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Specificity and Patterning in Biobehavioral Systems

Implications for Behavior Change

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ABSTRACT: *Parallels between global descriptions of internal states in clinical and personality psychology and notions of global arousal in autonomic and central psychophysiology are illustrated. Such assumptions about the undifferentiated nature of internal states are questioned on the basis of recent psychophysiological research. Data are reviewed on cortical specificity and its implications for conceptualizing clinically relevant cognitive and affective processes. Principles of psychophysiological specificity are applied to the understanding and self-regulation of anxiety. General implications of this approach for the rationally based construction of therapeutic interventions are discussed.*

Much of the foundation upon which clinical and personality psychology are based rests upon the assumption of hypothetical, relatively global internal states such as anxiety and depression, which presumably result in particular behavioral dysfunctions (see Davidson & Schwartz, 1976). Thus, for example, a large literature has emerged on the relationship of global trait anxiety to a variety of behavioral and physiological measures. However, much of this literature has uncovered disappointingly low correlations between self-report measures of fear and anxiety and other behavioral and physiological parameters that all have considerable face validity as measures of these constructs (e.g., Hodgson & Rachman, 1974; Lang, 1969; Weinberger, Schwartz, & Davidson, 1977).

The assumption of global, undifferentiated internal states in the clinical-personality area was paralleled by a similar history in peripheral psychophysiology. Malmö (1959) and Duffy (1962; 1972) established activation theory as a core principle in psychophysiological research on autonomic processes. This view held that autonomic response systems all change in the same direction in response to an arousing stimulus. A similar development can be discerned in the area of cerebral psycho-

physiology. Beginning with the observations of Moruzzi and Magoun (1949) on global, spontaneous electroencephalographic (EEG) activation in response to reticular stimulation, many workers, including some contemporary investigators (e.g., Lindsley & Wicke, 1974), have assumed that the EEG is, at best, an indicator of global cortical arousal useful only in differentiating between sleep and wakefulness. Questions of scalp topography and site-specific patterning of activation were almost never asked until quite recently (e.g., Davidson, Schwartz, & Rothman, 1976; Doyle, Ornstein, & Galin, 1974; Galin & Ornstein, 1972), with some rare and notable exceptions (e.g., Knott & Tjossem, 1943; Wilson, Darrow, Vieth, & Maller, 1959).

Recently, a number of converging lines of evidence have begun to call into question traditionally held assumptions about the undifferentiated nature of clinically relevant internal states and their psychobiological concomitants. This challenge emerges principally from behavior-therapy research and studies of psychophysiological patterning and specificity. In his review of laboratory studies on desensitization, Lang (1969) explained that although the various measures of fear employed in desensitization research all have considerable face validity, the intercorrelations among these measures are typically low and therefore suggest the possibility that specific behavioral sys-

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tems may be separately manipulated. He later suggests that "fear is a loosely woven fabric of responses, with many edges where an unraveling process may be initiated" (Lang, 1969, p. 190). Lang's empirically based suggestion regarding the possibility of system-specific behavioral intervention has recently been explored and extended in the clinic. Lazarus (1973) has urged that we work toward a multimodal therapy in which therapeutic regimes may be individually constructed to reduce troublesome symptoms in the specific modes and systems that have gone awry.

Psychophysiological research designed to explore central and autonomic concomitants of complex normal and abnormal behavioral states has further reinforced notions of specificity and patterning and compels contemporary workers to be as specific as possible about the underlying *mechanisms* and *substrates* that interact to produce what may at first appear to be global, undifferentiated psychological states. Dramatic illustrations of psychobiological specificity have frequently been overlooked because of interpretative misdiagnoses. For example, Elliot (1964) and others (e.g., Eason, Harter, & Storm, 1964; Kreitman & Shaw, 1965) have computed intraindividual correlations between a variety of both central and autonomic measures recorded from adults across a wide variety of behavioral tasks. According to Elliot (1964), the highest correlation observed between any two measures was .16. Unfortunately, many workers have viewed these and similar data as reflecting poor validity for a number of the measures in question or inadequacies in the measurement procedures (e.g., Duffy, 1972).

An alternative perspective on data such as these is that the dissociations observed among different response systems are meaningful and are indicative of the specific patterning of physiological processes that are associated with particular behavioral states. It was not until the pioneering work of the Laceys in the late 1950s (Lacey, 1959) that this view was explicitly expressed, and compelling data were presented that demanded interpretation and could not parsimoniously be reconciled with activation theory. As is now well known, Lacey (1959) demonstrated that while the generation of cognitive activity, such as mental arithmetic, is associated with increases in both heart rate and skin-conductance level, the deployment of attention to the external environment can be associated with an increase in skin conductance and a de-

crease in heart rate. This latter condition was termed *directional fractionation* and referred to the meaningful dissociation between measures of different autonomic effectors. Similar types of fractionation have been observed in other autonomic response systems as well as in EEG measures of cortical activation.

These issues are further illustrated in this article by a number of experiments using both behavioral and psychophysiological measures to assess system-specific activation during complex cognitive and behavioral tasks. These studies were all designed to answer certain basic questions about the underlying substrates and biocognitive composition of behavioral states typically described in global terms without reference to underlying mechanisms. For example, when people are asked (a) to picture and describe the last situation in which they cried, versus (b) to picture and describe their bedrooms at home, are the underlying cognitive modes employed to answer each of these questions similar or different? Although both involve imagery, it will soon be seen that the differential requirements to process affect in these questions are associated with reliable differences in the patterning of hemispheric activation.

Another issue addressed in the data I describe concerns possible differences in the specificity of cortical activation during attention and imagery in different modalities. Is the generation of a visual versus a kinesthetic image accompanied by reliable differences in EEG patterning? And finally, the application of the concepts of biobehavioral specificity to the clinical domain are illustrated by describing some recent theorizing and research on cognitive and somatic components of anxiety and the differential effectiveness of particular relaxation procedures on the attenuation of anxiety in these two basic modes.

Cortical Specificity

I shall begin with a study by Schwartz, Davidson, and Maer (1975) in which lateral eye movements were employed as an index of hemispheric activation (see Gur, 1975; Kinsbourne, 1972; Kocel, Galin, Ornstein, & Merrin, 1972) while subjects were presented with 40 reflective questions in a 2 × 2 design. Verbal versus spatial, and emotional versus nonemotional dimensions were crossed to yield 10 questions in each of the four cells of the 2 × 2 design: verbal-nonemotional (VNE), verbal-emotional (VE), spatial-nonemotional (SNE), and

spatial-emotional (SE). The following are examples of each question type: VNE, "What is the primary difference between the meanings of the words 'recognize' and 'remember'?"; VE, "For you, is anger or hate a stronger emotion?"; SNE, "On the face of a quarter, does George Washington look to the right or to the left?"; and SE, "When you visualize your father's face, what emotion first strikes you?" Based upon suggestions from the clinical neuropsychology literature, we hypothesized that emotional questions would, on the average, be associated with relatively greater right-hemisphere activation and would therefore elicit more left-eye movements and fewer right-eye movements than comparable nonemotional questions (e.g., Gainotti, 1972; Galin, 1974). In addition to expecting a main effect for the verbal versus spatial conditions, with verbal questions eliciting more right-eye movements (i.e., left-hemisphere activation) than spatial questions, we hypothesized that spatial-emotional questions, presumably placing the greatest demand on the right hemisphere, would elicit the greatest number of left-eye and fewest number of right-eye movements, with the reverse pattern expected for the verbal-nonemotional questions. The data from this experiment indicate that the complex cognitive tasks employed could be meaningfully differentiated on the basis of their underlying hemispheric substrates. Verbal questions elicited more right-eye movements than spatial questions, while nonemotional questions were associated with both a greater number of right-eye and fewer number of left-eye movements compared with emotional questions. These data suggest that the manner in which the verbal-spatial dimension interacts with cerebral asymmetry is different from that of the affective-non-affective dimension. Moreover, spatial-emotional questions were associated with the greatest overall right-hemisphere activation (fewest number of right-eye and greatest number of left-eye movements), while verbal-nonemotional questions were associated with the greatest overall left-hemisphere activation (fewest number of left-eye and greatest number of right-eye movements).

I and my colleagues have recently replicated these findings with an independent measure of affective arousal (skin resistance) to be sure that our affective questions were, in fact, eliciting greater affective activation than the nonemotional questions. The results of this study confirmed our previous eye-movement data and indicated that

the affective questions were associated with significantly greater response amplitude (i.e., less resistance) than the comparable nonemotional questions (Davidson, Schwartz, & Weinberger, Note 1). Importantly, no significant differences in skin resistance were found between the verbal and spatial questions.

These findings suggest that different information-processing modes indexed unobtrusively by the assessment of lateral eye-movement directionality are reliably associated with particular kinds of stimulus material. The biocognitive mechanisms called into play by responding to questions that vary along verbal-spatial and affective-non-affective dimensions are specific to the question content and should be taken into account in any effort to understand, predict, and control this type of behavior.

In a study designed to assess the specificity of cortical activation during mode-specific selective attention and imagery generation (Davidson & Schwartz, 1977; Davidson, Schwartz, & Rothman, 1976), EEG was recorded from the left-occipital and left-sensorimotor areas, filtered for alpha activity, and quantified on-line. The presence of alpha activity over a particular cortical region is associated with the absence of active information processing, while alpha blocking is indicative of the reverse (e.g., Shagass, 1972). By examining shifts in the amount of alpha activity present at each of these two cortical loci, inferences can be made about the relative degree of activation in these brain regions. Subjects were required to selectively attend to either a flashing light or a sequence of taps on the right forearm during a series of half-minute trials. In another similar experiment, subjects were asked to generate an image of a light (visual) or of a tap (kinesthetic) while no external stimuli were present. In addition, a number of trials were included in which subjects were simply requested to clench and release their right fist and to tap with the fingers on their right hand. The latter trials were included to test the hypothesis that the generation of motor behavior would be associated with *selective* activation in the sensorimotor region.

The results of the first study (Davidson, Schwartz, & Rothman, 1976) indicated that selective visual attention is associated with less occipital alpha (greater activation) and more sensorimotor alpha (less activation) than during kinesthetic attention.

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A similar pattern of results was obtained when subjects were requested to generate images in the different modalities (Davidson & Schwartz, 1977). During this block of trials, in addition to asking subjects to generate visual and kinesthetic imagery, we also requested that during particular trials they generate an image of *both* the visual and kinesthetic stimulus. The EEG data indicate that kinesthetic imagery is associated with the greatest relative sensorimotor activation, with the visual imagery condition showing significantly less. As predicted, when imagining both visual and kinesthetic imagery, the EEG data reflected a pattern of activation in between the two unimodal imagery conditions. Importantly, the overall amount of alpha (across site) did not differ between these conditions.

These data have important bearing on notions of specificity and patterning of activation and challenge long-held assumptions about the undifferentiated nature of the EEG. The findings suggest that attention to or imagination of a stimulus in a particular modality is associated with specific activation in the cortical region specialized to process information from that modality. The results are consistent with literature on cognitive approaches to imagery (e.g., Neisser, 1967; Segal, 1971) in which it has been suggested that the mechanisms of perception and of imagery share the same basic underlying structure. These findings also have clinical relevance insofar as they suggest that since both overt and covert stimuli in specific modalities are processed in different cortical regions, the attenuation of anxiety occurring predominantly in one mode versus another might be most efficaciously accomplished by mode-specific training programs rather than by more globally oriented therapeutic interventions.

In addition to examining the impact of selective attention and imagery, we (Davidson, Schwartz, & Rothman, 1976) also collected data on the effects of tapping the fingers and clenching the fist of the right hand. The results from these trials again reveal important specificity. When subjects engage in motor behavior with their right hands, they show about twice the magnitude of alpha reduction at the sensorimotor region than at the occipital region. These findings have a number of interesting, and as yet untested, implications for the system-specific assessment of anxiety. Subjects may differ in the degree to which they typically experience anxiety in particular modes. Some subjects may

experience primarily somatic symptoms that would presumably be reflected in an increase in motor output throughout many parts of the skeletal musculature. It may be that these individuals would show a tonic difference in degree of activation of the sensorimotor cortex compared with other brain regions. Those individuals experiencing anxiety as primarily disturbing visual images might be expected to show greater tonic activation in the occipital region relative to other cortical loci.

Psychophysiological Specificity and Anxiety Self-Regulation

The application of notions of psychophysiological specificity to the domain of anxiety and its reduction has resulted in our development of a model (Davidson & Schwartz, 1976) differentiating between anxiety in two basic subsystems: cognitive and somatic (see also Barrett, 1972; Borkovec, 1976; Corah, 1964; Eysenck, 1961; Schalling, Cronholm, & Asberg, 1975). In addition, we have proposed that different procedures utilized in the reduction of anxiety differ in the degree to which they effect the cognitive versus somatic system. For example, we have proposed that physical exercise would result in reductions primarily in somatic anxiety with less of an effect upon cognitive anxiety. Alternatively, a technique requiring the self-generation of cognition should lead to greater reductions in cognitive versus somatic anxiety. These predictions are based upon well-known psychobiological specificity and suggest that the generation of behavior in a particular mode or system will inhibit or attenuate other ongoing behavior in that particular system or mode more than in others. (For some examples of this principle, see Hicks, 1975; Kinsbourne & Cook, 1971; Segal, 1971; Segal & Fusella, 1970.)

Table 1 presents a 2×2 matrix with the following four combinations of anxiety represented by each cell: (a) low-cognitive-low-somatic, (b) low-cognitive-high-somatic, (c) high-cognitive-low-somatic, and (d) high-cognitive-high-somatic. Within each cell, a number of techniques and/or activities are presented which theoretically should be maximally effective in eliciting relaxation for the particular configuration of anxiety represented by each cell. It can be seen from this table that high-cognitive-low-somatic anxiety may be a condition typical of the classic insomniac syndrome in which individuals who may lie down to go to sleep with their bodies fatigued can't fall asleep be-

TABLE 1

Cognitive and Somatic Components of Anxiety and Associated Activities Hypothesized to Reduce Such Anxiety

Cognitive anxiety	Somatic anxiety	
	Low	High
Low	Meditation	Progressive relaxation Hatha yoga
High	Reading Watching television	Active sports

Note. The activities in each of the cells maximally engage the system(s) in which anxiety is high. Thus, for example, both progressive relaxation and hatha yoga maximally engage the somatic system with little effect on the cognitive system, while reading and watching television are hypothesized to have the opposite effect. Active sports are thought to maximally engage both modes, while meditation is hypothesized to engage each of the two modes minimally. (Table adapted from Davidson & Schwartz, 1976.)

cause their minds are racing, that is, spontaneously generating a large number of cognitive events. Any technique that engages the cognitive system would be expected to attenuate this type of anxiety, and it is interesting, in this context, to consider the age-old procedure of visualizing and counting sheep. Such a practice would be expected to generate neutral cognitive activity and would thereby be expected to inhibit other ongoing negative cognitions. A similar type of analysis was applied to other cells of this 2×2 matrix. This method of the typological classification of anxiety modes and relaxation procedures helps resolve a number of existing anomalies in the psychophysiological literature (see Davidson & Schwartz, 1976), although space does not permit an extensive discussion of these issues.

While meditation was placed in the low-cognitive-low-somatic cell, it might be expected that a meditation procedure that specifically requires the self-generation of a cognitive stimulus (a mantra), would result in reductions in primarily cognitive anxiety, while those forms of meditation emphasizing attention to the somatic system might be expected to exert more of an effect upon somatic rather than cognitive anxiety. With this in mind, a study was performed (Schwartz, Davidson, and Goleman, in press) utilizing a pencil-and-paper scale designed to separately assess cognitive and somatic trait anxiety. We hypothesized that subjects regularly practicing physical exercise (who were in a weekly physical exercise class) would show less somatic and more cognitive anxiety than those subjects regularly practicing, for a comparable period of time, primarily Transcendental

Meditation, a cognitively based meditation procedure. Forty-four physical exercisers and 33 meditators were given a 14-item anxiety scale with an equal number of cognitive and somatic items randomly interspersed. Subjects were asked to rate the degree to which they typically experienced such symptoms when they were feeling anxious on a scale from 1 to 5. A typical cognitive item was, "Some unimportant thought keeps running through my mind and disturbs me." A typical somatic item was, "I experience butterflies in my stomach." The sum of the ratings were separately computed for the cognitive and somatic items. While contributions of self-selection could not be assessed with such a design, the results are suggestive and warrant further investigation.

The results indicated that meditators show less cognitive and more somatic anxiety than a comparable group of exercisers. There was no significant difference between the groups on overall anxiety. These findings are consistent with the general approach of system-specific assessment and treatment. The practice of two relaxation procedures differing in their underlying mechanisms was found to be associated with a specific pattern or configuration of anxiety, with less anxiety present in the mode specific to the relaxation technique in question.

These general principles are further illustrated in a study just completed in collaboration with Gerald Davison and Eric Freedland on physiological patterning in response to anxiety-provoking stimuli and brief analogue treatments in different modes (Davidson, Davison, & Freedland, Note 2). Approximately 150 female undergraduates were given an 87-item questionnaire listing situations in which they might typically experience anxiety. For each of the 87 items, subjects were asked to rate on a 7-point scale the degree to which the situation was associated with overall global anxiety, with cognitive anxiety, and with somatic anxiety. These terms were defined in a written set of instructions. After the questionnaires were completed, we selected a subset of the original subject pool whose ratings allowed us to select at least three items in each of the four cells of the 2×2 matrix displayed in Table 1. Subjects were then run in an experimental session consisting of three phases: pretreatment, treatment, and post-treatment. During each of these phases, the verbal descriptions of the situations eliciting anxiety in each of the four modes were randomly presented

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on slides, while heart rate, frontalis EMG, and palmar skin resistance were recorded. After the pretreatment phase, subjects were randomly assigned to one of two treatment groups: (a) a rational-emotive therapy analogue in which subjects were instructed to modify statements about themselves and to covertly generate more realistic and appropriate cognition, and (b) a progressive-relaxation analogue in which subjects were instructed to take a deep breath and attend to and relax the skeletal musculature. Subjects were given the instructions for the particular therapeutic technique on tape and were then asked to apply the method when the anxiety-provoking stimuli were shown again.

One of the major hypotheses tested in this experiment was whether the different anxiety modes could be reliably distinguished on the basis of autonomic patterning during the anxiety-provoking slides. Both heart rate and frontalis EMG have been linked to somatic activation in previous research (e.g., Obrist, Howard, Lawler, Galosy, Meyers, & Gaebelin, 1974; Obrist, Webb, & Sutterer, 1969). Alternatively, skin resistance level has been found to correlate relatively highly with cognitive effort (e.g., Kilpatrick, 1972). Based upon such psychophysiological specificity, we hypothesized that slides rated as being high in cognitive anxiety and low in somatic anxiety would elicit a greater skin conductance level (less resistance) than slides rated as representing the opposite pattern (low-cognitive-high-somatic anxiety). Alternatively, we expected the latter slide type to elicit higher heart rate and/or EMG levels than the former. During the pretreatment phase, slides rated as being low in cognitive anxiety and high in somatic anxiety elicited significantly higher heart-rate levels than slides rated as high-cognitive-low-somatic. Moreover, this latter slide type elicited a significantly higher skin conductance level than did low-cognitive-high-somatic slides. These data provide direct support for the suggestion that anxiety can be meaningfully differentiated into its specific biobehavioral subcomponents.

Another hypothesis tested in this study was that progressive relaxation, a somatically based procedure, should result in reductions primarily in measures of somatic activation (heart rate and EMG), while rational-emotive therapy should elicit reductions primarily in skin conductance level. We found that treatment with progressive

relaxation resulted in EMG reductions in response to both low-cognitive-high-somatic and to high-cognitive-low-somatic slides. Rational-emotive therapy was associated with significant changes only in skin conductance. Skin conductance level was found to decrease only in response to high-cognitive-low-somatic slides. These findings confirm that therapeutic interventions result in significant changes primarily in the biobehavioral systems which they engage. The data specifically suggest that particular therapeutic regimes are maximally effective in attenuating different types of anxiety.

The data and theorizing presented above all serve to emphasize the importance of considering the fractionation and specificity of multiple physiological processes in the understanding of both normal and dysfunctional behavioral patterns. Previous conceptions of global, undifferentiated internal states prevalent in personality and clinical psychology as well as in the literature on autonomic and central psychophysiology no longer seem tenable in light of contemporary research findings. More often than not, instances of dissociation between multiple behavioral and physiological measures are providing important information on the specific psychobiological substrates of behavior. This body of data provides an important foundation for those interested in behavior change, for it suggests the possibility of tailoring specific therapeutic regimes to the underlying substrates of the dysfunctional behavior. With the contemporary sophistication of psychophysiological recording methodology, we have much to look forward to in future research on these important phenomena.

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ABSTRACT
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