactivity to specific categories of stimuli (e.g., sexual or phobic stimuli). In addition, diminution of these psychophysiological responses are generally viewed as indicating a positive psychotherapeutic outcome. McCaffrey and Fairbank (1985), for instance, evaluated the effectiveness of flooding, relaxation training, and desensitization in the treatment of posttraumatic stress syndrome following transportation accidents by monitoring heart rate and skin conductance of subjects before and after treatment while they viewed videotapes of accidents.

A common measure of psychophysiological reactivity and treatment efficacy is the simple change score (e.g., poststimulus–prestimulus; stressor–baseline; posttreatment–pretreatment). However, Lacey (1959) criticized the use of the simple change score because it contains variance attributable to prestimulus as well as poststimulus levels of activity (see Cohen & Cohen, 1975). Lacey also noted that simple change scores can yield misleading results because of the law of initial values, and recommended the use of regression (or residualized change score) procedures.

Research in social and clinical psychophysiology indicates that residualized as well as simple change scores can be misleading, however. First, change scores contain measurement error inherent in prestimulus and in poststimulus scores and therefore tend to have poor test–retest reliability (e.g., Kasprowicz, Manuck, Malkoff, & Krantz, 1990). Residualized change scores do not eliminate the errors present in prestimulus and poststimulus measures and therefore can also suffer poor reliability (Kasprowicz et al., 1990).

Second, the law of initial values has been shown to be a special case instantiation of a broader law of dynamic range (e.g., floor and ceiling effects), which is itself only one of three major sources of autonomic constraint on the direction and magnitude of autonomic responses (Berntson, Cacioppo, & Quigley, in press). Furthermore, the law of initial values describes only two of the four manifestations at the level of visceral activity of the law of dynamic range (those deriving from reciprocal modes of autonomic control). Indeed, in many cases, the broader set of autonomic constraints outlined by Berntson et al. do not manifest in variations in tonic levels of prestimulus activity. Simple and residualized change scores are therefore ineffective in dealing with a broad class of autonomic constraints. To salvage this variance in autonomic response from the error term, one needs measures of the relative activities of the ANS divisions within an organ or functional division. Noninvasive measures that provide information about the functional neural input underlying a physiological response are being developed (e.g., see Porges & Bohrer, 1990; Quigley & Berntson, 1990), and should help overcome the problems for psychophysiological response definition posed by the laws of autonomic constraints.

Although noninvasive measures of functional neural input (i.e., ANS modes of control) may be optimal, there are a number of available procedures that are preferable to change scores. One is to compare basal (or prestimulus) values across conditions. If statistically equivalent, then comparisons among poststimulus measures are conducted to assess treatment effects. Although simple, this procedure does not capitalize on the advantages of repeated-measures experimental designs, nor does it consider the contribution of prestimulus values on poststimulus values. A better alternative, which accomplishes both, is to treat the prestimulus and poststimulus measures of physiological activity as two levels of a repeated-measures factor. Significant treatment effects on physiological activity are indicated by a significant interaction test. Multivariate solutions are also available when the number of repeated measures exceeds two (Vasey & Thayer, 1987). A third alternative is to express physiological activity in standard measure (e.g., *z* scores) within subjects when differential reactivity across treatments is of interest (e.g., Furedy & Ben-Shakhar, in press). These and additional procedures are described by Russell (1990), Cohen and Cohen (1975), and Jaccard and Dittus (1990).

Psychophysiological Arousal Versus Physiological Fractionation and Patterns

The third problem on which Lacey (1959) focused was that no single measure of physiological "arousal" could be used to index the state of other physiological measures. In retrospect, the observed fractionation among physiological measures was not the problem, but rather it was the discrepancy between the dominant conceptualization of psychophysiological activity as varying along a unidimensional arousal continuum and the low intercorrelations observed among physiological measures. However, because arousal theory continues to guide the interpretation of psychophysiological data in social and clinical psychophysiology (e.g., see Turpin, 1989; Wagner, 1988), Lacey's observations and the research he stimulated may be of some general interest.

The groundwork for psychophysiological arousal theory can be traced to the physiological studies of Gaskell (1916) and Langley (1921) establishing anatomical and functional differences between the sympathetic and parasympathetic branches of the autonomic nervous system. Cannon (1929) subsequently advanced the hypothesis that there was a diffuse, nonspecific sympathetic outflow through the interconnections in the sympathetic ganglia during emergency states and that this sympathetic discharge was integrated with expressive–behavioral states—the so called "fight-or-flight" reaction. Cannon's view was consistent with the energy-releasing role ascribed to the sympathetic nervous system in autonomic regulation and with subsequent research on brain stem and limbic structures that suggested an integration of autonomic, electrocortical, and somatic–behavioral states. This cast a foundation for a broad class of theories in which autonomic (Cannon, 1929), somatic (Malmo, 1959), and electrocortical (Lindsley, 1957) response channels are activated, and proprioception is intensified (Mandler, 1975; Schachter & Singer, 1962), as bodily resources are mobilized in intense emotional or motivational states.

Lacey (1959; see also, Lacey, 1967) questioned the basic assumption underlying arousal theories by suggesting that electrocortical, autonomic, skeletomuscular, and behavioral measures do not covary highly. He further indicated that the physiological responses obtained from effectors within a single system (e.g., autonomic) do not tend to covary, any more than one would expect somatic activities of diverse muscle groups to share a high degree of covariance. He reviewed evidence that when subjects performed a task that required them to attend to environmental stimuli, such as monitoring flashing lights, the subjects' heart rate decreased while electrodermal activity increased. This directional fractionation of physiological responding across and within physiological systems represented a difficult problem for arousal theories: Were the subjects more aroused (as their electrodermal activity might indicate) or were they less aroused (as their heart rate might suggest) during the task than before it?

As noted above, models of physiological organization and control now recognize the specificity, modularity, and complex response patterning (e.g., stimulus response specificity) that can be evoked in behavioral contexts (e.g., Berntson et al., in press; Gazzaniga, 1989; Neiss, 1988). The orienting response exemplifies the differential patterns of response of the two autonomic divisions across organ systems in that it is frequently associated with cardiac deceleration (parasympathetic activation), pupillary dilation (parasympathetic withdrawal), and electrodermal responses (sympathetic activation; Berntson, Boysen, & Cacioppo, 1991).

The pattern of activation–inhibition across multiple physiological measures can provide more detailed information about the nature of an associated psychological process or state based on logic as well as on biology. This is illustrated in Figures 2 and 3 in the mappings of the relationships among the relaxation, orienting, defense, and startle response as elements within Ψ, and changes in skin conductance and heart rate as elements within Φ (Cacioppo & Tassinary, 1990b). Even though we have simplified the elements to include only four behavioral processes within Set Ψ and to include only two physiological responses within Set Φ, heart rate or skin conductance by itself provides ambiguous information about the associated psychological event. Thus, consistent with Lacey's (1959) concerns, "arousal" is not a particularly useful overarching construct. However, Set Φ can be redefined such that any subset of physiological elements reliably associated with at least one psychological element is replaced by a single, unique element in Set Φ′—an element that represents the pattern or syndrome of activation (see Figure 3, middle panel). This reconceptualization of what constitutes an element in the physiological domain results in a one-to-one relation between the relaxation response and physiological events, and between the orienting response and physiological events. It also yields a many-to-one relation between the concepts of startle and defense reactions and physiological events, a mapping that does not allow Ψ to be specified as a function of Φ. Of course, there are no limits on how one can reconceptualize elements in the psychological domain (e.g., individual differences, developmental stages, psychopathology) or elements in the physiological domain. Set Φ′ can be redefined, for instance, to consider yet another feature—the form of the physiological events as they unfold across time. The result is Set Φ″. As depicted in the bottom right panel of Figure 3, both defense and startle are associated with increased heart rate and skin conductance response, but the heart rate acceleration peaks and returns to near normal levels within approximately 2 s in the case of a startle and does not begin to rise for several seconds and peaks much later following the stimulus in the case of a defense response (Berntson, Boysen, & Cacioppo, 1991). Thus, contrary to the single-measure approach spawned by arousal theories, multiple measures (or multiple features of physiological functions) and low intercorrelations among measures make it plausible to relate physiological functions to associated psychological processes, states, or disorders.

Several assumptions were made to simplify this illustration. Most important, we assumed robust effects (e.g., that the physiological events (Φ_1–Φ_n) constituting a response syndrome (Φ′) covary reliably with the corresponding element in Set Ψ). The importance of establishing a robust effect, even if only in a well-defined assessment context, cannot be overemphasized. A drawback to the use of multiple physiological measures, therefore, is that the experimentwise Type-I error rate can be increased. Multivariate analyses (e.g., MANOVAs, discriminant analyses, canonical correlations, etc.) do not provide protection against inflated Type-I error rates if these analyses are then followed by univariate tests. Moreover, the weightings of the variables in multivariate solutions describe a physiological syndrome, but these empirically derived weightings can be unstable across samples. On the other hand, conservative corrections such as the Bonferroni can yield Type-II errors or discourage the study of patterns of activation in psychophysiology. If the physiological syndrome can be defined a priori, then the multiple physiological measures can be reduced to a single measure through user-defined weights (cf. Harris, 1975). Alternatively, cross-validations (e.g., exact replication) can be used as a matter of course when multiple measures are taken. Only tests that are significant in both replications (or profiles of weightings that are stable across replications) are deemed reliable. This procedure provides a degree of assurance that statistical tests significant at the .05 alpha level are in fact replicable and it diminishes the disincentive for measuring more than one physiological response.

We also assumed that all of the relevant elements in Sets Ψ and Φ could be specified, and the mappings between the elements in Set Ψ and Set Φ were generalizable. This we know to be an oversimplification, but neither of these assumptions is necessary (e.g., see Cacioppo & Tassinary, 1990b, Figure 4 and Equation 2). Consider the property of generality. Peripheral physiological events are influenced by a host of local physiological and social events, only a small subset of which might be psychologically or clinically significant. The psychological significance of physiological events may therefore be clarified when irrelevant determinants of the physiological events are controlled. Of course, this is true for a variety of laboratory tests in medicine (e.g., blood glucose tolerance tests), in which physiological measures can be interpretable only if taken in accordance with specific protocols. Although physiological responses as a function of attention, cognitive categorization, language processing, emotion, and various homeostatic challenges have been studied extensively (e.g., see Coles et al., 1986; Gale & Edwards, 1983; Wagner & Manstead, 1989), additional research is needed on molar psychotherapeutic processes and outcomes and on the physiological effects of the various social and contextual factors in psychotherapy so that specific and sensitive protocols can be developed.

Individual Differences

Several mechanisms have been proposed by which stressors may lead to illness or behavioral disorders (e.g., Sternbach, 1966; Zegans, 1982). The diathesis–stress hypothesis is that the

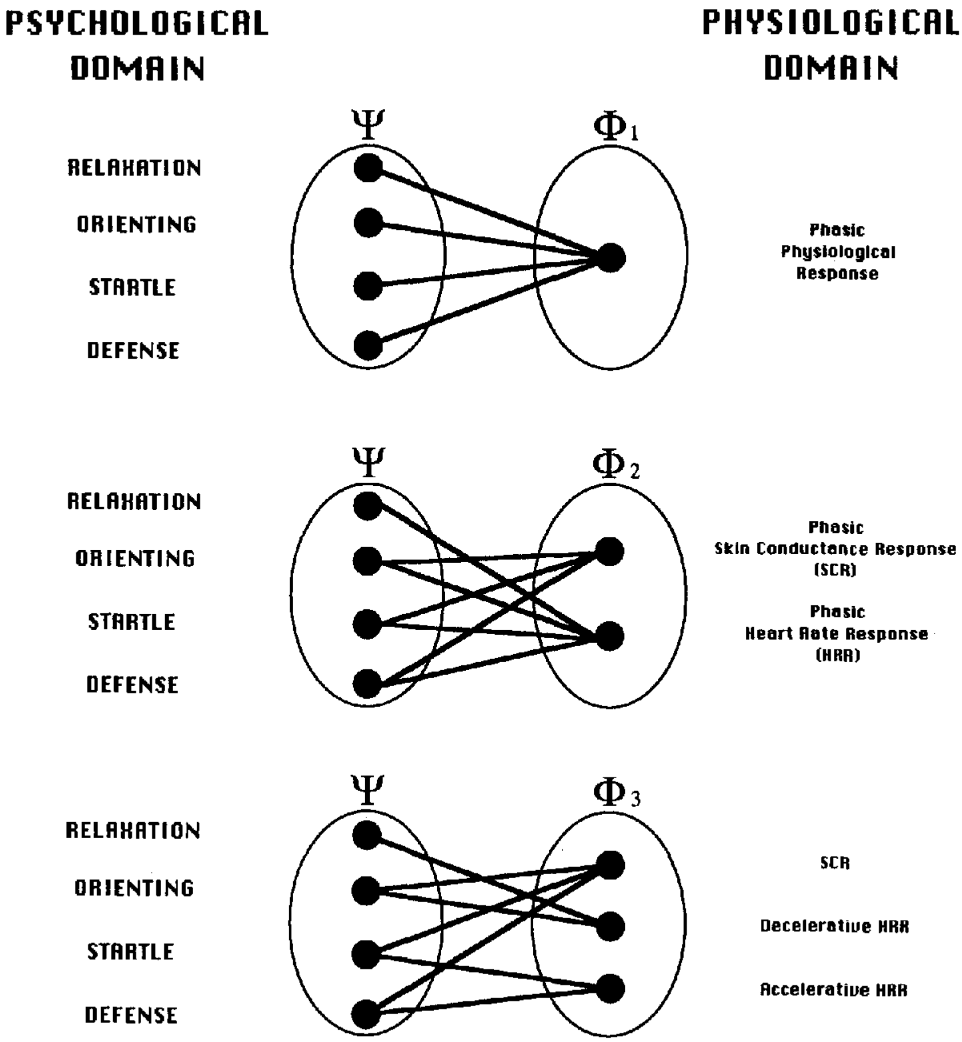

Figure 2. Depiction of relations between the psychological constructs of relaxation, orienting, startle, and defense and the physiological measures of heart rate (HR) and skin conductance response (SCR). (*Note.* Top panel: links between the psychological elements and a change in physiological activity. Middle panel: links between the psychological elements and absolute change in heart rate and skin conductance. Bottom panel: links between the psychological elements and individual physiological responses.)

physiological response to stressors might directly damage an organ or organ system, or initiate a behavioral disorder. This is especially likely when an organ system in an individual is inherently vulnerable (i.e., genetic predisposition) or when an organ system has been weakened previously because of, for instance, the individual's diet or lifestyle. A variation on this hypothesis is that repeated exposures to stressors might cause permanent damage, particularly in individuals whose genetic constitution, diet, and lifestyle render them at risk. A third hypothesis is that a physiological response becomes classically conditioned to some stimulus associated with the stressor, and that this physiological response (e.g., muscle tension, sexual arousal, adrenergic activation) gets evoked in inappropriate contexts. Although not exhaustive (see Zegans, 1982), these hypotheses suggest that normal and clinical samples are likely to be heterogeneous in their constitution, learning histories, and physiological responses, and that different social environments may or may not aggravate predispositions in individuals.

Lacey (1959) recognized these features and noted that the intercorrelations among autonomic measures were low within subjects as well as between subjects. An important implication of the variability within and across individuals, Lacey argued, was that single autonomic measures could not be used unequivocally to categorize the "arousal value" of different stimuli for a given individual, or the "arousability" of different individuals. This problem was partially addressed above. We focused in the preceding section on redefining elements in the physiological domain to disambiguate relations between elements in Set Ψ and elements in Set Φ when addressing the problem of nonunitary physiological activity. Elements in the psychological domain can also be redefined to represent individual differences, developmental stages, psychopathologies, and so forth. Dis-

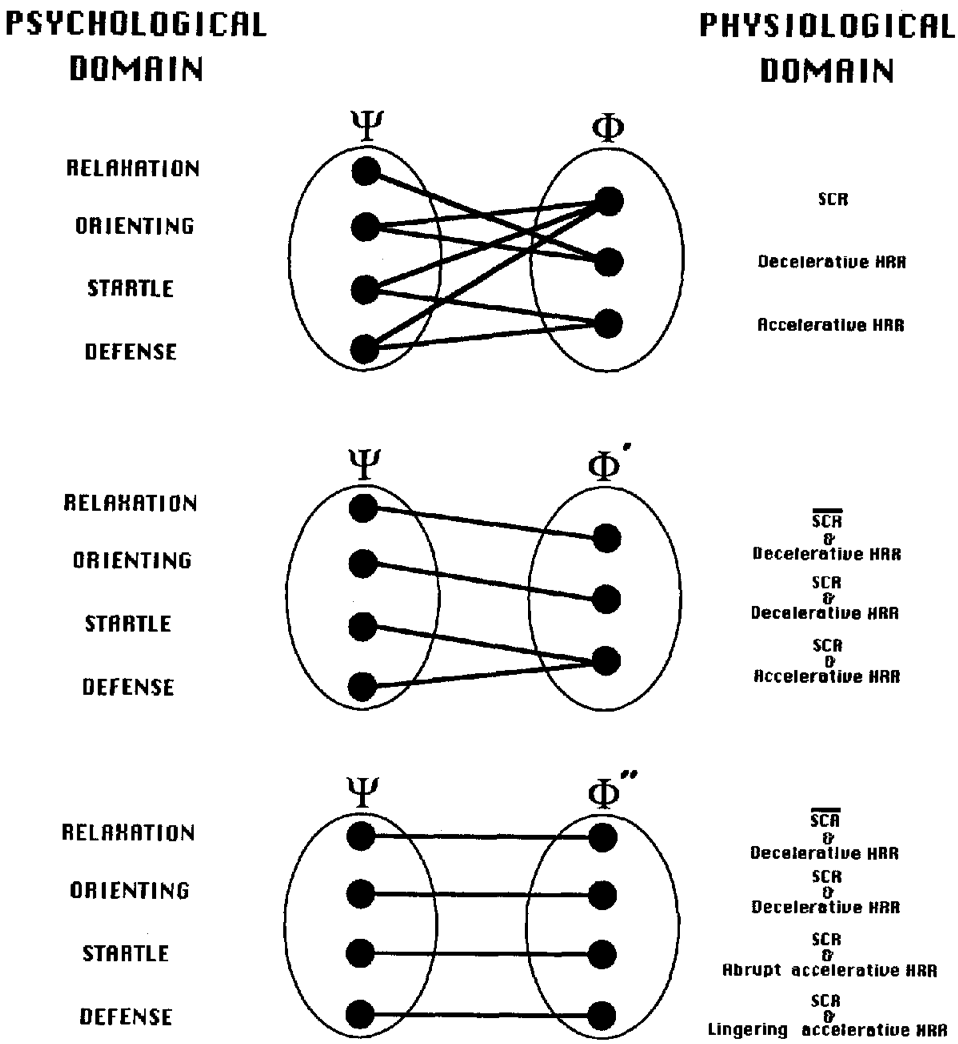

Figure 3. Depiction of relations between the psychological constructs of relaxation, orienting, startle, and defense and the physiological measures of heart rate (HR) and skin conductance response (SCR). (*Note.* Top panel: links between the psychological elements and individual physiological responses. Middle panel: links between the psychological elements and the physiological response pattern. Bottom panel: links between the psychological elements and the profile of physiological responses across time.)

tinctions have been drawn in the clinical literature, for instance, between the physiological effects of sexually explicit materials on pedophiliacs and normals (Abel, Blanchard, Murphy, Becker, & Djenderedjiam, 1981) and of negative life events on repressors and nonrepressors (e.g., Weinberger, Schwartz, & Davidson, 1979). Redefining the elements in Set Ψ to reflect moderating individual difference variables therefore can yield clearer relations between psychotherapeutic events and physiological response (cf. Malmo, 1975).

Early observations by Lacey (1959; Lacey, Bateman, & VanLehn, 1953; Lacey & Lacey, 1958) revealed two additional points: (a) striking consistency could be found within individuals in terms of their pattern of physiological responding across tests, and (b) clear differences could be found within individuals in terms of which physiological systems show relatively high reactivity and which show relatively little reactivity across tests. The notion that there were reliable individual differences in physiological functioning led to a spate of research on the nature and health implications of these differences (e.g., Engel, 1960; Garwood, Engel, & Capriotti, 1982; Kasprowicz et al., 1990; Sherwood, Dolan, & Light, 1990).

Individual response specificity has come to serve as a generic term to refer to the variance in physiological activity that is attributable to the person or to person–situation interactions (e.g., reactivity measures; distinctive physiological responses attributable to idiosyncratic appraisals or coping strategies). In an interesting study illustrating person–situation interactions in physiological response, Hare (1973) has reported that subjects low in fear of spiders showed heart rate deceleration and vasodilation of cephalic vessels when shown pictures of spiders (interpreted as an orienting response), whereas subjects high in fear of spiders showed heart rate acceleration and vasoconstriction of cephalic vessels (interpreted as a defense response). Klorman, Weissberg, and Weisenfeld (1977) found similar results when a group of subjects was divided according to individual levels of fear about mutilation and was shown slides depicting mutilation. These studies suggest that a subject's level of fear about a category of stimuli can determine whether his or her response to a stimulus is one of orienting or defense (Stern & Sison, 1990). Note, too, that a common psychophysiological response across individuals (heart rate) to something as simple as emotionally evocative slides would have appeared unreliable and would have obscured important psychological differences were individual differences ignored or simply relegated to the error term. Given the complexity of behavior and its determinants, meaningful measures within and across individuals are likely also to be complex. More longitudinal studies are needed to differentiate clinical from statistical significance and to describe how individual differences (e.g., diagnostic categories) interact with social and environmental factors to produce psychophysiological responses.

The concept of individual response specificity has been further differentiated over the past 32 years. *Individual response hierarchy* refers to individual differences in the response (or responses) showing maximal, second most maximal, and so forth, to least maximal activation across stressors. Malmo and Shagass (1949), for instance, found that psychiatric patients who chronically complained of headaches showed relatively high reactivity to stressors in muscle tension in the forehead region, whereas psychiatric patients who chronically issued heart complaints (e.g., heart palpitations) showed relatively high reactivity in heart rate and heart rate variability. Related to this concept is the notion of *individual response consistency,* which refers to the reliability of these physiological response profiles across time. Lacey et al. (1953) has demonstrated that individuals could be differentiated on the basis of their response patterns across stressors, and Lacey and Lacey (1958) have found vast individual differences in response consistency in their longitudinal study of children's response to stressors. Lacey (1959) has further distinguished between intrastressor stereotypy, which denoted the tendency for individuals to show the same pattern of response to the same stressor, and interstressor stereotypy, which denoted the tendency for individuals to show the same pattern of response to different stressors. Myrtek (1984) has provided an extensive review of recent data.

Finally, *individual response uniqueness* refers to differences across groups of individuals (e.g., hypertensives, normotensives) in response hierarchies. Moos and Engel (1962) have found that hypertensive subjects showed more blood pressure changes to stressors than did normotensive arthritic patients, whereas the arthritic patients showed more muscle tension over their arthritic joints than did hypertensive subjects. Furthermore, Kasprowicz et al. (1990) have demonstrated that hypertensives' elevated pressor response to stressors can belie different physiological dispositions; some subjects showed pronounced increases in myocardial contractility and elevated blood pressure, whereas others exhibited large increases in vascular resistance and elevated blood pressure.

The ontogeny of individual differences in physiological functioning is less clear, though genetic contributions appear to be involved. Hypertensives and offspring of hypertensives, for instance, are more likely to exhibit high cardiovascular reactivity than are normotensives and offspring of normotensives (e.g., Fredrikson et al., 1985). This illustrates that individual-response uniqueness can be apparent in the absence of patent pathology. It also reveals a need for twin studies to provide information about the extent and nature of genetic involvement in maladaptive physiological responses and behavioral disorders.

In sum, psychophysiological measurements might appear unreliable in part because their manifestation can differ so dramatically among individuals. This problem has led to work on methods to partition the variance, and to proposals that reliable individual differences in physiological response can be used systematically to develop more sensitive physiological assessments of psychotherapeutic progress. For instance, autonomic measures are commonly used to monitor progress in the treatment of fear/anxiety response. However reasonable the theoretical rationale for measuring autonomic responses to gauge reductions in fear and anxiety might be, dramatic variations among individuals can plague autonomic evaluations of clinical progress. Levis and Smith (1987) have proposed a strategy by which to capitalize on this individual response stereotypy. Before the start of the experiment, they administered a stress (balloon burst) test to determine each subject's most reactive autonomic channel. Subjects were then classified by a median-split, rank-ordered procedure as high-heart-rate responders, high-skin-conductance responders, high responders in both channels, or low responders in both channels. Next, subjects were exposed to presentations of a fear-eliciting, bodily-injury slide. Consistent with the research reviewed above, the response hierarchies identified in the stress test generalized to the fear-eliciting stimuli. Levis and Smith went on to suggest that although no single autonomic measure may be best to gauge fear/anxiety and their reductions across individuals, the autonomic response on which an individual shows the greatest reactivity to a stressor may serve as a relatively sensitive means of evaluating stressful topics and clinical progress. This does not mean that the autonomic response is a specific index of fear and anxiety, but only that it is a variable that for specified individuals in a limited setting can be used to help monitor clinical progress. Decreases in fear and anxiety can be expected to lead to decreases in autonomic response. It remains the case, though, that variations in autonomic response may result from the operation of other factors as well.

The problems raised by Lacey (1959) helped shape research for several decades (Coles, Jennings, & Stern, 1984). Despite Lacey's recognition that social factors could exert powerful additive and interactive effects on psychophysiological functions, research on social and molar psychological processes and states was partially diverted to address the fundamental problems outlined by Lacey. This research has shed light on autonomic organization and assessment, but there remains an abyss separating physiological functions and clinical processes and outcomes. In the following section, we will discuss some principles and formulations in the area of social psychophysiology, and we will consider their implications for bridging this abyss.

Social Psychophysiology

Social psychophysiology concerns the study of the cognitive, emotional, and behavioral effects of human association as related to and revealed through physiological measures. This perspective encompasses the reciprocal relationship between physiological and social systems, as well as the specification of mental, social, and behavioral processes as a function of physiological events. Social psychophysiology, therefore, is a broad conceptual perspective encompassing work on the impact of society on the individual (e.g., socialization), the impact of individuals on one another (e.g., social support), and the impact of artifacts, cultures, and histories produced by others (e.g., ethnic differences in symptomatologies). It encompasses the interactive (moderating) effects of human association or the social environment on a person's physiological response to stimuli, the mental or behavioral responses to physiological events, and the reciprocal relationship between events in the social and in the physiological domains. Theory and research in social psychophysiology, therefore, may be of some interest.

The possibility that important aspects of human nature and human problems might be discovered by focusing on the interaction between an information-processing organism and social and environmental stimuli was recognized more than 2,000 years ago (Mesulam & Perry, 1972). Only recently, however, have developments stimulated in part by Lacey's (1959) seminal paper enabled investigators to use physiological principles and measures to address fundamental questions about the organization and governance of normal and disordered thought and behavior in humans. Recent reviews of social psychophysiological research are available elsewhere (Cacioppo & Petty, 1983, 1986; Wagner, 1988; Wagner & Manstead, 1989; Waid, 1984). Our aim in this section is to survey briefly several general principles that suggest that the study of social factors and processes is a necessity, not a luxury, if psychophysiology is to produce general answers to complex mental health disorders or to provide information about the psychotherapeutic processes and outcomes.

Social Psychophysiological Principles

The term *levels* has been used to refer to the level of structural organization or representation, the level of explanation, the level of processing, and the level of analysis (see Cacioppo & Tassinary, 1990a). We use levels here to refer to levels of organization, or to different scales in which the body or behavior can be represented. A psychological phenomenon can be represented, for instance, at the chemical, cellular, tissue, organ, system, human organism, social, or cultural level of organization.

The *principle of multiple determinism* states that elements in the physiological domain and elements in the psychological domain can be influenced by a multiplicity of factors within and across levels of organization. Erectile dysfunctions, for instance, can stem from psychogenic and organic problems, and psychophysiological assessments of penile erections during sleep have been used to differentiate these substrates (e.g., see Haynes & Wilson, 1979). Considerable evidence has amassed over the past several decades demonstrating that a target event at one level of organization (e.g., autonomic response, expressiveness) may vary as a function of changes within or across levels of organization (New Frontiers in the Behavioral Sciences and Health, 1989). An important implication is that the concordances observed across multimodal assessments can vary because the set of determinants for each response channel is only partially overlapping. Overt and autonomic expressions of emotion are a case in point. We recently replicated previous research showing that college students viewing slides alone exhibit stronger skin conductance and expressive reactions to negative stimuli than to neutral stimuli, and they rate the negative stimuli as being more arousing and emotionally intense than the neutral stimuli. When these subjects spoke with an experimenter about emotionally disturbing and neutral topics during a follow-up assessment, they again showed higher skin conductance activity and rated the negative discussions as being more arousing and emotionally intense than the discussions about the neutral topics; analyses of the videotapes of their facial expressions, however, revealed these subjects were less expressive when speaking to the experimenter about emotionally troublesome topics than about neutral topics (Uchino & Cacioppo, 1990).

A corollary of the principle of multiple determinism is the *corollary of proximity*, which states that the mapping between elements across levels of organization becomes more complex (e.g., many-to-many) as the number of intervening levels of organization increases. This is because an event at one level of organization (e.g., depressive behavior) can have a multiplicity of determinants at an adjacent level of organization (e.g., psychological), which in turn may have a multiplicity of implementations at the next level of organization (e.g., physiological), and so forth. The implication is not to avoid venturing across the abyss separating physiological and behavioral levels of organization, but to proceed incrementally. Understanding a behavioral problem at multiple levels of organization can be important in optimizing the selection and application of clinical interventions. Linking physiological functions to clinical progress and outcomes by using intervening psychological and social processes may improve predictions of these outcomes and, more important, may differentiate similar outcomes that were achieved by different means (cf. Cacioppo & Petty, 1986). This could ultimately prove useful in answering questions about what interventions and therapist behaviors are best for what problems in which individuals.

Another important implication of the principle of multiple determinism is that an exclusive focus on a reductionistic (e.g., neurophysiological, molecular, genetic) level of analysis may mask contributions of other levels of organization to mental disorders. For instance, let Ψ represent an element in the psychological domain (e.g., a cognitive or affective disorder) and Φ_1 represent an element in the neurophysiological domain (e.g., the dopaminergic system). Evidence that manipulations of Φ_1 are followed by Ψ have led to claims ranging from the assertion that Φ_1 is a "marker" of the psychological disorder to the conclusion that Φ_1 represents the mechanism responsible for the disorder. However, neither conclusion logically follows from these data. The fact that controlled variations in Φ_1 lead to corresponding changes in Ψ does not imply that the emergence or maintenance of Ψ is invariably (or even usually) initiated by Φ_1; Φ_1 may represent but one of many physiological mechanisms capable of producing Ψ, or one of a complex of biochemical variables in which subsets (coalitions) are capable of generating Ψ. Another possibility is that Φ_1 is not an antecedent to Ψ but rather, like Ψ, is a consequence of some other underlying process. For instance, dopamine antagonists (neuroleptics) alleviate some of the symptoms of schizophrenia but they do not eliminate schizophrenia, as might be expected if this disorder were caused exclusively by an excess in dopamine. The point is that identifying a physiological or biochemical feature of a psychological process or outcome can be important but does not itself establish ultimate causality.

A second principle, the *principle of nonadditive determinism*, also implies that the understanding of complex mental processes and behavior can be advanced by multilevel integrative analyses. According to this principle, certain properties of a behavioral phenomenon or of the order underlying it may emerge only when examined across levels of organization. Analyses have traditionally focused on a given level of organization (e.g., behavioral, molecular) with generally good success. Theories of emotion within social psychology, for instance, have been derived largely from verbal analyses, and the resulting knowledge regarding people's conceptual organization of emotion has contributed to our understanding of the cognitive antecedents and consequences of emotion (e.g., priming, mood congruence effects). Analyses limited to phenomena within a given level of organization can also mask the underlying order in data, however. In an illustrative study, Haber and Barchas (1983) found that the administration of amphetamine had no reliable effect on primate behavior until the primate's position in the social hierarchy was considered: Amphetamine administration increased dominant behaviors in primates high in the social hierarchy but increased submissive behaviors in primates low in the social hierarchy. Although this result can be explained in terms of Hull-Spence drive theory, it is interesting because it demonstrates how the effects of the physiological changes on behavior can appear unreliable (or chaotic) until analysis is extended across multiple levels of organization. A physiological analysis, regardless of the sophistication of the measurement technology, may not have unraveled the orderly relationship that existed between the physiological manipulation and behavior. There are, of course, physiological mechanisms underlying these phenomena, but the identification of these mechanisms may often be better served by systematic investigations within and across multiple levels of organization rather than by a reductionistic focus alone. Disorders of human thought and emotion may be at least as stealthy a set of behavioral phenomena.

Finally, the *principle of reciprocal determinism* specifies that there can be a reciprocal influence between biological and environmental–social factors in determining brain and behavioral processes. Research in behavior genetics has revealed that there are a wide variety of genetic influences that are repressed unless or until certain environmental factors are introduced (i.e., brain and behavioral processes are a function of particular genetic factors, which in turn are governed by environmental agents; Plomin, 1989). Within social psychology, Zillmann (1984) has demonstrated that violent and erotic material influences the level of physiological arousal in men, and that the level of physiological arousal has a reciprocal influence on the perceptions of and tendencies toward sex and aggression. Of course, the reciprocal influences between biological and social factors cannot be mapped if either level of organization is regarded as irrelevant.

Implications for Psychophysiological Evaluations of Psychotherapeutic Processes and Outcomes

Lacey (1959) alluded to but did not pursue the complexities posed by multiple determinism when he observed:

> Nobody seems ever to wonder whether something other than "arousal" or "affect" may be involved, or whether the interpretation of the significance of somatic response involves more than a simple one-to-one formula for the relationship (p. 174).

Multiple determinism of physiological responses, however, has perhaps constituted as important and troublesome an obstacle to psychophysiological evaluations as any problem identified in Lacey's review (e.g., see Coles, Gratton, & Gehring, 1987; Donchin, 1982). Psychophysiology has traditionally been defined as the study of the physiological effects of psychological or behavioral variables (e.g., Sternbach, 1966). The relations observed between elements in Sets Ψ and Φ have been characterized as "correlates," and measures of physiological response have been called on to index the psychological process or state with which it was known to be associated (Lacey, 1959). However, traditional psychophysiological studies are better expressed as the conditional probability $P(\Phi/\Psi)$ than as the joint probability $P(\Phi, \Psi)$ when the element or elements in the psychological domain serve as the independent (or blocking) variable, and element or elements in the physiological domain serve as the dependent variable. For instance, let Ψ represent a defense response, and let Φ represent a skin conductance response. The evocation of a defense response has been linked reliably with a skin conductance response (e.g., see Turpin, 1986)—that is, the $P(\Phi/\Psi)$ is large and positive. Given the multitude of factors that lead to skin conductance responses, the $P(\Phi, \Psi)$ can nevertheless be near zero. Establishing that $P(\Phi/\Psi)$ is large and positive says very little in and of itself about the magnitude of the psychophysiological or brain–behavior correlation.

Furthermore, $P(\Psi/\Phi)$—not $P(\Phi/\Psi)$ or $P(\Phi, \Psi)$—represents the question at hand when physiological events are asked to index a psychological element or event (e.g., psychopathologies, psychotherapeutic processes or outcomes). Although the terms $P(\Psi/\Phi)$, $P(\Phi/\Psi)$, and $P(\Phi, \Psi)$ are related, they are not interchangeable (Cacioppo & Tassinary, 1990b). Psychophysiological (and brain–behavior) "correlates" in the literature are not always what they pretend to be.

The most common method for dealing with the problem of multiple determinism in psychophysiology has been to appeal to an extant theory of psychophysiological relations, typically developed on the basis of studies showing that some psychological or behavioral construct (e.g., anxiety) has a particular physiological effect, at least for a specifiable subset of individuals. The physiological responses observed during psychotherapy are then interpreted in light of this theoretical context (Lacey, 1959). This is a form of weak inference, and one that can yield errors and inconsistencies. This is simple to show. Let the statement, *if* Ψ *then* Φ, represent a theoretical hypothesis or an empirical outcome.

If Ψ *then* Φ logically implies *if not-*Φ *then not-*Ψ (1)
If Ψ *then* Φ does not logically imply *if* Φ *then* Ψ (2)
If Ψ *then* Φ does not logically imply *if not-*Ψ *then not-*Φ (3)

Extant theory, based on *if* Ψ *then* Φ, yields predictions that can be disconfirmed—that is, *if not-*Φ *then not-*Ψ. The reader may recognize that the statement, *if not-Φ then not-Ψ*, in Equation 1 represents a scientific inference based on hypothetico–deductive logic. The logical basis for this reasoning is why hypothetico–deductive research provides grounds for strong inference. One implication for psychophysiological assessments of psychotherapeutic processes and outcomes (or for scientific inquiry generally) is that strong inferences can be drawn if these assessments are based on hypothetico–deductive logic. The limitation to the hypothetico–deductive approach when given *if Ψ then Φ* is that physiological events provide evidence about the absence, not about the presence, of an element in the psychological domain.

Equation 2, which denotes the logical fallacy of affirmation of the consequent, reveals why the presence of a predicted physiological event does not constitute logical grounds for inferring that the theoretical construct was also present. Nevertheless, Equation 2 represents the form of inference used when the presence of a physiological response is interpreted in light of some psychophysiological theory to "index" a particular psychotherapeutic process or outcome. As indicated by Equation 2, this reasoning constitutes weak inference, which Platt (1964) has argued undermines the incremental nature of scientific inquiry. Given this form of reasoning, it should not be surprising that physiological events have appeared fickle.

Equation 3 denotes the logical fallacy of denying the antecedent, which can lead to hazards such as an overestimation of psychophysiological (e.g., brain–behavior) covariations and elevated false-alarm rates. Consider, for instance, a hypothetical element in the psychological domain (e.g., guilty knowledge, early childhood trauma) that reliably evokes a physiological response when broached (e.g., skin conductance response). Equation 3 represents the form of reasoning used when statements about the "correlation" between these elements is based on analyses of the physiological event as a function of the variations in the psychological element. As noted above, the former term can be specified as $P(\Phi, \Psi)$, whereas the latter can be specified as $P(\Phi/\Psi)$. The important point here is that the former can be much smaller than the latter when Φ is multiply determined.

It is important to note that there is a commonality in the logical fallacies in Equations 2 and 3 that holds a key to circumventing this limitation. These fallacies are based on the denial that different events can produce similar outcomes. Thus, a procedure that ensures that there are not different events producing the same outcome (i.e., that yields a one-to-one mapping between the element of interest in the psychological domain and the element or elements in the physiological domain) provides a basis for strong inference and yields a physiological index of the psychological element. Although this may seldom be completely achievable in practice, the strength of inference is clearly improved by working to achieve (rather than simply assuming) a one-to-one mapping between Ψ and Φ.

As noted above, one key to improving the specificity of psychophysiological mappings is to reconceptualize what constitutes elements in the psychological domain and what constitutes elements in the physiological domain. A second and related key is to recognize that the relation between the physiological data and theoretical construct may have a limited range of validity (i.e., the relation may hold only for certain persons or situations). These limits to generalization can constitute an interesting theoretical challenge that, once solved, leads to a reconceptualization of elements in one or both domains. Recall that Hare (1973) has found that arachnophobics exhibit heart rate increases when shown slides of spiders, whereas nonphobics exhibit heart rate decelerations. If arachnophobia were a diagnostic category of interest, then the elements in the psychological domain (i.e., Ψ) might be reconceptualized to represent the differential psychological reactions to stimuli expected of "normals" and of arachnophobics. Thus, a deceleratory heart rate response to a spider would contraindicate the classification of an individual as arachnophobic, whereas an acceleratory heart rate response would be consistent with such a classification.

Limits to the ranges of validity of psychophysiological relations may also be due to events other than the psychological element or elements of interest causing changes in physiological activity (i.e., $P[\text{Not-}\Psi, \Phi] > 0$; Cacioppo & Tassinary, 1990b). Therefore, in addition to considering how one defines elements in Sets Ψ and Φ, one can usefully think of psychophysiological relations in terms of their specificity (e.g., one-to-one vs. many-to-one) and generality (e.g., situation specific vs. cross-situational or pancultural). Knowledge that *if Ψ then Φ* constitutes a psychophysiological outcome. Once this outcome has been established as being robust, the questions of specificity (i.e., $P[\text{Not-}\Psi, \Phi]$) and generality can be addressed. For instance, an acceleratory heart rate response would not be compelling evidence of arachnophobia unless research also demonstrated that the heart rate response was highly specific and diagnostic in the particular assessment context used. Because greater specificity may be achieved by redefining what constitutes an element in the psychological and physiological domains, research designed to maximize the degree of specificity in a limited paradigm should often precede questions about the generality of the psychophysiological mapping.

Potential contributions to psychotherapeutic evaluation: An illustration. In this section, we will examine a study in which physiological events (facial efference) were used to mark changes in affect or arousal that are subtle and otherwise not easily detectable in the course of a therapeutic interview. This focus is meant only to be illustrative. Pretreatment psychophysiological assessments have also been used to aid in the selection of an appropriate intervention and in the prediction of treatment outcomes. Reviews of this research are provided by Haynes et al. (1989) and Zahn (1986). Although some notable successes have been achieved, Haynes et al. (1989) have correctly noted that

> The identification of psychophysiological indices or "markers" of expected intervention effects necessitates complex and carefully conducted longitudinal research programmes which take into consideration individual differences in causality of behaviour disorders and the multiple treatments available. . . Such research has been infrequently conducted (p. 188).

We hope that the conceptual framework outlined in this article will contribute to productive research examining the links between psychophysiological functions and psychotherapeutic outcome as well as between psychophysiological functions and psychotherapeutic processes.

Ekman and Friesen (1969) have suggested that involuntary (i.e., automated) expressions of emotion might leak despite an individual's efforts at disguise, but that this leakage would emerge in subtle aspects of facial activity such as microexpressions. Only recently have detailed analyses of overt facial actions been conducted to investigate spontaneous and deliberately controlled facial expressions of emotion (e.g., Ekman, Friesen, & O'Sullivan, 1988; Ekman, Hager, & Friesen, 1981). Furthermore, facial efference can result in muscle action potentials that are too weak or brief to produce a visible facial action even though these muscular actions can be recorded continuously through the use of facial EMG. Evidence from several laboratories now exists showing that (a) positive, in contrast to negative, emotional imagery, sensory stimuli, and social events are associated with increased EMG activity over the *zygomaticus major* (cheek) and *orbicularis oculi* (ocular) muscle region, and decreased EMG activity over the *corrugator supercilii* (brow) muscle region; (b) EMG activity over the *medial frontalis* (forehead) and *orbicularis oris* (perioral) muscle regions, on the other hand, has not varied consistently as a function of these mild affective stimuli; and (c) EMG activity over the perioral region has varied consistently as a function of silent language processing (for a recent review, see Cacioppo, Tassinary, & Fridlund, 1990).

Note that this research allows one to make statements about physiological events as a function of psychological events, but it does not provide a basis for strong inference about the psychological significance of physiological events. To examine this latter issue, we conducted a study in an analogue clinical interview setting (Cacioppo, Martzke, Petty, & Tassinary, 1988). Specifically, we sought to determine whether distinctive EMG responses over the *corrugator supercilii* muscle region could be used as a marker of the valence of subjects' momentary affective reactions while they were talking about themselves. Previous research has examined the spatial pattern of facial EMG activity evoked by variations in emotion, but this spatial patterning in EMG activity across the face can be insensitive when individuals are speaking (e.g., due to the EMG cross talk recorded over the *zygomaticus major* muscle region, which is attributable to overt articulatory movements and to false or nervous smiles) or when very mild emotions are involved. To predict mild variations in people's emotional experiences as they were speaking during an interview, attention was given to the manner in which the EMG response over the *corrugator supercilii* muscle region unfolded over time (i.e., its waveform) while matching for the gross level of EMG activity observed over the *zygomaticus major* and *medial frontalis* muscle regions.

Four forms of phasic EMG activity over the *corrugator supercilii* muscle region were identified during pilot testing. The first represented basal levels of EMG activity over the *corrugator supercilii* muscle region and was included to establish baselines for reports of emotional experience (EMG controls or "pseudotrials"). The second represents an acicular burst of EMG activity over the *corrugator supercilii* muscle region (an EMG spike). Acicular EMG responses could be expected to occur for a variety of reasons. Increases in muscle tonus (which might result from sustained attention to a task) result in changes in spontaneous EMG responding, which can manifest as very brief semistochastic unimodal EMG pulses or spikes (i.e., less than 2 s in duration). Such activity is said to be spontaneous because the spikes occur in the absence of any known precipitating stimulus or associated thought, emotion, or intention (see Sternbach, 1966, p. 68). Eye blinks can also manifest in this form. In addition, a fleeting emotion could lead to this form of EMG response, but the transient nature of the emotion, coupled with the various nonemotional determinants of EMG spikes, should weaken the prediction of an individual's emotional experience based on the appearance of an EMG spike during an interview.

The final two forms of EMG response were defined as (a) a relatively smooth response less than 5 s in duration, marked by a gradual onset and offset (an EMG mound), and (b) a ballistic EMG response also less than 5 s in duration, which manifests more like a cluster of two more partially overlapping EMG spikes (an EMG cluster). Facial actions include those that serve primarily an interpersonal communicative function (e.g., lowering of the brows while speaking, to emphasize nonverbally a point made verbally), as well as those, to paraphrase Darwin, that are in direct or indirect service of personal sensations and desires (see Darwin, 1872/1965, p. 28). Phasic EMG clusters over the *corrugator supercilii* muscle region are less likely than EMG spikes or mounds to be associated with nonemotional events (e.g., spontaneous activation, paralinguistic signaling) and, hence, may be especially likely to mark variations in emotions during an interview (Cacioppo et al., 1988; cf. Darwin, 1872/1965). Thus, four specific forms of phasic EMG response over the *corrugator supercilii* muscle region were investigated as predictor variables during a clinical interview: (a) basal levels of activity, (b) spikes, (c) mounds, and (d) clusters. Because relatively few nonemotional antecedents were thought to exist for EMG clusters over the *corrugator supercilii* muscle region during an interview, the emotional experiences marked by EMG clusters were expected to differ from those marked by basal levels, and the emotional experiences marked by EMG spikes and mounds were expected to fall between these extremes.

Subjects were interviewed individually while unobtrusive video recordings and recordings of facial EMG activity were obtained. Specifically, subjects, seated in a dimly lit room, were instructed to talk about themselves with the goal of disclosing their "true selves." The interviewer, an advanced clinical psychology student who was located in a separate room and was unaware of the experimental condition, sought descriptions ranging from the superficial (e.g., physical attributes, demographics) to the intimate (e.g., perceived strengths and inadequacies, traumatic experiences). Throughout the interview, two other experimenters, who were unaware of the experimental hypothesis and of the subjects' self-disclosures, identified exemplars of each of the four types of EMG responses over the brow region. To ensure that these periods were otherwise comparable, exemplars were selected only if the individual was speaking, and EMG activity over the *corrugator supercilii* muscle region did not reflect a blink or generalized activation of the facial muscles.

Immediately following the interview, the interviewer conducted a videotape reconstruction with the subject. Subjects watched and listened to the entire videorecording, which was paused at 20 separate segments (five randomly selected exemplars from each of the four preceding response forms). At each pause, subjects were asked to report what thoughts and images "flashed through their minds" at that moment during the interview, and the entire videotape reconstruction was audiotaped. Subjects returned within a few days for a final session, at which time they rated each of the 20 verbal descriptions that were recorded during the videotape reconstruction along an abbreviated version of the differential emotions scale. Results revealed that the rating of the reported associations varied as a function of the type of EMG burst: Recollections during the transient spike and control periods were equal and positive, those during EMG clusters were rated as being more negative, and those during EMG mounds were rated between these extremes. The results also suggested that these EMG responses did not differentiate among the negative affects (e.g., sad, fearful). Thus, the results provided support for the notion that specific forms of EMG activity over the *corrugator supercilii* muscle region, when identified within a particular pattern of facial EMG activity, can serve as an episodic marker of negative affect when subjects are unaware of the target physiological response and of the experimental hypothesis (and, hence, are unlikely to engage somatic actions that would inhibit or mask the responses of interest).

For exploratory purposes, an expert judge (a licensed clinical psychologist in a large academic psychology clinic) viewed the videotapes and rated each of the 20 verbal descriptions that were recorded during the videotape reconstruction along the same abbreviated version of the differential emotions scale as used by the subjects. This was done to examine whether an expert could detect the transient emotional fluctuations that were manifest in the incipient facial responses. Analyses of his ratings failed to reveal any significant differences across types of EMG response. Although these results are preliminary, they raise the possibility that certain forms and patterns of facial EMG response may provide information about transient affective events that are normally not accessible to therapists.

Conclusion

Lacey (1959) alerted psychotherapy researchers to the pitfalls of simplistic views of autonomic and skeletomotor responses—either as a single dimension (e.g., increases across measures index "arousal") or as a simple set of invariants (e.g., EMG "indexes" anxiety; heart rate "indexes" anger/conflict). An unfortunate consequence of this alert was to diminish the enthusiasm for and use of psychophysiological measurements in studies of social, contextual, and molar psychological processes:

> A number of different factors influence states of arousal. Also, a number of different factors in addition to arousal account for psychophysiological responding. Unfortunately, we have known for years that psychophysiological responses are not well correlated even with each other, reflecting, as they do, different bodily functions. Building a precise theory of anxiety reduction based on psychophysiological responding, no matter how promising, will be time-consuming and difficult. (Barlow, 1988, p. 308)

This need not be the case. We have reviewed progress in conceptual, methodological, and statistical avenues for the use of psychophysiological measures in psychotherapy research. Much was needed to be accomplished, in Lacey's (1959) view, for psychophysiology to make substantive contributions to detect otherwise unknown changes in the client's affect or arousal, to reveal conflict and problems during the course of therapy, to determine the differential effectiveness of therapists, and to provide another important measure of therapy progress and outcome. Much has in fact been accomplished in the 32 years since Lacey's review.

Physiological fractionation, for instance, is a complexity that can be turned to an advantage. It makes possible a more detailed view of specific psychological and biological processes than would be the case if physiological activity simply increased or decreased in a uniform fashion. Further specificity in psychophysiological relations are possible when the configural and temporal patterns of physiological events, and the ranges of validity of psychophysiological mappings, are considered. The use of multiple measures with low intercorrelations within and across individuals can therefore be informative, particularly when combined with cross-validations to ensure that the outcomes are reliable, and due attention is given to the logic and the biologic of the psychophysiological assessments. Finally, evidence was reviewed demonstrating that the social environment is more than a powerful determinant of psychophysiological response, that it could also moderate psychophysiological and brain–behavior relationships. To the extent that the interactive effects of social factors and processes manifest in psychotherapy, factors and processes derived from the social environment will need to be incorporated, to eschew the appearance of unreliable psychophysiological data and to fully realize the substantive uses of psychophysiological evaluations in psychotherapy envisioned by Lacey a third of a century ago.

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Received January 5, 1991
Revision received January 18, 1991
Accepted January 18, 1991 ■