JOURNAL OF RESEARCH IN PERSONALITY 17, 1–21 (1983)

Personality Research and Psychophysiology: General Considerations

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A general discussion of psychophysiological methods in relationship to personality research is presented for the investigator without an extensive knowledge of psychophysiology. The paper is organized in four sections: (a) advantages inherent in the use of psychophysiological measures (e.g., continuous measurement, sensitivity to subliminal responses); (b) psychophysiological constructs that are particularly well suited to personality research (e.g., different kinds of physiological arousal, normal/pathological distinctions, perceptual states); (c) how to choose a set of psychophysiological measures and special considerations involved with their use (e.g., obtrusiveness, context and timing of measurement, costs, and capabilities); and (d) whether or not to "psychophysiologize" personality research. Within each section, illustrative applications of psychophysiology to personality research are described.

In this paper, I will be attempting to provide a framework that will be useful for the personality researcher who does not have an extensive knowledge of psychophysiology and who needs to make decisions about whether to incorporate psychophysiological techniques into his or her personality research. The paper will be divided into four sections that discuss: (a) advantageous uses of psychophysiological methods; (b) useful psychophysiological constructs; (c) choice and use of psychophysiological measures; and (d) when to "psychophysiologize' personality research. These topics will be treated in a general and nontechnical way. In writing and in reading this paper it will be necessary to suspend disbelief concerning two possibly controversial assumptions, one concerning personality and the other concerning physiology. Regarding personality, I will be assuming that there is such a thing; thus I will be using terms such as "trait" with considerable, but hopefully not too reckless, abandon. And regarding physiology, I will be assuming that the kinds of physiological processes that psychophysiologists measure do manifest orderly relationships with

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0092-6566/83/010001-21$03.00/0

phenomena occurring outside of the body. No attempt will be made to comprehensively review the large body of existing research that has studied personality from a psychophysiological perspective, but I am hopeful that some of the issues raised here will be useful in evaluating this kind of research and in understanding why it is often characterized by seemingly discrepant findings.

WHAT ARE SOME ADVANTAGEOUS USES OF PSYCHOPHYSIOLOGY?

First some pessimism: Adding psychophysiological measures to personality research is expensive, adds complexity to the process of data analysis, and, owing to its methods of measurement, is obtrusive and constrains the behavior of experimental subjects. After working in this area for a number of years, I have become convinced that psychophysiology can only provide answers to appropriately framed simple questions, and that many research questions in psychology are not appropriate for psychophysiological pursuit. Psychophysiologal measures, on the surface, are not as conceptually rich as other kinds of measures in psychology; the speed at which the heart beats is not of great interest to a psychologist until it is enriched by virtue of its relationship to other kinds of observable behavior. Psychophysiology certainly is not the panacea for all that ails psychological research. Now for some optimism: Psychophysiology can provide certain kinds of answers and information that cannot be obtained as readily, if at all, using other research methods. Many of the most interesting questions in psychology are those that involve the interaction of mind and body; psychophysiology provides a set of quite accessible tools for studying the physiological substrate of behavior. Thus, this paper will begin with some examples of what I believe to be optimal uses of psychophysiology in psychological research.

When Comparing Stressfulness

The autonomic nervous system (ANS) is responsible for preparing the body to cope with changes in the external environment. If we assume some linearity of relationship between the "stressfulness" of the environmental change and the extent of ANS adjustment or adaptation it engenders, then we can assess the relative stressfulness of environmental events using a common metric (e.g., amount of increase in heart rate, or amount of increase in skin conductance level, or some weighted average obtained from multiple physiological response systems). We can provide alternatives to self-report for asking questions such as: Which is more stressful, a hand grabbing your shoulder in a dark room or a sudden loud noise in a quiet room? And in personality research we can ask whether different hierarchies of "stressfulness" obtain for different personality types. A variant of this kind of question can be asked in terms of deviations from "normal" responses. If large randomly selected samples of subjects are exposed to a given stimulus, then norms can be established for specific ANS responses to that stimulus. This can lead to interesting research questions such as: Are cardiovascular responses of shy individuals to simulated social interactions significantly larger than those of nonshy individuals?

When Continuous Measurement is Needed

Psychophysiological measures can be obtained on a continuous basis with a very fine grain of measurement. Once the recording devices are attached, each repetition of measurement does not add *additional* obtrusiveness nor further interfere with the stream of behavior. These features are in sharp contrast with self-report measures, which obtrude and interfere each time they are obtained. If the research question in a given study can be posed in terms of changes in a certain kind of physiological arousal (see discussion of arousal below), then a continuous index of that arousal can be obtained. This is particularly useful when a long sequence of behavior is involved, when the stimulus is complex and there are many moments of interest (e.g., films), and when no a priori designation can be made as to when the moments of interest will occur (e.g., loosely structured interactional segments). In many of these instances, interrupting the stream of behavior to obtain a verbal or written report of "tension" or "arousal" would be far less desirable than looking at the physiological records obtained during the moments of interest.

When Self-Report is Inappropriate or Suspect

It is fashionable to bemoan the unreliability of self-report data. Compared to self-report data, psychophysiological data may be much more reliable, but much *less* valid, for investigating a given research question. Putting aside the issue of their reliability, there are instances in which self-report data are just not appropriate. Examples of this can be found in research using infants or very young children, or using subjects with low intelligence, high defensiveness, or mental disorders. In these examples, psychophysiological measures might be particularly useful *if* the research questions can be phrased in appropriate ways. A number of years ago I was involved in a study of the ability of very young infants to detect differences among speech sounds (Glanville, Best, & Levenson, 1977). We could not ask the preverbal infants whether they recognized when two speech sounds were different, so we built the study around the cardiac deceleratory response that accompanies orientation to novel stimuli. Sometimes the nature of the stimulus used in an experiment can make self-report data suspect. For example, the use of erotic stimuli can elicit all sorts of confounding factors that influence self-report; thus a physiological measure such as penile erection might be more reliable and appropriate than a self report of "sexual arousal."

When Extra Sensitivity is Needed

There are times when a researcher wants to increase the "gain" of measurement to be able to detect minute responses that would be beyond the sensitivity of self-report measures. Psychophysiological measures can certainly detect very small physical changes of which the subject would be totally unaware. The critical issue with psychophysiological measures is not whether they are sensitive enough; time-based measures with a resolution of 1 msec and amplitude-based measures with a resolution of 1 microvolt are readily obtainable. The issue is whether such small changes have any relevance to the research question.

An example in which the extra sensitivity of physiological measures can be put to good use is in research using the electrical activity or electromyogram (EMG) from the facial muscles. Very small changes in facial muscle tonus that are well below the detection threshold of the subject (or of even a trained observer) can be detected from the EMG record. If subtle, specific, or mild stimuli are being used (as opposed to more obvious, generic, or strong stimuli such as electric shock), this extra sensitivity could be crucial for being able to test a hypothesis concerning response differences between groups or stimulus conditions. The role of the facial muscles in the expression of emotion provides some interesting possibilities in this regard. Let us take the zygomatic major muscle, which produces smiling, as an example. If the researcher were willing to accept that smiling reflects the underlying emotion of happiness, then EMG increases associated with small increases in zygomatic major tonus (which were not sufficient to produce observable smiling) could be used as an indicator of small increases in happiness. This would allow the investigator to test hypotheses regarding the relative emotional states of subjects without resorting to stimuli that were so powerful as to overwhelm any potential individual differences. This approach has been used to test differences between depressed and nondepressed populations (e.g., Schwartz, Fair, Salt, Mandel, & Klerman, 1976) and can be adapted to a number of personality research questions concerning emotional reactivity (assuming the emotion of interest can be related to a manageable number of facial muscles).

The extra sensitivity of psychophysiological measures also has inherent advantages as regards human subjects issues since it allows the use of less noxious stimuli. This can be particularly helpful in personality research using patient populations. Suppose you are interested in testing the hypothesis that asthmatics with a certain set of personality characteristics are more likely to have their asthma attacks triggered by a certain category of stimulus than asthmatics without these characteristics. You would be much better off in performing the necessary experiment if you could use small changes in bronchial constriction that precede a full blown asthma attack, as opposed to using the occurrence of an actual attack, as your dependent measure. Using stimuli whose intensity can only produce "subclinical" bronchial changes both diminishes the ethical problems inherent in producing asthma attacks and avoids a number of methodological problems (e.g., response ceiling effects, experiment is terminated when first response occurs).

SOME USEFUL PSYCHOPHYSIOLOGICAL CONSTRUCTS

Psychophysiology is a strange beast. Because the phenomena that it wishes to study are all hidden within the confines of the body, and because that body cannot be violated in ways that would allow *direct* measures of physiological functions, the first concern of psychophysiologists has always been methodological. From its inception, psychophysiology has had to devote a disproportionate amount of its energy to solving problems of measurement. Many books and articles have been written and will continue to be written on ways to measure *indirectly* the bodily processes of interest. Many of these bodily functions have successfully eluded measurement; thus a sizable proportion of the future efforts of psychophysiologists will by necessity be directed toward methodological issues. Unfortunately for psychologists who wish to make use of psychophysiology, the concern with methodology is often frustrating. Choice fine points of methodology that delight and fascinate psychophysiologists may be seen as insurmountable obstacles to nonpsychophysiologists who wish to use these methods. It is my belief that psychophysiology *can* provide personality researchers with useful and important information, and that the methodological issues that sometimes dominate psychophysiology are not so insoluble as to necessitate holding further research in abeyance until they are solved.

Not all information that psychophysiology can provide, however, is going to be useful to personality researchers. I believe that the major determinant of this utility is whether or not the raw physiological data can be "reduced" into a construct that has the following characteristics: (a) it can be related to behavior either directly or metaphorically, (b) subjects can be differentiated and classified in terms of the amounts of this "construct" they manifest (i.e., the physiological equivalent of an *individual difference*), and (c) the relevant data can be obtained in a manner that does not unduly disrupt or intrude upon the behavioral and personality phenomena under study (see discussion of obtrustiveness below). Let us take a look at some of the psychophysiological constructs that meet these criteria.

Arousal

The construct of arousal remains the most venerable and useful psychological construct. I believe it would be safe to assert that by far the most common use of psychophysiology in the study of personality has been to ask a variant of one of two research questions:

(a) Is a "Type X Person" more aroused than a "Type Y Person" in a "Type 1 Situation"? *or*
(b) Is a "Type X Person" more aroused in a "Type 1 Situation" than in a "Type 2 Situation"?

"Arousal" is a term that has many *behavioral* referents; however, the focus of this discussion will be on its *physiological* referents. As a metaphor for summarizing bodily states, and for simplicity and heuristic value, "arousal" is without peer. However, the construct of arousal has fallen into some disrepute because of its imprecision. I believe the term can be extremely useful if it is used in well-specified and nongeneric ways. It is important to realize that psychophysiology's exclusive romance with the sweat glands has long since given way to physiological polygamy. Arousal, viewed within the domain of contemporary psychophysiology, can refer to the ANS and much more.

The brain. The first referent of the term "arousal" is the brain, and for psychophysiology the cortical areas of the brain in particular. Stimulation of the organs of sensation produces both localized cortical activity (reflecting the mapping of the sense organs on the brain) and more generalized widespread activity. Psychophysiologists measure the electrical activity of the cortex using surface electrodes to detect the electroencephalogram (EEG). In current vogue are two classes of EEG measures, both of which indicate cortical arousal: (a) frequency measures, and (b) averaged evoked potential (AEP) measures.

The "resting and ready to respond" state of the brain is characterized by the production of *alpha* waveforms in the EEG. These are regular, synchronized, high-amplitude waves that occur at a frequency between 8 and 13 Hz. When stimulated, the brain produces more irregular, unsynchronized, low-amplitude waves that occur at frequencies higher than alpha; these are called *beta* waveforms and are characteristic of the aroused and active brain. We can use mathematical techniques such as Fourier transformations to take the complex EEG signal and break it down into its sine wave components at various frequencies, and can then determine the amount of power of activity in theoretically important frequency bands such as alpha and beta. In this way we can characterize the relative arousal of two subjects in terms of the amount of EEG activity that occurs at the alpha and beta frequencies (more beta and/or less alpha indicating greater arousal). These frequency measures are frequently used in the literature and provide useful information concerning cortical arousal.

When the brain is stimulated it produces a "burst" of EEG activity that may have a recognizable pattern. Unfortunately, this stimulus-contingent EEG is adrift in a sea of noncontingent activity that vastly complicates recognition of the pattern with the unaided eye. However, if the stimulus is presented repeatedly, and the resultant bursts of EEG are mathematically averaged (usually taking EEG samples less than 1 sec. long that are matched up at the point of stimulation), then the stimulus-contingent pattern will emerge from the noncontingent "noise." Once this AEP pattern has been identified it can be analyzed in terms of the amplitudes and latencies of its peaks and valleys, to provide an indicator of the quantitative response of the brain to the stimulus. In addition, certain particular components of the AEP have been implicated as having specific behavior referents. Thus, for example, the positive going wave that may occur 300 msec after stimulation has been said to reflect stimulus uncertainty or novelty (Sutton, Braren, Zubin, & John, 1965; Dochin, Ritter, & McCallum, 1978) while the negative going wave that *precedes* the stimulus has been said to indicate the readiness of the organism to respond (Walter, Cooper, Aldridge, & McCallum, 1964). The AEP technique provides a useful measure of the cortical arousal or reactivity produced by a given stimulus. It does impose certain restrictions on the kinds of stimuli that can be used; stimuli must be short, discrete, and capable of multiple repetitions (100 repetitions are not unusual to derive the AEP).

A special issue concerned with cortical arousal is that of hemispheric asymmetries. The notion that (in right-handed people) the left hemisphere of the brain is more involved in verbal tasks, while the right hemisphere is more involved in spatial tasks has garnered a considerable amount of experimental support (e.g., Ornstein, 1972). Although precise localization of the source of EEG activities picked up by surface electrodes is not possible, a measure of "relative" localization can be obtained that may be sufficient to determine whether left or right hemisphere activity is predominant in a given subject during a given task. If personality characteristics thought to relate to predominance of "verbal" or "spatial" orientations are identified, the distribution of left and right hemisphere EEG activity during a task that has both verbal and spatial components could be used to provide physiological validation of a self-report inventory thought to measure these characteristics.

The autonomic nervous system. If the ANS really was the simple "all or none" system that it is often described as being, then it would be simple to obtain a measure of ANS arousal. In truth, the ANS has two very different subsystems, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) which do not by any stretch of the imagination function in an "all-or-none" manner. The SNS *is* capable of fairly diffuse actions when it mobilizes the body in the classic "fight or flight" arousal pattern (i.e., faster cardiac rate, increased cardiac stroke volume, dilation of blood vessels in large muscles and heart, constriction of blood vessels in gastrointestinal tract and skin, dilation of pupils, stimulation of adrenal medulla to secrete epinephrine, dilation of airways in lungs, increased sweating), but there are certainly other instances when less than the total pattern occurs and SNS activation is involved. Recent pharamacological evidence (e.g., Alquist, 1976) concerning receptor sites suggests that the SNS can be subdivided into alpha and beta branches that respond quite differently to various pharmacological agents, and that even further pharmacological specificity is likely. The PNS, which is associated with increased activity or "arousal" in the stomach, intestines, pancreas, genitals, salivary glands, and tear (lacrimal) glands, is capable of quite specific action.

Where does this leave us in our search for a measure of ANS arousal? My suggestion is to think less generically and more specifically. The concept of general ANS arousal should be abandoned and instead researchers should think in terms of specific ANS arousal systems. One possible categorization of arousal systems would include (a) cardiovascular arousal (e.g., increased heart rate, increased cardiac contractility, increased systolic blood pressure, changes in peripheral blood flow), (b) electrodermal arousal (i.e., sweat gland activity), (c) other exocrine gland arousal (e.g., tears, salivation), (d) visceral arousal (e.g., stomach contractions or motility, gastric secretions), (e) genital arousal, (f) miscellaneous arousal (i.e., pupil dilation, piloerection—hair "standing up"). It should be noted that these categories and examples do not exhaust the domain of ANS-mediated responses, and further that measures of all of these ANS functions are not readily obtainable. They are merely presented as an example of a more precise specification of the aspect of ANS arousal under study and, in addition, indicate the breadth of measurement necessary to obtain a more complete accounting of ANS activity. It is important to realize that two experiments using otherwise identical procedures may measure different ANS arousal systems and obtain quite disparate findings.

Other kinds of physiological arousal. Some mention should be made of two other kinds of physiological measures that are often reported by psychophysiologists. The first of these are the respiratory measures such as respiratory rate and respiratory depth, and the second are the measures of muscle activity such as general somatic activity and the EMG from specific muscles. The physiological controls for these responses do not fall within the ANS; however, respiration and muscle activities are closely integrated biologically with ANS activities, especially those of the cardiovascular system.

Finally, there is the important level of arousal associated with hormones in the endocrine system. Psychophysiologists have a natural inclination toward study of the hormones secreted by the medulla of the adrenal gland (epinephrine mostly, and some norepinephrine) under control of the SNS. These hormones or catecholamines have important and relatively long-acting effects on the target organs of the ANS as well as on the brain, but because they are secreted directly into the blood, they cannot be measured noninvasively. Urine samples *can* be taken and analyzed for the presence of catecholamines and their metabolites, but this does not allow for precise determination of the events that were associated with the original adrenal medullary release.

There are other hormonal systems of theoretical interest to psychophysiologists that are rarely studied because of difficulties in measurement. The secretions of the cortex of the adrenal gland (e.g., cortisone, cortisol, aldosterone) under control of the pituitary gland have been implicated in the adaptive and maladaptive responses of the body to a wide variety of stressors (e.g., Selye, 1956). Sexual hormones secreted by the gonads are also of great potential interest. It is important to remember that these kinds of hormonal activities legitimately fit within the scope of the term "arousal," and further indicate the importance of using the term in well-specified ways.

Normal versus Pathological

The normal versus pathological dimension is potentially useful for psychophysiological research on personality; however, for this potential to be realized two conditions need to be met. First, we must have normative data for a given channel of physiological information so that we can assign the "scores" of each subject to their proper place on the normal–pathological continuum. Second, we must be dealing with personality groupings where we have reason to believe that pathological or near-pathological physiological levels will be encountered. We can start by looking at the availability of normative data for the different arousal systems discussed in the previous section.

The electrical activity of the brain is regularly examined for indications of pathology. The EEG record can reveal certain recognizable waveforms indicative of pathology (e.g., the spike and dome pattern seen in epilepsy). Similarly, the "normal" EEG is characterized by definable distributions of activity at given frequencies and amplitudes, and cortical responses to external stimulation can be similarly characterized. Normative data are certainly available for many cardiovascular variables. For example, we expect the "average" subject to have a resting heart rate of approximately 72 beats per minute. Rates slower than 60 beats per minute are usually considered to be pathological (i.e., sinus bradycardia), as are rates faster than 100 beats per minute (i.e., sinus tachycardia). We also can arrange resting levels of systolic and diastolic blood pressure along a normal–pathological continuum, perhaps adjusting for subjects' ages. Normative data for psychophysiological measures of the electrodermal, exocrine gland, visceral, and genital systems are less readily obtainable. In some cases it is questionable whether or not the normal–pathological dimension has any meaning. For example, are there pathological levels of skin conductance? In other cases, there clearly are pathological levels, but the available psychophysiological measures may not be sensitive to them. For example, the existence of pathological gastric states (e.g., hyperacidity, ulceration) cannot be argued, but available measures of stomach contractions cannot directly detect these states. The measures of somatic muscle activity have excellent potential for distributing subjects along the normal–pathological dimension in terms of resting levels of tension (and specific muscles may be of particular theoretical interest). Large scale normative studies with EMGs obtained under standardized conditions are needed to realize this potential. As was the case with cardiovascular functioning, normal and pathological levels of respiratory functioning (e.g., vital capacity, forced flow, and volume rates) are already well specified in the medical literature.

Obviously, the availability of some agreed upon values that demarcate the normal–pathological dimension is of little consequence to personality researchers unless there is some reason to expect that a given personality group would manifest pathological levels of some physiological function. A recent example in which the normal–pathological dimension has been put to good use is the research on cardiovascular functioning in individuals manifesting the Type A behavior pattern. One research question that has been asked in this literature is whether the Type A person, who is thought to be at heightened risk for coronary heart disease, has unusually "high" resting cardiovascular levels and/or unusually "large" cardiovascular responses. This question, which has often been answered in the affirmative, becomes more meaningful when vague terms such as "high" and "large" can be specified in terms of cardiovascular levels considered to be pathological. This kind of research, in which attempts are made to relate certain personality characteristics to certain disease states, seems to periodically recycle itself in psychology, with each reincarnation using new terminology and manifesting higher levels of sophistication in its specification of personality, situation, and physiological response. Given the love of psychology for a productive paradigm, we can expect that the success of the research using the Type A construct will spawn other attempts to relate personality to pathological physiological conditions.

Identification of Perceptual States

There have been a number of attempts to define perceptual states in terms of patterns of peripheral physiological responses. Perhaps the best known are those associated with the work of Sokolov and with the work of the Laceys. Sokolov (1963) distinguished between two response dispositions, *orienting* and *defense*, both accompanied by different ANS patterns. In this model orienting was indicated by a response pattern that included dilation of the blood vessels in the head and constriction of those in the finger. Defense was indicated by generalized and high amplitude sympathetic nervous system activity and constriction of blood vessels in the head and finger. In the Laceys' model (e.g., Lacey, Kagan, Lacey, & Moss, 1962), the distinction was made between *environmental rejection* and *environmental acceptance* (or *attention*). Independent of level of arousal (indicated by similar skin conductance and respiratory levels in the two states), environmental rejection (as when doing mental arithmetic) was associated with increased heart rate and increased systolic blood pressure, while environmental acceptance (as when listening to tones) was associated with decreased heart rate and unchanged or decreased systolic blood pressure. Note that while different ANS signs are used by Sokolov and the Laceys to identify the perceptual states of interest, it is quite possible that "orientation" and "environmental acceptance" refer to the same perceptual state (in the same way that "defense" and "environmental rejection" could have similar referents). These distinctions among perceptual states could be well utilized in personality research. For example, we could ask whether repressive individuals differed from nonrepressive individuals in terms of the latency of their orienting response to emotionally charged stimuli (e.g., erotic or unpleasant materials), as opposed to more neutral stimuli.

Defining perceptual states in terms of physiological responses is not without its problems. There can be little doubt that ANS and central nervous system adaptations occur whenever the internal bodily milieu needs to adapt to a changing external environment. However, this does not mean that every deceleration in heart rate is indicative of an "attending organism" or that every constriction of the arteries in the forehead is indicative of a "defensive organism." There are internal metabolic factors that can produce these physiological patterns quite independent of the subject's perceptual state. Still when used judiciously, these models are often quite useful in research in which hypotheses concerning perceptual states are involved. Another common problem occurs when these models are applied to long term (i.e., tonic) physiological changes; in their original formulations the models clearly referred to short term (i.e., phasic) physiological changes. Interpreting a deceleration of heart rate that is sustained for 15 min as "environmental acceptance" "attention" or "orientation" distorts the original sense of the model.

Recently, there has been a shift away from exclusive use of ANS indicators of perceptual states in psychophysiology and a movement toward central nervous system (CNS) indicators used alone or in conjunction with ANS indicators. There is certainly sufficient biological basis for expecting both ANS and CNS concomitants of sensation and perception. Convergence of ANS and CNS indicators can only lead to greater confidence in our attempts to physiologically characterize perceptual states.

Two Elder Statesmen: Autonomic Balance and Individual Response Stereotypy

Whereas adapting any of the preceding psychophysiological constructs to the demands of personality research requires some tinkering, Autonomic Balance seems to fit the demands of this kind of research without alteration. As proposed by Wenger (1941), the notion of Autonomic Balance was that individuals could be assigned a single score that indicated their placement on a dimension measuring the relative dominance of the PNS or SNS branches of the ANS. The score was determined by measuring a number of ANS functions (e.g., amount of saliva production, heart rate, skin conductance) under "resting" conditions. The resultant score was thought to reflect a stable individual difference in terms of the relative "tonus" of the two ANS branches. The Autonomic Balance score was readily related to behavior using the prevailing metaphorical description of the sympathetic nervous system as the "go" system, and the parasympathetic nervous system as the "no go" system. For example, Eysenck (1953) hypothesized that sympathetic dominance would be a characteristic of *extroverts* while parasympathetic dominance would be a characteristic of *introverts*. Although the notion of Autonomic Balance at one time had considerable appeal, it is seldom used in contemporary psychophysiological research.

Individual response stereotypy (e.g., Malmo & Shagass, 1949) has fared somewhat better over the years. The term refers to the tendency of an individual to respond maximally with the same ANS response system to a number of different stimulus situations. Thus, one person might be a "stomach responder" while another might be a "cardiac responder." The major use of individual response stereotypy in psychophysiology has been to relate the active response system to subsequent (or concurrent) pathology (e.g., Do stomach responders tend to develop ulcers? Are hypertensives primarily cardiac responders?). While recognizing that most individuals probably do *not* manifest strong patterns of response stereotypy, it would still be interesting to determine whether individuals with the same response stereotypies manifest similarities in personality characteristics as well.

CHOOSING AND USING PHYSIOLOGICAL MEASURES

Once the decision has been made to include some kind of physiological measurement, a very important decision needs to be made concerning which measures to choose. As I hope became clear in the earlier discussion of arousal, physiological measures are not freely interchangeable. Different kinds of physiological measures tell us very different kinds of things about bodily states. In choosing physiological measures in the real world, all too often the decision is dictated by the availability of equipment. There is not too much that can be said about choosing measures on this basis other than to make several observations: (a) if the available equipment is not capable of providing appropriate measures, then using no measures is better than using poor measures; (b) it is neither wise nor necessary to obtain *every* kind of measure that your equipment can provide in every study; and (c) decisions concerning *how* to use measures are at least as important as decisions concerning *which* measures to use. Having made these observations, we can safely leave the real world and enter the ideal world in which all measures are possible.

Breadth or Specialization

A useful first question to ask in the process of choosing physiological measures is whether the nature of the research question *necessitates* inclusion of measures from any particular response systems. For example, if you are interested in the impact of gender-stereotypical sexual stimuli, such as photos of nude men and nude women, on subjects who score high or low on an androgyny scale, the selection of a measure of genital arousal would be mandated. If you are interested in individual differences in the effects of alcohol on the central nervous system, then the research requires a brain measure. If you are interested in the relationship between repressed hostility and hypertension, then you would need to obtain cardiovascular measures.

On the other hand, if your research is of the more common variety that does not necessitate any particular kind of measure, and you are primarily interested in a "global" measure of arousal, then you are faced with a more difficult decision. As I indicated earlier, there is no single arousal system but rather a number of different arousal systems. A study that attempts to draw conclusions regarding the state of physiological arousal of the subject based on a single measure is ill-advised. So what should you choose? What follows is what I consider to be a reasonable minimal set of measures for a study concerned with "arousal": (a) a cardiovascular measure, (b) an electrodermal measure, and (c) a somatic muscle measure. The cardiovascular measure should probably be heart rate as this measure is sensitive to both parasympathetic and sympathetic ANS influences, in contrast to many other cardiovascular measures that primarily reflect sympathetic influences (e.g., pulse transmission times and velocities, pulse amplitudes and volumes). The electrodermal measure can be any of several measures of skin conductance (sweat gland activity is under exclusive control of the sympathetic nervous system although its stimulation chemistry is idiosyncratic). Finally, the simplest muscle measure is one of general somatic activity (such a measure is described in the next section). You *could* record the EMG from individual muscles, but no single muscle can provide a "global" indication of muscle tension or muscle activity, and successful EMG recording requires considerable care in electrode placement and attachment. If you were able to include other measures you would be well advised to go for greater breadth. A cortical measure would provide sensitivity to CNS arousal. Whenever appropriate and feasible, more studies should include ANS, somatic, *and* CNS measures.

Muscle measures are all too often omitted in psychophysiological studies of personality. This omission is particularly unfortunate when heart rate is one of the included measures, since heart rate changes typically parallel changes in somatic muscle activity. Obtaining a muscle measure will enable you to establish whether heart rate differences between two experimental groups can be parsimoniously accounted for in terms of differences in muscle activity. For example, suppose you were comparing the heart rate responses of subjects with the Type A and Type B behavior patterns while they were performing difficult mental arithmetic tasks and you found that Type A subjects had larger heart rate responses to the task than Type B subjects. Now if you wanted to use these results to support an argument that the autonomic nervous systems of Type A subjects were producing heart rate changes that exceeded the biological demands of the situation, you would first want to determine whether Type A subjects were more somatically active during the mental arithmetic task. If they were not, then you would have much stronger evidence of a hyperreactive ANS on the basis of their larger heart rate responses. On the other hand, if Type A subjects were more somatically active, then their heart rate changes might be quite appropriate given the higher demand on the heart for blood associated with their greater somatic activity. In this case, the picture looks more like somatic hyperreactivity leading to greater autonomic drive on the heart, rather than autonomic hyperreactivity per se. These two contrasting patterns would lend themselves to very different kinds of hypotheses for explaining the statistical link between the Type A behavior pattern and heightened risk for coronary heart disease.

Obtrusiveness

An important criterion for selecting physiological measures for personality research is that of obtrusiveness, and the measures used by psychophysiologists differ greatly in this regard. For example, you can obtain a nice global measure of a subject's somatic activity by having him or her sit in a chair that is situated on top of a piece of thick plywood that is resting on a set of strain gauge transducers that generate electrical current whenever bodily movements cause slight changes in the force exerted by the platform on the transducers. This measure is *entirely* unobtrusive. At the other extreme you can obtain a nice measure of a subject's stomach contractions by having him or her swallow a balloon-like device attached to a long tube. By partially inflating the balloon and placing a pressure sensitive device at the top of the tube, you will be able to detect stomach contractions from the changes in pressure that occur. This measure is *entirely* obtrusive (and then some). Using an obtrusive physiological measure can wreak havoc on an otherwise well-designed piece of personality research by introducing confounding interactions between personality variables and reactions to obtrusive measures. Thus, in a study of gastric responses to electric shock in which individuals with antisocial personality show greater responses than normals, we would not know if these responses were primarily to the electric shock or to the invasion of the sanctity of their bodies by the messy and unpleasant gastric measure. In personality research in which relationships between the trait of interest and a physiological measure may be subtle and not overly robust, a very obtrusive measure can easily overpower the relationship.

Quite obviously, obtrusiveness of measures is a relative matter. A number of years ago I was involved in some research on the bronchial responses of asthmatic subjects to stress (Strupp, Levenson, Manuck, Snell, & Boyd, 1974; Levenson, 1979). We needed an accurate measure of bronchial constriction; no other physiological response was as meaningful for our study. The measure we used required subjects to have their nostrils clamped shut, and to bite down on a large rubber mouthpiece. The mouthpiece was connected to a long flexible tube attached to an imposing device that made a number of strange sounds and, in addition, puffed air through the tube and into the subject's lungs at a rate of three puffs per second. One of the reasons that we selected this measure was because it was relatively *unobtrusive*. The only alternative measure required subjects to enter a phone booth size air tight metal box with a lucite door and to pant rapidly and continuously into a rubber tube with a "shutter" periodically blocking their breathing. Previous research had indicated that some asthmatics experienced asthma attacks in response to this device itself. Our measure might have been arguably *less* obtrusive, but in both cases the impact of these measures became a force to be reckoned with.

Context of Measurement

When choosing a context to collect physiological data, the first context that probably comes to mind is the so-called "baseline." A researcher may be interested in whether subjects who have high scores on a measure of trait anxiety have higher "basal" heart rates than low-trait anxious subjects. This kind of research question begs the additional question of what is the appropriate experimental context for obtaining a "baseline" measure. I would contend that there is *no* satisfactory answer to this question, and that the term "baseline" should be forever banished from psychophysiological studies of personality. Here are a number of misguided research questions (from personality and psychopathology research) that presume the existence of some true baseline:

(a) Are introverts more aroused than extroverts?
(b) Are antisocial individuals less aroused than normals?
(c) Are schizophrenics more aroused than depressives?
(d) Do field independent people show more left hemisphere EEG arousal than field dependent people?

All of these questions beg the additional question of "When"? Are schizophrenics more aroused than depressives when they are asleep? When they are playing volleyball? When they are hooked up to electrophysiological recording equipment in a strange room? Obviously lurking behind these questions are some very interesting notions about the relationships between personality or psychopathology and physiology. But, examination of these relationships will require a much higher degree of specification of the experimental context (*and* of the kind of arousal) if we ever hope to see the day when replicability of results becomes the rule rather than the exception.

There are a number of experimental contexts that *can* be well specified. As a heuristic, I think it is generally better to think in terms of "responses" rather than "baselines" or "levels." The physiological response to a well-defined stressful stimulus (e.g., an unexpected 70-dB tone at 1000 Hz with a duration of 1 sec) is probably the most frequently used context for comparing subject groups. Totally replicable complex stimuli, such as photographic slides or thematically unified segments of films, are also useful. And there is no reason to limit ourselves to *stressful* stimuli; *pleasant* stimuli can also be used.

Another useful context that can be well specified makes use of physiological responses to drugs (assuming the investigator is working in a setting in which drugs can be administered). Recently in my laboratory we combined the contexts of "response to stress" and "response to drug" in a series of studies concerned with personality characteristics of individuals who differ in the extent to which a fixed dosage of alcohol reduces their physiological responses to stressful stimuli (Sher & Levenson, 1982). In these studies we found that we could predict individual differences in the magnitude of the stress response dampening effects of alcohol on the basis of personality traits thought to predispose the individual to subsequent alcoholism.

When to Measure and How Often

Selecting an appropriate "grain" of measurement is one of the most difficult decisions encountered in any psychophysiological study. The selection represents a compromise between several considerations including (a) the inherent limits of measurement associated with the response system;

(b) the cost and capabilities associated with data collection, storage, and analysis; and (c) the temporal attributes of the stimulus and the associated response.

Inherent limits. Measures based on the time period between repetitions of some physical event impose inherent limits: in measuring heart rate, the single heart beat is the finest grain of measurement possible. Other measures such as skin conductance and muscle activity can be quantified every millisecond, if the experimenter is willing and the equipment is able. There are really no limits on the opposite end of measurement: heart rate, skin conductance, and muscle activity can be averaged over as long a measurement period as is desired, given proper signal recording preparations. Physiological measures also have inherent differences in latency of onset, duration of action, and rapidity of offset. For example, the EEG response to a tone stimulus can occur within milliseconds, have a very brief duration, and a rapid offset. The skin conductance response to the same tone can have a latency and duration of seconds and a gradual offset. Heart rate responses can have very short latencies of onset, but can remain "on" for quite long periods, especially if appreciable amounts of epinephrine are released by the adrenal medulla in response to the stimulus. All of these inherent qualities can be very important. If you are interested in using a stimulus that involves rapid repetitions or that changes its affective tone frequently, then you would need to select a measure that could follow its perturbations. If you wanted a measure that tended to "average out" minor stimulus changes, then you would be well advised to choose a "slower" measure.

Costs and capabilities. Physiological data collection initially involves expenses associated with measurement equipment. Equipment that is capable of providing a permanent record of the raw electrical data (e.g., a pen writing polygraph) will be more expensive than equipment that doesn't provide that capability (e.g., oscilloscopes). Similarly, equipment that provides a permanent record of averaged data (e.g., computers) is more expensive than equipment that requires an operator to manually record meter readings (e.g., "biofeedback" equipment). Fine grained measurement requires expensive computer equipment or vigilant, tireless research assistants, or laborious postexperimental scoring of polygraph records. In addition, the finer the grain of measurement, the more "bulky" the data set becomes. A personal example may be instructive. The research question in a recent study that I was involved with required second-by-second averages of six physiological measures obtained during a 40-min experimental protocol for each of 17 subjects. This meant that there were 244,800 datum in the final data set (17 subjects × 40 min × 60 sec × 6 measures). The logistics of storing and manipulating this amount of data can be staggering. The experimenter would be well advised not to use a finer grain of measurement than is needed, but there will be many instances when even a 1-sec grain of measurement is too coarse (e.g., most studies using EEG measures). Fortunately, few studies will require an extremely fine grain of measurement *and* long periods of continuous data collection.

Temporal considerations of stimulus and response. I believe that these are the most important considerations of all and the most likely place for errors and unfortunate decisions to be made (even among experienced psychophysiologists). The researcher needs to ask the question of "how long?" the response of interest is going to last and *then* select a suitable grain of measurement. Sometimes the question can be answered on the basis of existing literature, but often it will be necessary to undertake pilot experimentation. It is very easy to "miss" short-term (i.e., phasic) responses. Let us take a common error as an example. The researcher is interested in studying differences in heart rate responses to a 10-min stressful film between "repressors" and "sensitizers." Three measures are obtained: (a) average heart rate for the 5 min before the film; (b) average heart rate for the 10 min of the film; and (c) average heart rate for the 5 min following the film. This measurement scheme represents a very coarse grain of measurement. With it you would *not* be able to look at differences in responses to a 10-sec segment of the film that had particular theoretical relevance to the repressor/sensitizer dimension. Erring on the side of overly coarse grain of measurement is quite common and totally irreparable (with overly fine measurement you can always "coarsen" the grain by averaging). Even if the stimulus is quite short and simple (e.g., a brief electric shock), the physiological response pattern might be quite complex and could require a second-by-second analysis to truly capture the response pattern. Biphasic responses (e.g., a 5-sec heart rate decrease followed by a 5-sec heart rate increase) that occur within a single measurement period (e.g., 10 sec) may cancel out and lead the experimenter to falsely conclude that *no* response has occurred. Many research questions relevant to personality are going to require fairly fine grained measurement. For example, if the research concerns emotions and their purported physiological indicators, the question needs to be asked: How long does an emotion last? In most cases, emotions are fleeting and quite ephemeral; thus a fine grain of measurement will be required.

WHY "PSYCHOPHYSIOLOGIZE"?

Having spent some time discussing the kinds of information that psychophysiological measures can provide and some of the methodological considerations that these measures require, it may be time to consider the question of whether or not to "psychophysiologize" an otherwise perfectly coherent piece of personality research. The realm of psychology is usually seen as encompassing the domains of observable behavior, subjective experience or phenomenology, and the physiological concomitants or underpinnings of psychological events. The fact that all of these domains are legitimate concerns for psychology certainly does not translate into a mandate for sampling from all three domains in every study. Still, most psychologists do not seem to be satisfied with their understanding of a phenomenon until it has been studied in the context of each of these domains.

In the area of personality research, the first issue to be considered is whether the research can be strengthened by addition of physiological measures. Obviously a physiological measure can only add useful information to a personality study if the measure bears some relevance to the personality construct under investigation. It would seem that in the case of most personality constructs some theoretical linkage *can* be made to the physiological domain. However, if the linkage is tenuous, or if the primary personality research question does not really pertain to the physiological domain, then clearly the measure should not be included. There is a school of research design that subscribes to the position that dependent measures are like money, you never can have too much of either, but this is a difficult position to defend. Some examples may be useful.

If you are studying the personality construct of "anxiety," there are compelling reasons to include some measurement from the physiological domain. Well worked out theories of anxiety always explicitly include a physiological component; thus a direct rationale exists for including physiological measures. Agreement among physiological, self-report, and behavioral measures of anxiety provide concurrent validation for the construct. With many theories of anxiety, failing to include a physiological measure would be an equivalent sin to failing to administer an anxiety inventory, or failing to code fidgeting, voice tremors, or changes in performance level. Personality constructs that have a direct relationship to anxiety are also excellent candidates for physiological measurement. For example, a model of "neuroticism" that postulates a high level of anxiety, or a model of "sociopathy" that postulates a low level of anxiety, are both well suited for psychophysiological treatment by virtue of the physiological component of anxiety.

Other personality constructs may not have as obvious a physiological component. To me, the constructs of "Machiavellianism," "ego strength," "androgyny," and "locus of control" do not seem to have any *direct* physiological concomitants. However, *indirect* theoretical bridges can be built that are not overly far fetched. The "anxiety bridge" is often useful. Place subjects who are high in Machiavellianism or who have an internal locus of control in situations in which they are helpless to control their fates, or place subjects who are high on androgyny in situations in which astereotypical sex role behavior is punished. In these instances you would predict high levels of anxiety, accompanied by its physiological manifestations. An "arousal bridge" is also possible. Subjects who are low in ego strength might be more aroused by negative personal feedback than subjects with high ego strength, and this high arousal should produce predictable physiological changes. There are many similar examples that can be constructed. Even when the primary research objective is the development of paper and pencil measures of a presumed personality trait, the ability of the measure to predict into the physiological domain may be just as useful in establishing its validity as its ability to predict into the behavioral domain.

At this point, the objection might be raised that *every* imaginable personality trait can be seen as having a physiological concomitant if sufficient care is taken in drawing the theoretical connections. To the extent that there are no practical limits to theoretical imagination, then this may in fact be true. Nonetheless, I believe that the longer and more convoluted the theoretical connection is between a personality trait and a physiological response, the more inconclusive and uninterpretable the results from the research will be. In such cases the value of adding a physiological measure to a study of personality will be negligible at best, and highly detrimental at worst.

A CONCLUDING COMMENT

The starting point for writing this paper was my conviction that psychophysiology can provide valuable tools for enhancing the study of personality, and that "pure" personality researchers and "pure" psychophysiologists can only benefit from knowing more about each other's approach to research. It is very easy for personality researchers to fall into the trap of viewing the work of psychophysiologists in the area of personality as being dilettantish, naive, and misguided. And a similar trap awaits psychophysiologists as they view the attempts of personality researchers to use psychophysiology in personality research. It would be unfortunate if researchers in both areas avoided doing research that cuts across the two subdisciplines because of the vulnerability of such research to criticism from *both* sides. Both of these research areas could use the infusion of new ideas, new methods, and new paradigms that well-designed and well-conceptualized psychophysiological research in personality would encourage.

REFERENCES

Alquist, R. P. Present state of alpha and beta-adrenergic drugs: I. The adrenergic receptor. *American Heart Journal*, 1976, **92**, 661–664.

Donchin, E., Ritter, W., & McCallum, C. Cognitive psychophysiology: The endogenous components of the ERP. In E. Callaway, P. Tueting, & S. Koslow (Eds.), *Brain event-related potentials in man*. New York: Academic Press, 1978. Pp. 349–441.

Eysenck, H. J. *The structure of human personality*. New York: Wiley, 1953.

Glanville, B. B., Best, C. T., & Levenson, R. W. A cardiac measure of infant cerebral asymmetries in auditory perception. *Developmental Psychology*, 1977, **13**, 54–59.

Lacey, J. I., Kagen, J., Lacey, B. C., & Moss, H. A. The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In P. Knapp (Ed.), *Expression of the emotions in man*. New York: International Universities Press, 1962. Pp. 161–196.

Levenson, R. W. Effects of thematically relevant and general stressors on specificity of response in asthmatic and nonasthmatic subjects. *Psychosomatic Medicine*, 1979, **41**, 28–39.

Malmo, R. B., & Shagass, C. Physiologic study of symptom mechanism in psychiatric patients under stress. *Psychosomatic Medicine*, 1949, **11**, 25–29.

Ornstein, R. E. *The psychology of consciousness*. San Francisco: Freeman, 1972.

Schwartz, G. E., Fair, P. L., Salt, P., Mandel, M. R., & Klerman, G. L. Facial expression and imagery in depression: An electromyographic study. *Psychosomatic Medicine*, 1976, **38**, 337–347.

Selye, H. *The stress of life*. New York: McGraw–Hill, 1956.

Sher, K. J., & Levenson, R. W. Risk for alcoholism and individual differences in the stress response dampening effect of alcohol. *Journal of Abnormal Psychology*, 1982, **91**, 350–367.

Sokolov, E. N. Higher nervous functions: The orienting reflex. *Annual Review of Physiology*, 1963, **25**, 545–580.

Sutton, S., Braren, M., Zubin, J., & John, E. R. Evoked potential correlates of stimulus uncertainty. *Science*, 1965, **150**, 1187–1188.

Strupp, H. H., Levenson, R. W., Manuck, S. B., Snell, J. D., & Boyd, S. Effects of suggestion on total respiratory resistance in mild asthmatics. *Journal of Psychosomatic Research*, 1974, **18**, 337–346.

Walter, W. G., Cooper, R., Aldridge, V. J., McCallum, W. C., & Winter, A. L. Contingent negative variation: An electrical sign of sensorimotor association and expectancy in the human brain. *Nature (London)*, 1964, **203**, 380–384.

Wenger, M. A. The measurement of individual differences in autonomic balance. *Psychosomatic Medicine*, 1941, **3**, 427–434.