

Psychophysiological Dysfunctions in the Developmental Course of Schizophrenic Disorders

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Abstract

Psychophysiological anomalies in symptomatic schizophrenic patients, remitted schizophrenic patients, and individuals at heightened risk for a schizophrenic disorder are reviewed with an emphasis on electrodermal anomalies. Two electrodermal anomalies are identified in different subgroups of symptomatic patients: (1) an abnormally high sympathetic arousal and (2) an abnormal absence of skin conductance orienting responses to innocuous environmental stimuli. The same two electrodermal anomalies also have been observed in remitted schizophrenic patients. Among high-risk individuals, the offspring of schizophrenic patients display abnormally high electrodermal responsiveness to aversive stimulation, whereas a substantial proportion of college students who score high on physical anhedonia (a putative risk factor for schizophrenia) exhibit skin conductance nonresponsiveness. Thus, heightened sensitivity to aversive stimulation appears to be associated with a genetic vulnerability to schizophrenia, while tonic hyperarousal, which occurs in subgroups of symptomatic and remitted schizophrenic patients, may reflect a later developmental consequence of the underlying vulnerability. Skin conductance nonresponsivity may represent a different developmental consequence associated with the same underlying vulnerability or it may represent a different type of vulnerability. Other psychophysiological anomalies also are promising indicators of the vulnerability to schizophrenia (e.g., deviant smooth pursuit eye movements, attenuated P300 component of the event-related brain potential, reduced electroencephalic

(EEG) alpha activity, and heightened EEG delta activity).

Psychophysiology is a hybrid scientific discipline concerned with the interrelationships between physiological measures on the one hand and psychological states and processes on the other hand. Characteristic psychophysiological research involves recording physiological responses noninvasively from human subjects involved in different types of psychological tasks (Stern 1964). For example, typical psychophysiological research paradigms involve measuring electrodermal responses while subjects anticipate aversive environmental stimuli, measuring event-related brain potentials while subjects detect a significant environmental event, or measuring heart rate during the preparatory interval of a forewarned reaction time task. The general goal of these paradigms is to obtain quantitative, nonverbal, and relatively unobtrusive physiological indices associated with certain psychological states (e.g., arousal and stress) and processes (e.g., attention and information processing).

Physiological measures associated with individual differences, both in the normal and abnormal spectrum, are of central interest to many psychophysiologicalists. For example, extensive psychophysiological research has been conducted with schizophrenic patients, involving a large number of response measures obtained in a variety of stimulus situations. One of the most widely employed psychophysiological research paradigms in the study of schizophrenia during the past decade

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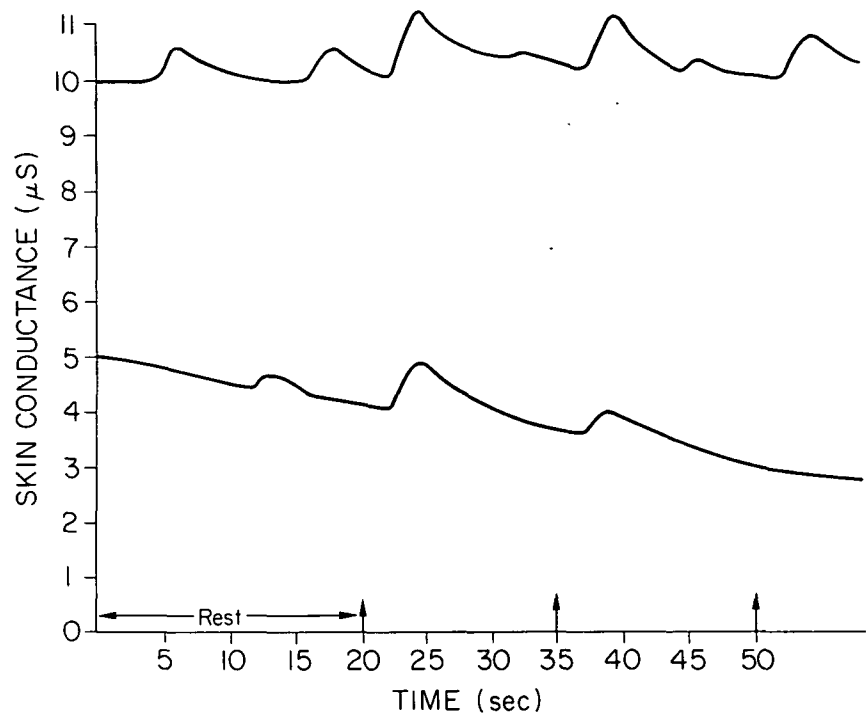
has involved the measurement of electrodermal activity, particularly in response to mild innocuous stimuli. The present article focuses primarily on electrodermal anomalies in schizophrenia that have been observed within this paradigm, although other response systems and research paradigms are briefly mentioned where relevant and where space permits.

The purpose of the article is to review the evidence regarding electrodermal and other psychophysiological anomalies in schizophrenia, with the ultimate aim of identifying the functional significance of these anomalies in the developmental course of schizophrenia. The evidence presented is divided into five sections: (1) The physiological and psychological nature of the electrodermal measures is briefly reviewed. (2) The electrodermal anomalies occurring during periods of active schizophrenic symptomatology, as indicated by cross-sectional comparisons of schizophrenic patients with normals, are presented. Then, to attempt to determine whether these anomalies reflect temporary symptom-linked states or more enduring vulnerability-linked traits, (3) electrodermal anomalies in subjects at risk for schizophrenia, and (4) anomalies among patients with schizophrenic disorders in remission are reviewed. (5) The potential prognostic relevance of these anomalies is discussed. An attempt to integrate this evidence into general heuristic models of the developmental course of schizophrenic episodes is presented in the final article of this series (Nuechterlein and Dawson 1984).

The Electrodermal Response System

Electrical conductivity of the skin can

Figure 1. Hypothetical skin conductance recordings



The upper tracing shows a higher and more stable skin conductance level, more "nonspecific" skin conductance responses, and slower habituation to stimulus repetitions. (The symbol † indicates the presentation of a mild innocuous stimulus.)

be measured by applying a small constant voltage across a pair of electrodes positioned on the surface of the skin. With appropriate instrumentation, one can obtain a continuous polygraphic tracing of the tonic skin conductance level (SCL) and, superimposed on this level, waves of phasic increases in skin conductance (skin conductance responses, SCRs). The principal peripheral effectors mediating these electrodermal phenomena are the eccrine sweat glands. These sweat glands are most dense on the palmar surface of the hands and fingers and are innervated solely by the sympathetic branch of the autonomic nervous system (Edelberg 1972; Venables and Christie 1973; Fowles

1974). Psychophysicologists are interested in electrodermal phenomena principally because increases in arousal and allocation of attentional capacity are associated with increased sympathetic nervous system activity which, in turn, is associated with increases in SCL and SCRs.

Figure 1 shows polygraphic tracings of two hypothetical skin conductance recordings during rest and during presentation of a series of innocuous environmental stimuli (e.g., brief tones). Several important electrodermal phenomena can be seen by comparing these two tracings. First, one tracing has a higher tonic SCL than the other (the upper tracing starts at 10 μ S SCL and the lower

tracing starts at 5 μS SCL).¹ Another aspect of the SCL is its change over time (the upper tracing remains relatively stable while the lower tracing shows an overall decline). Second, the upper tracing shows more frequent "spontaneous" or "nonspecific" SCRs than does the lower tracing. Nonspecific SCRs (NS-SCRs) are those skin conductance responses that occur in the absence of identifiable eliciting stimuli. Third, the upper tracing shows less of a decline in stimulus-elicited SCR amplitudes and frequencies associated with stimulus repetitions (habituation). In fact, in the lower tracing the third stimulus presentation fails to elicit a measurable SCR.

In addition to these three primary electrodermal phenomena (SCL, NS-SCRs, and rate of SCR habituation), other useful electrodermal measures include the magnitude, latency, rise time, and recovery time of stimulus-elicited SCRs. Bilateral differences in electrodermal activity also are potentially fruitful measures. However, because of space limitations and the fact that less is known about the relationships of these measures to schizophrenia, the present article does not emphasize these additional electrodermal measures.

The following material summarizes typical findings obtained with normal subjects with each of the three major electrodermal phenomena mentioned above. The aim of this section is to give the

reader who is only partially familiar with electrodermal measures a better sense of these phenomena in order to aid interpretation of the anomalies found in schizophrenia.

Skin Conductance Level (SCL). Tonic SCL reflects primarily fullness of the sweat glands and amount of hydration of the skin. Tonic SCL is generally considered a useful index of sympathetic arousal, although it can be influenced by nonsympathetic factors such as density of sweat glands and thickness of the corneum. Evidence for its usefulness as an index of sympathetic arousal includes the observations that SCL is significantly increased by pharmacological manipulations (e.g., administration of dextroamphetamine; Zahn, Rapoport, and Thompson 1981) and behavioral manipulations (e.g., threat of electric shock; Bohlin 1976). In addition to the evidence relating SCL to states of arousal, there is also evidence that SCL is a relatively stable trait. For example, the median test-retest reliability of SCL in normal subjects is between .60 and .70 over periods ranging from a few days up to 5 months (Lacey and Lacey 1958; Bull and Gale 1973; Siddle and Heron 1976).

Within-session decreases in SCL, such as that shown in the lower portion of figure 1, reflect general adaptation of tonic sympathetic arousal to the test situation. Typically, SCL gradually decreases when normal subjects are at rest in a quiet environment, increases when novel stimulation is introduced, and then gradually decreases again as the stimulus is repeated (e.g., Montagu 1963). Manipulations that increase arousal (e.g., threat of electric shock) also generally slow the rate at which the within-session SCL decreases (Bohlin 1976). What little data exist

suggest that this measure is relatively stable when retested over several weeks ($r = .74$; Bull and Gale 1973).

Nonspecific Skin Conductance Responses (NS-SCRs). The frequency of NS-SCRs is also considered a useful index of sympathetic arousal. Thus, behavioral manipulations which increase arousal (e.g., threat of shock or instructions to perform a task) also significantly increase the rate of NS-SCRs (Katkin 1975; Bohlin 1976). Moreover, the stimulant dextroamphetamine increases the frequency of NS-SCRs (Zahn, Rapoport, and Thompson 1981) while, conversely, phenobarbital and the barbiturate cyclobarbitone decrease the frequency of NS-SCRs (Burch and Greiner 1958; Lader 1964). Test-retest reliabilities of NS-SCRs among normal subjects are generally between .50 and .70 across periods ranging from a few days up to 5 months (Lacey and Lacey 1958; Crider and Lunn 1971; Bull and Gale 1973; Siddle and Heron 1976), indicating that frequency of NS-SCRs is a moderately stable trait. As is true of other electrodermal measures, however, there is "random" day-to-day variation, and computing a representative rate of NS-SCRs over several days for each individual can increase longer-term test-retest reliabilities (Docter and Friedman 1966).

Rate of SCR Habituation.

Presentation of a novel, unexpected, or significant stimulus typically elicits a constellation of motor, autonomic, and central nervous system (CNS) responses, collectively referred to as the "orienting response" (OR). The SCR is one of the most reliable indices of the OR, occurring to the first presentation of a novel stimulus in 95 percent of normal subjects (Lynn 1966, p. 93).

¹ Skin conductance traditionally has been expressed in units of micromhos in the psychophysiological literature. However, the term microsieman (μS) has replaced the term micromho as the internationally recognized unit for conductance (Fowles et al. 1981).

The SCR-OR typically has a latency between 1 and 3 seconds, reaches a peak within 1-2 seconds, and returns back to baseline within 5-10 seconds (see figure 1). The SCR-OR reflects a phasic increase in sympathetic arousal thought to be related to a subject's attention to, and cognitive processing of, the eliciting stimulus and possibly related to improved processing of subsequently presented stimuli (Sokolov 1963; Öhman 1979;). Öhman (1979, p. 444) has proposed that the autonomic OR denotes a call for information processing in a central channel with limited capacity, while Dawson et al. (1982, p. 291) have suggested that the SCR-OR reflects the actual expenditure of processing capacity. In either case, the elicitation of SCR-ORs is considered to be intimately related to attention and information processing instigated by the eliciting stimulus.

One of the defining characteristics of the OR is its gradual reduction and eventual disappearance with stimulus repetition. This ubiquitous phenomenon of habituation is an adaptive process whereby the subject becomes less responsive to familiar, predictable, and nonsignificant stimuli. One of the most commonly employed measures of habituation is the number of stimulus repetitions required to reach some predetermined level of habituation (e.g., three consecutive stimulus presentations with no measurable response). Typically the SCR-OR requires between three and nine stimulus repetitions of a mild nonsignificant stimulus to reach this criterion. However, this value can be substantially increased if the stimulus is made task-significant (Ray, Piroch, and Kimmel 1977) or intense (Turpin and Siddle 1979) or if the subject's tonic arousal level is increased (Bohlin 1976). This measure of

habituation exhibits moderately high test-retest reliabilities in normal subjects, generally between .50 and .60 for mild stimuli and between .60 and .70 for strong stimuli for periods ranging from 1 week up to 5 months (Crider and Lunn 1971; Bull and Gale 1973; Crider and Augenbraum 1975; Siddle and Heron 1976).

There is a small subgroup of subjects in the normal population, usually between 5 and 10 percent, which at any one time fails to give SCR-ORs to innocuous environmental stimuli. Simons et al. (1983) tested 250 college undergraduates and selected 24 SCR-OR nonresponders and 24 SCR-OR responders for further study. Nonresponders had lower SCL and less frequent NS-SCRs than the responders. Upon retest 2 weeks later, most of the SCR-OR nonresponders (62 percent) remained nonresponders, but a substantial minority (38 percent) did now emit SCR-ORs. These results demonstrate that SCR-OR nonresponding is associated with low electrodermal arousal and is relatively stable, although it is not a fixed and immutable trait.

Summary and Conclusions. The overall picture that emerges from an examination of the electrodermal measures is that states of sympathetic arousal are usually associated with (1) high SCL that remains relatively stable across time, (2) high frequency of NS-SCRs, and (3) slow SCR-OR habituation. Thus, the upper tracing in figure 1 illustrates the electrodermal pattern typically associated with high sympathetic arousal, while the lower tracing shows the pattern typically associated with low sympathetic arousal.

It is important to note that the concept of a unidimensional continuum of arousal has had a checkered history in psychophysiology.

The once widely used concept has been a source of controversy since the seminal chapter of Lacey (1967). Lacey's basic argument was that the concept was untenable because the various indices of arousal were not intercorrelated highly. Instead, Lacey concluded that electrocortical, autonomic, and behavioral arousal are neurophysiologically separable, complexly interacting, systems. The term arousal, therefore, is used with considerable caution here.

First of all, the term is qualified as "sympathetic arousal" in recognition of the fact that one cannot safely generalize from the sympathetic nervous system to the whole organism. Even with this qualifier, conceptual problems still exist. For example, different sympathetic nervous system measures (e.g., electrodermal and cardiovascular) do not correlate highly in all cases. Worse yet, different electrodermal measures purportedly reflecting sympathetic arousal (e.g., NS-SCR and SCL) are generally only weakly correlated with each other (Lader 1964; Bull and Gale 1973; Martin and Rust 1976). The dissociation of NS-SCR and SCL may be due to peripheral physiological factors (Fowles 1980, p. 95), but the point is that no single measure can serve as "the" index of sympathetic arousal, much less generalized arousal.

The concept of sympathetic arousal is used here for heuristic and descriptive purposes, but with the caveat that different physiological measures of the same concept do not always agree. Despite this serious caveat, we believe that the concept of sympathetic arousal is a useful descriptive summary term and has heuristic value.

Finally, it should be noted that the electrodermal measures, while sensitive to changes in psychological

states, also are relatively stable individual traits. For example, while frequency of NS-SCRs will increase from a period of rest to a period of anticipation of an aversive stimulus (hence, this measure is state sensitive), subjects will nevertheless tend to maintain their relative rankings compared to other subjects in the two situations (hence, the measure is also trait sensitive). Other lines of evidence suggesting trait-like qualities are the reports that SCL, NS-SCR, and rate of habituation are partially under genetic control (Lader and Wing 1966; Zahn 1977; Iacono and Lykken 1979; Lykken 1982).

Cross-sectional Comparisons of Schizophrenic Patients and Normal Controls

In this section, studies that have compared symptomatic schizophrenic patients with normal controls on electrodermal measures are reviewed. For comparisons involving electrodermal arousal measures, it is essential that the patients be free of neuroleptic medications because these medications lower SCL and usually reduce the frequency of NS-SCRs (see reviews by Tecce and Cole 1972; Venables 1975). Although not generally acknowledged, it is also important that the patients not be receiving commonly used antiparkinsonian medication (e.g., Cogentin), as these drugs have anticholinergic effects that lower electrodermal arousal indexes. Neuroleptics also reduce phasic SCR-ORs to stressful or noxious stimuli in schizophrenic patients (Pugh 1968; Gruzelier and Hammond 1978), but, fortunately for research purposes, they appear to have little or no effect on the frequency of SCR-ORs to innocuous nonsignal stimuli (Gruzelier and Hammond 1978; Straube 1980; Bernstein et al. 1981).

Tonic Sympathetic Arousal. Table 1 summarizes the results of 10 representative studies that compared unmedicated schizophrenic inpatients with normal controls on electrodermal measures of tonic sympathetic arousal. All of the studies in table 1 recorded the electrodermal measures during periods of rest and nonstimulation and/or during the presentation of innocuous nonsignal stimuli. Some of the studies included both medicated and unmedicated schizophrenics, but only the results for the unmedicated subgroups are shown.

All 10 studies listed in table 1 reported SCL results; six found higher SCL among schizophrenic patients, three found no significant difference in SCL, and one found lower SCL among schizophrenics. Only five of the studies examined within-session changes in SCL; four found less SCL decrement among schizophrenics and one found no significant difference. Seven of the studies reported NS-SCR results; three found more frequent NS-SCRs among schizophrenics, three found no significant difference, and one found less frequent NS-SCRs among schizophrenics.

Thus, the evidence indicates a predominance of higher than normal electrodermal arousal in unmedicated schizophrenics. However, there is considerable variability among the studies and apparently considerable heterogeneity among schizophrenic patients within the studies. Similar variability has been found with other autonomic measures such as heart rate (Gray 1975; Zahn 1975). We turn next to the elicitation and habituation of phasic SCR-ORs, measures that may help identify more homogeneous subgroups of schizophrenic patients.

SCR-OR Habituation. As stated

above, presentation of innocuous nonsignal stimuli to normal subjects usually will initially elicit SCR-ORs which then habituate after a few repetitions of the stimulus. In an influential study, Gruzelier and Venables (1972) reported a bimodal distribution of SCR-ORs elicited by 15 innocuous nonsignal tones in a group of 80 heterogeneous medicated schizophrenic patients. The bimodal distribution reflected the finding that 54 percent of the schizophrenics failed to give any SCR-ORs while 42 percent not only responded but failed to reach the criterion of habituation (in contrast, 100 percent of the normal controls responded and then met the habituation criterion). The two extreme SCR-OR subgroups were referred to as "nonresponders" and "responders," respectively. The promise of these striking results was that two distinct and relatively homogeneous subgroups could be identified on the basis of SCR-OR recordings, and that apparent inconsistencies in the psychophysiological literature could be eliminated or at least reduced by identification of these subgroups. As will be shown below, this promise has been only partially fulfilled in the decade since the original Gruzelier and Venables (1972) publication.

Table 2 summarizes the results of six recent SCR-OR cross-sectional comparisons of hospitalized schizophrenic patients and normal controls that were completed in different laboratories. Taken as an aggregate, table 2 summarizes the SCR-OR results for 242 schizophrenic patients and 241 normal controls. The schizophrenic patients represent a heterogeneous group in their current symptomatology, length of hospitalization, drug status, and premorbid adjustment, as did the group studied by Gruzelier and Venables (1972). Table 2 shows the percentage of

Table 1. Cross-sectional comparisons of unmedicated schizophrenic patients and normal subjects on three measures of electrodermal tonic arousal

References	Unmedicated schizophrenic patients	Normal control subjects	Measures of tonic arousal		
			SCL	ΔSCL	NS-SCRs
Ax et al. (1970)	28 chronic patients	18 staff & students	↑	—	—
Bernstein et al. (1981)	Subgroup of 10 unmedicated chronic patients	40 hospital staff	↑	↑	—
Gray (1975)	16 nonparanoid chronic patients	8 hospital staff & 8 prisoners	0	—	—
Gruzelier et al. (1981a)	36 heterogeneous patients (mostly chronic)	36 normals (unspecified source)	↑	—	0
Gruzelier et al. (1981b)	33 heterogeneous patients (consecutive admissions)	31 hospital staff	↑	↑	↑
Horvath & Meares (1979)	24 acute paranoid & 12 acute non-paranoid patients	15 normals (unspecified source)	↑ paranoid ↑ nonparanoid	—	0 paranoid 0 nonparanoid
Straube (1979)	Subgroup of 21 unmedicated acute patients	32 clinic staff (mostly)	0	↑	↓
Thayer & Silber (1971)	32 heterogeneous patients (mostly chronic)	32 normals (unspecified source)	0	—	0
Zahn, Rosenthal, & Lawlor (1968)	52 chronic patients	20 NIH staff	↑	↑	↑
Zahn, Carpenter, & McGlashan (1981b)	46 acute, good prognosis patients	118 twins	↓	0	↑
	Evidence of hyperarousal		6/10	4/5	3/7
	Evidence of normal arousal		3/10	1/5	3/7
	Evidence of hypoarousal		1/10	0/5	1/7

Abbreviations used in table text:

↑, higher than normal arousal;
 0, no difference from normal arousal;
 ↓, lower than normal arousal;
 —, no data reported.

Abbreviations used in table heading:

SCL, skin conductance level;
 ΔSCL, within-session changes in SCL;
 NS-SCR, frequency of nonspecific skin conductance responses.

Table 2. Summary of SCR-OR habituation results from six recent studies

Reference	Schizophrenic (SZ) sample	Normal (Norm) sample	Non-responders		Fast habituators		Normal habituators		Slow habituators	
			SZ	Norm	SZ	Norm	SZ	Norm	SZ	Norm
Bernstein et al. (1981) ¹	20 chronic patients	20 hospital employees (mostly)	50%	15%	40%	25%	10%	50%	0%	10%
Patterson & Venables (1978) ²	73 chronic patients	20 hospital employees	42%	10%	21%	10%	27%	45%	10%	35%
Gruzeller et al. (1981b)	33 recently hospitalized heterogeneous pts.	31 hospital staff	30%	10%	6%	29%	9%	29%	55%	32%
Rubens & Lapidus (1978) ³	20 chronic patients	20 employees of religious institutions	35%	0%	30%	10%	0%	90%	35%	0%
Straube (1979)	50 acute patients	32 hospital staff (mostly)	40%	3%	18%	19%	22%	34%	20%	44%
Zahn, Carpenter, & McGlashan (1981a) ⁴	46 acute patients	118 twins	28%	6%	15%	16%	39%	48%	17%	30%
Weighted means			38%	7%	19%	18%	22%	47%	21%	28%
			91	16	47	43	54	114	50	68
			242	241	242	241	242	241	242	241

¹ Data are from the left hand of subjects presented 60-dB tones and were supplemented by personal communication (Bernstein, October 1981).

² Data are from the right hand (Patterson & Venables 1978, p. 558).

³ Schizophrenic data are based on the inpatient sample reported by Rubens & Lapidus (1978, pp. 202-203). There is an apparent discrepancy between the text of the original report (which indicates that 100% of the normal controls gave at least 3 SCR-ORs before habituating) and figure 1 in the original report (which indicates that 2/20 normal controls gave only 2 SCR-ORs before habituating). The present summary of the data for the normal controls is based on results depicted in the figure.

⁴ Data are supplemented by personal communication (Zahn, September 1981).

patients and controls in each study that exhibited: (1) SCR-OR nonresponding, (2) SCR-OR fast habituation, (3) SCR-OR normal habituation, and (4) SCR-OR slow habituation. These electrodermal subgroups are defined by the number of trials required before meeting the habituation criterion of three consecutive trials with no SCR-ORs. Nonresponding is defined as meeting the habituation criterion on the initial three trials (hence, zero trials required before meeting criterion), fast habituation is defined as meeting the habituation criterion after only one or two trials, normal habituation is defined as meeting the habituation criterion after three to nine trials, and slow habituation is defined as requiring 10 or more trials before meeting criterion.

The most consistent finding, obtained in all six studies summarized in table 2, is that a sizable proportion of schizophrenic patients, compared to normal controls, are SCR-OR nonresponders. Averaged across the studies in table 2, 38 percent (91/242) of schizophrenics are nonresponders compared to 7 percent (16/241) of normal controls. This finding is reasonably consistent with the original Gruzelier and Venables report, in which 54 percent of schizophrenics and 0 percent of normal controls were SCR-OR nonresponders. However, in contrast to the original Gruzelier and Venables report, only two of the six studies (Gruzelier 1981*b*; Rubens and Lapidus 1978) found a higher than normal proportion of slow habituators among schizophrenics.

In conclusion, cross-sectional comparisons of symptomatic schizophrenic patients and normal controls rather consistently indicate a high incidence (approximately 40 percent) of SCR-OR nonresponders among

the schizophrenics, whereas the incidence of SCR-OR slow habituation appears inconsistent. Similar conclusions were reached in two recent review articles. In the first, Öhman (1981) provided an exceptionally thorough and insightful analysis, reviewing over 30 independent samples involving nearly 1,000 schizophrenic patients. He concluded that while the results are somewhat variable across different studies, on the average approximately 40 percent of schizophrenic patients are SCR-OR nonresponders to innocuous nonsignal stimuli, compared to 5-10 percent nonresponders among normals. Among the schizophrenics who do exhibit SCR-ORs, Öhman reported that the majority of the evidence indicated no abnormality in trials-to-habituation.

The most useful way of summarizing the data, therefore, is to conclude that the shape of the response frequency distribution differs between schizophrenics and normals not in bimodality but in skewness, so that the schizophrenic distribution is more positively skewed than the normal one. [Öhman 1981, p. 101]

In the second review article (Bernstein et al. 1982), Bernstein, Frith, Gruzelier, Patterson, Straube, Venables, and Zahn analyzed their independently collected SCR-OR data using common definitions of "nonresponders" (absence of SCR-ORs on all three initial stimulus presentations) and "slow habituators" (failure to exhibit three consecutive trials without SCR-ORs within 10 trials). In this major undertaking, the same statistical-analytical procedures were applied to SCR-OR data collected in 14 studies conducted in 6 different laboratories from 3 different countries. One SCR-OR dysfunction emerged in practically all of the studies; namely, on the average nearly 50 percent of the schizo-

phrenics were SCR-OR nonresponders compared to 5-10 percent of normals. To quote the authors:

A singular schizophrenic deficiency does emerge from these divergent examinations. In Bernstein's and Patterson's studies of chronic schizophrenics, and in Straub's and Zahn's studies of acute schizophrenics, as well as within the Gruzelier-Venables studies, schizophrenics consistently display a markedly increased incidence of nonresponsiveness. [p. 190]

There was less agreement among the multinational investigators (Bernstein et al. 1982) regarding the course of habituation among the responder schizophrenics. Faster than normal habituation (or a trend in that direction) was the majority finding, but a minority reported slower than normal habituation using the trials-to-habituation criterion. Perhaps the schizophrenic responders should be further subdivided into "fast habituators" and "slow habituators" (Patterson and Venables 1978), although the theoretical and/or clinical usefulness of this distinction remains to be demonstrated.

It should be noted that most schizophrenic nonresponders will respond if stimulus intensity is increased (Bernstein 1970; Bernstein et al. 1981; Gruzelier 1981*b*) or if the stimuli are task-significant (Gruzelier and Venables 1973; Bernstein et al. 1980). These results indicate that schizophrenic nonresponders are physiologically capable of electrodermal responding. The underlying dysfunction for the nonresponders apparently involves a heightened threshold for SCR-OR elicitation, suggesting that mild innocuous stimuli are not adequate to elicit allocation of attentional resources in this subgroup.

It should also be noted that the absence of orienting responses in a substantial proportion of schizo-

phrenic patients has been confirmed with response measures other than the SCR. For example, most SCR-OR nonresponders also fail to respond to innocuous tones with the finger pulse volume measure (Bernstein et al. 1981) and show significantly reduced pupillary response to light stimuli (Patterson 1976). There also is considerable evidence that schizophrenics as a group exhibit a small P300 component of the event-related brain potential (Roth 1977). The P300 is a positive-going potential which occurs approximately 300 msec following a stimulus and appears to have many of the properties of an OR (Donchin 1981; Roth 1983). Recently, Cohen, Sommer, and Hermanutz (1981) examined the relationship between P300 and SCR-ORs by measuring SCR-ORs to a series of mild innocuous tones and then measuring P300 event-related potentials to task-significant stimuli in a group of 25 chronic nonparanoid schizophrenics. Small P300 responses were found among the schizophrenic patients, and this was true whether the patients were SCR-OR nonresponders, normal habituators, or slow habituators. These results appear to suggest that SCR-OR and P300 measures reflect different processes and are related to different aspects of schizophrenia. However, the SCR-ORs and P300s were measured in different stimulus paradigms, thus limiting the inferences that can be drawn (Roth and Tinklenberg 1982). Further research on the concordance of different physiological measures of orienting, especially autonomic and cortical measures, is needed; see Bernstein et al. (1980) for evidence about autonomic and cortical dissociation.

Correlates of SCR-OR Responding/Nonresponding. While

the clear dichotomy between SCR-OR nonresponders and slow habituators originally reported by Gruzelier and Venables (1972) remains a minority finding, the distinction between patients who fail to respond and those who do respond to at least the initial stimulus presentations does appear useful in identifying meaningful subgroups. More specifically, SCR-OR responding/nonresponding has been found to be significantly correlated with other physiological measures, with attentional and information processing measures, and with behavioral-symptomatic ratings.

Physiologically, SCR-OR responders are consistently observed to have higher tonic sympathetic arousal than SCR-OR nonresponders, each group often differing from normal in opposite directions in tonic arousal. For example, within the electrodermal response system, Gruzelier and Venables (1972) reported that schizophrenic responders exhibited higher SCL and more frequent NS-SCRs than normal controls (the difference reaching statistical significance only in patients hospitalized for less than 5 years), while schizophrenic nonresponders exhibited lower SCL and less frequent NS-SCRs than the normal controls. Rubens and Lapidus (1978) found similar differential deviations from normal in schizophrenic "overresponders" (slow habituators) and "underresponders" (nonresponders and fast habituators). Gruzelier and Venables (1975a) also observed higher systolic blood pressure, finger skin temperature, and heart rate levels in responder schizophrenics than nonresponder schizophrenics.

It is important to emphasize that the patients in these studies were medicated with neuroleptics, especially phenothiazines. While

these medications apparently do not affect the frequency of SCR-ORs to mild stimuli, they do significantly decrease tonic electrodermal arousal measures. Therefore, the abnormalities in tonic arousal are difficult to interpret. Öhman (1981) has suggested that, given the drug effects on tonic electrodermal measures, it is safest to conclude that schizophrenic responders exhibit higher than normal electrodermal arousal levels but that schizophrenic nonresponders do not differ from normal (i.e., the hypoarousal level reported among nonresponders is probably a drug effect). This conservative conclusion is consistent with Gruzelier et al. (1981b), who reported the only study of which we are aware in which unmedicated schizophrenic responders and nonresponders were compared to normal subjects on electrodermal arousal measures. The responders exhibited significantly more NS-SCRs than did the normal controls, whereas the nonresponders did not differ significantly from the normal controls. Thus, evidence of tonic hyperarousal in schizophrenia, as was summarized in table 1, is reliably found only among SCR-OR responder schizophrenics.

There also is evidence that SCR-OR responders and nonresponders differ on attentional and information-processing tasks. For example, these two subgroups have been found to differ on a dichotic-listening and verbal-shadowing task—a test of selective attention. This task involves the presentation of different verbal stimuli to each ear simultaneously, with the subject instructed to repeat aloud (shadow) one set of stimuli and ignore the other distracting stimuli. SCR-OR nonresponder schizophrenic patients have been observed to make more errors, particularly errors of omission, on this task than SCR-OR

responders (Straube 1979). More recent research has failed to replicate this specific effect, but nevertheless did find that nonresponders exhibited a more rapid increase in shadowing errors as the distracting stimuli became more significant (Straube et al. 1983). While the results of these studies are not entirely consistent, they both suggest that the subgroup of nonresponder schizophrenics performs more poorly on a test of selective attention. In a somewhat similar vein, nonresponders have been found to exhibit poorer perceptual resolution than responders as measured by the two-flash threshold (Gruzeliier and Venables 1974, 1975b).

Given these results, one would expect nonresponders to perform poorly on a signal detection vigilance task while responders, especially slow habituators, might perform well because of hypervigilance to environmental stimuli. Patterson and Venables (1980) measured auditory vigilance performance in three subgroups of schizophrenic patients (SCR-OR nonresponders, fast habituators, and slower habituators) and normal controls. The task involved detecting a faint signal (pure tone) embedded within bursts of white noise. As expected, the nonresponders showed lower overall perceptual sensitivity (lower d') than the normal controls. Contrary to expectation, however, the slower habituators also performed more poorly than the normals, while only the fast habituators performed as well as normals. It is possible that the nonresponders and slower habituators performed poorly for different reasons. The poor performance of the nonresponders may reflect an inability to allocate sufficient processing resources to the task, whereas the poor performance of the slower habituators may reflect an

inability to attend selectively to the signal and ignore the white noise. In any event, the relationship between SCR-ORs and information processing in schizophrenia is in need of further investigation and appears to be a particularly promising area for future research.

Lastly, behavioral-symptomatic correlates of SCR-ORs have been reported. Gruzeliier (1976) found that slow habituator schizophrenics selected from admission and rehabilitation wards were rated by the ward nurses as more manic, anxious, assaultive, belligerent, and attention-demanding than the nonresponders. Rubens and Lapidus (1978) reported that SCR-OR slow habituator schizophrenics exhibited less ability to tolerate and cope with stimulation, as measured by the Bellak stimulus barrier rating scale (Bellak, Hurvich, and Gediman 1973), than did the SCR-OR nonresponder schizophrenics.

Straube (1979) also found symptomatic differences between responder and nonresponder subgroups of newly hospitalized acute schizophrenic patients. The two subgroups did not differ significantly in total scores on the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham 1962), but responders were rated higher on "excitement" and on "mannerisms and posturing" while nonresponders were rated higher on "emotional withdrawal," "conceptual disorganization," "motor retardation," "somatic concern," and "depressive mood." Bernstein et al. (1981) found similar relationships among chronic schizophrenics. Responders were rated higher on "excitement," whereas nonresponders were rated higher on "emotional withdrawal" and "conceptual disorganization" and showed a trend toward more "blunted affect." These results are also consistent with an

earlier report by Bernstein (1970). SCR-OR nonresponding to the initial mild innocuous tone occurred in nearly 50 percent of patients who were markedly confused, disorganized, and disoriented whereas SCR-OR nonresponding to the initial tone was rarely seen in "clear" schizophrenics without this symptom picture. As discussed by Venables (1977), however, it is difficult to reconcile these behavioral-symptomatic correlates of the SCR-OR responder/nonresponder distinction with earlier findings that the more withdrawn patients exhibited the highest arousal (Venables and Wing 1962).

It is noteworthy that Bernstein et al. (1981) and Straube (1979) found similar relationships between symptomatic status and electrodermal responding although neither study obtained a bimodal distribution of SCR-ORs. The "responders" in these two studies were often fast habituators, not the slow habituators reported by Gruzeliier and Venables (1972). Thus, behavioral-symptomatic status is related to the responder/nonresponder distinction independent of the extreme bimodal distribution.

Summary and Conclusions. Two different electrodermal anomalies have been observed in symptomatic schizophrenic patients during the presentation of mild innocuous stimuli. First, 40-50 percent of schizophrenic patients fail to give SCR-ORs to innocuous nonsignal environmental stimuli, compared to 5-10 percent of normal subjects. Second, tonic sympathetic hyperarousal (e.g., heightened SCL and NS-SCR) is found among the subgroup of schizophrenic SCR-OR responders, but not among the nonresponders. Thus, the variability in tonic arousal measured (see table

1) may be substantially reduced by identification of SCR-OR responder/nonresponder subgroups.

SCR-OR nonresponders generally tend to be more withdrawn and conceptually disorganized while responders generally tend to be more excited and active. Therefore, the proportion of nonresponders versus responders in any particular study will depend upon the behavioral characteristics of the patients one selects. For example, two recent studies have found a predominance of SCR-OR responder schizophrenics with few if any nonresponders (Frith et al. 1979; Bartfai et al. 1983). Both of these studies selected only patients who exhibited active, florid symptomatology and excluded patients with passive, negative symptoms. Based on the behavioral correlates of SCR-OR responding, these selection criteria may account for the predominance of SCR-OR responders and the atypical low incidence of nonresponders (Bernstein et al. 1982). As in all areas of schizophrenia research, great care must be taken in the selection criteria and studies using different criteria should be compared with considerable caution.

In addition, responders and nonresponders appear to differ in performance on attentional and information-processing tasks, although more research is needed to clarify the nature of these cognitive differences. This line of research takes on particular relevance given that attentional and cognitive dysfunctions are among the most prominent schizophrenic symptoms (Chapman 1966; Freedman and Chapman 1973; McGhie and Chapman 1961). Moreover, there is a recent trend to interpret SCR-ORs as being related to the allocation of processing capacity (Öhman 1979; Dawson et al. 1982). Seen from this

theoretical perspective, slow habituator and possibly other hyperaroused responder schizophrenics allocate processing capacity indiscriminantly, while nonresponder schizophrenics fail to allocate sufficient processing capacity. Thus, one would expect slow habituator and other responder schizophrenics to be hypervigilant and hypersensitive to environmental stimuli, whereas one would expect nonresponder schizophrenics to be hypovigilant and hyposensitive. This description seems to be generally consistent with the behavioral-symptomatic correlates of SCR-OR responding. However, several theoretical issues are raised by this approach, most of which are only beginning to be addressed. For instance, do the responders and nonresponders differ in total available processing capacity, in the decision rules for allocating capacity (Bernstein et al. 1982), or in the usage of "automatic" processing (noncapacity demanding) versus "controlled" processing (capacity demanding) (Öhman 1981)?

Many important questions are raised by the cross-sectional data. Is the responder/nonresponder distinction a truly dichotomous variable or a continuous variable? Can the convergence of different electrodermal measures (e.g., tonic arousal measures in addition to SCR-ORs) and additional response systems (e.g., heart rate and event-related brain potentials) sharpen the subgroup distinctions further? Do SCR-OR responders/nonresponders represent fundamentally different disorders with different etiologies, prognoses, and treatments of choice? Alternatively, do they represent different routes to the same final common pathway, or different stages within the same disorder? Perhaps most important, are the electrodermal anomalies stable, trait-like

vulnerability characteristics or are they temporary, state-like correlates of the current symptomatology?

Questions about trait versus state characteristics simply cannot be answered by cross-sectional studies. The fact that patients are symptomatic (not to mention institutionalized and usually medicated), while controls are not, precludes determination of whether the psychophysiological anomalies are linked to the symptomatic state or are linked to an enduring trait. In an attempt to shed light on the state versus trait issue, we next examine psychophysiological (especially electrodermal) data from individuals who are at high risk for a schizophrenic episode.

Studies of High-Risk Subjects

If certain psychophysiological measures reflect longstanding traits associated with the vulnerability to schizophrenia, then they should be present in individuals who carry the vulnerability but who are not (yet) manifesting schizophrenic psychosis. The study of "high-risk" subjects has generated a great deal of interest during the past 15 years as a means of testing this hypothesis (Garmezzy and Streitman 1974). One approach to high-risk research involves the study of offspring of schizophrenic patients because these subjects are known to be at heightened statistical risk for schizophrenia. Approximately 10-15 percent of the offspring of a schizophrenic parent develop some form of schizophrenia compared to 1 percent or less in the general population (Gottesman and Shields 1972). A second approach to high-risk research involves the study of individuals who exhibit behaviors and personality traits believed to be related to an increased risk for later

schizophrenia (Chapman, Edell, and Chapman 1980). Psychophysiological studies employing each of these two approaches to high-risk research are reviewed below.

Genetically Defined High Risk. The first large-scale, and now classic, psychophysiological study of high-risk subjects was begun in Denmark in 1962 by Mednick and Schulsinger (1968). These investigators selected 207 (high-risk) children of mothers who had a history of severe chronic schizophrenia and 104 control (low-risk) children without known mental illness in the parents or grandparents. The two groups were matched for age (mean = 15.1 years), sex, social class, education, rural versus urban residences, and institutional versus family rearing.

The psychophysiological testing procedures for these adolescents included recording electrodermal and heart rate responses during 8 habituation trials with a mild innocuous tone, 14 partial-reinforcement classical conditioning trials with an "irritating" 96 dB noise as the unconditioned stimulus (UCS), and 9 nonreinforced extinction/generalization test trials. The principal findings were that the high-risk subjects, compared to the low-risk subjects, exhibited larger SCRs with shorter latencies and shorter recovery times (faster recovery rates) to the noxious UCS.² The high-risk subjects

also gave larger SCRs to the habituation and generalization stimuli, although the group differences were not so marked with these variables. Herman (1972, reported by Spohn and Patterson 1979) found that the heart rate levels during the conditioning session also were significantly higher in the high-risk subjects than the low-risk subjects. All in all, the data indicate that the high-risk subjects were autonomically hyperaroused and hyperreactive during the mildly stressful conditioning session.

By 1967, 20 of the high-risk subjects had experienced serious psychiatric problems (not necessarily schizophrenia). The initial 1962 electrodermal data of these 20 "sick" high-risk subjects were compared with those of 20 "well" high-risk subjects, and 20 low-risk subjects, all matched on age, sex, social class, and level of adjustment based on the initial assessment (Mednick and Schulsinger 1968). The sick group gave larger SCRs to the noxious UCS, to the CS presented during conditioning, and to the extinction/generalization stimuli than did either of the other two groups. The sick group also exhibited shorter SCR latencies and recovery times, particularly to the UCS, with fast SCR recovery being the best discriminator. The large SCR amplitudes, short latencies, and short recovery times resemble the pattern of SCRs reported for slow habituator schizophrenics described in the previous section (e.g., Gruzelier and Venables 1972). However, unlike the subgroup of responder schizophrenics who display this pattern of electrodermal

responses during presentation of innocuous nonsignal stimuli, the high-risk subjects who later develop psychiatric problems exhibit this behavior primarily when stressed by the presentation of noxious stimuli.

In 1972, an intensive diagnostic followup of the high-risk sample revealed that 13 subjects had developed clear schizophrenic symptoms and 29 others were borderline schizophrenic (Mednick et al. 1978). Diagnosis was based on the presence of Bleulerian primary and secondary symptoms as indicated by a 3¼-hour clinical interview and case history. An index derived from the 1962 electrodermal measures (specifically, the mathematical product of total SCR frequency and SCR recovery rate) was found to be predictive of future schizophrenia in males, but not females. Moreover, this electrodermal measure in males was closely related to the occurrence and severity of pregnancy and birth complications. Wynne (1978) has thoroughly critiqued these findings and indicated, based on possible sampling and statistical limitations, that they should most appropriately be regarded "as provocative leads rather than decisive conclusions" (p. 203).

In an effort to replicate and extend those "provocative leads," other investigators also have attempted to relate psychophysiological variables, especially electrodermal measures, to a heightened risk for schizophrenia. For example, Prentky, Salzman, and Klein (1981) recorded electrodermal responses from 7-year-old boys ($n = 11$) and 10-year-old boys ($n = 13$) of parents with a *DSM-III* (American Psychiatric Association 1980) diagnosis of schizophrenia or schizoaffective disorder. Control groups consisted of age-matched children of parents with a nonpsychotic disorder. The test procedures

² The Mednick and Schulsinger study recorded and analyzed skin resistance responses rather than skin conductance responses. (Skin conductance is the reciprocal of skin resistance.) However, for the sake of internal consistency, the results are summarized here in terms of conductance. A similar practice was followed for other studies which measured skin resistance rather than skin conductance. Also, the term SCR is used here instead of SCR-OR because the eliciting

stimulus was deliberately loud and mildly aversive. It is generally agreed that the latter type of stimuli do not elicit orienting responses, but rather defensive responses or startle responses (e.g., Graham 1979).

involved a modified version of those employed by Mednick and Schulsinger, including 20 habituation trials with a mild tone, 20 partial-reinforcement classical conditioning trials with a loud noise (95 dB) UCS, and 10 extinction/generalization trials. During the habituation phase, no group differences were found in SCL, NS-SCRs, SCR-OR amplitude, or the number of trials-to-habituation. On the reinforced classical conditioning trials, the offspring of schizophrenics tended to exhibit larger SCRs to the loud noise UCS than did the control groups, although this difference was statistically significant only on the first block of trials. On the nonreinforced classical conditioning trials and on the extinction/generalization trials, the schizophrenics' offspring produced larger conditioned SCRs at the time the UCS was due in the 10-year-old sample and showed a similar trend that was not statistically significant in the 7-year-old sample. No group differences were found in the recovery times of the SCRs elicited by the UCS, and latency data were not reported. These results fail to replicate many of Mednick and Schulsinger's (1968) specific findings. However, the differences that were observed (larger SCRs to the first block of the UCSs and better SCR classical conditioning) were suggestive of electrodermal hyperresponsiveness, particularly to the mildly aversive UCS, which is conceptually consistent with the data of Mednick and Schulsinger.

It should be noted that the Mednick and Schulsinger (1968) and the Prentky, Salzman, and Klein (1981) studies are not able to demonstrate conclusively a genetic influence on electrodermal hyperresponsiveness or the vulnerability to schizophrenia. The effects of early childhood environmental factors as well as

complications during pregnancy and birth are confounded with possible genetic influences in these studies. In an effort to isolate the genetic influences, Van Dyke, Rosenthal, and Rasmussen (1974) measured electrodermal responses from adoptees whose biological parents were process schizophrenics ($n = 47$) or whose biological parents had no history of psychotic illness ($n = 45$). The mean adoption age was 11.8 months for both groups. Most (83 percent) of the biological parents with a history of schizophrenia were not treated for a psychiatric disorder before the birth of the subject; hence, the prenatal and perinatal environments were presumably not influenced by serious psychopathology or psychotropic medication. Quite unlike the studies reviewed above, subjects studied by Van Dyke, Rosenthal, and Rasmussen were well into the age period of risk for schizophrenia at the time of the psychophysiological test (mean age = 33 years). Most of the subjects were functioning well at the time of the testing, although 23 percent of the index cases and 4 percent of the control cases evidenced some serious schizophrenia-related symptoms.

Van Dyke, Rosenthal, and Rasmussen (1974) used the same laboratory and similar testing procedures as did Mednick and Schulsinger (1968). They found that the two adoptive groups did not differ in SCL or NS-SCRs, nor did the groups differ in SCR latencies or recovery times to the loud noise UCS. However, the adopted-away offspring of schizophrenics did respond more frequently to the UCS than did the adopted-away offspring of normals. Moreover, the offspring of schizophrenics exhibited significantly larger SCRs to innocuous tones during habituation and marginally larger SCRs to the CSs

during conditioning. Hence, while again many of the specific differences reported by Mednick and Schulsinger were not replicated, the results were suggestive of electrodermal hyperresponsiveness and slow habituation among the biological offspring of schizophrenic patients. In this case, the electrodermal anomalies in the offspring of schizophrenics cannot be attributed to a childhood rearing environment containing a schizophrenic parent.

Janes, Hesselbrock, and Stern (1978) recorded electrodermal responses from children with a schizophrenic parent during 10 habituation trials (cool air), 20 classical conditioning trials (cool air paired with warm air), and 5 extinction trials (cool air alone). These investigators found no differences in electrodermal activity between the children with a schizophrenic parent and comparison groups of children. However, as the authors point out, other studies (Mednick and Schulsinger 1968; Prentky, Salzman, and Klein 1981; Van Dyke, Rosenthal, and Rasmussen 1974) found the most consistent group differences in responsiveness to a mildly aversive UCS, while the stimuli employed by Janes, Hesselbrock, and Stern were not particularly aversive or autonomically activating.

Erlenmeyer-Kimling and her colleagues (in press) measured SCRs to stimuli similar to those employed by Mednick and Schulsinger in a group of children from intact families with one or two parents having a history of schizophrenia. This research group failed to replicate the findings of Mednick and Schulsinger (1968), and in some cases found differences that were in the opposite direction (e.g., SCR latencies to the loud noise were longer, rather than shorter, among children of schizophrenics). As part of the same longi-

tudinal study of high-risk children, Friedman, Vaughan, and Erlenmeyer-Kimling (1982) reported that high-risk children exhibited smaller P300 event-related potentials to target tones than did matched normal control children. The finding of reduced P300 amplitude, as was indicated earlier, is consistent with findings obtained with adult symptomatic schizophrenic patients. Moreover, if one assumes that the P300 in this paradigm is an index of orienting, or allocation of processing capacity to task-significant stimuli, this is the first study to find hyporesponsiveness of these functions in genetically defined high-risk children.

Several methodological differences among the various high-risk studies might account for the variability in results. Age of the subjects at the time of initial testing, severity and chronicity of the illness in the parents, diagnostic criteria for schizophrenia, and intactness of the families are variables that differ among the studies and would likely influence the results. Mednick (1978), for example, has argued that the difference in electrodermal results between the Mednick and Schulsinger and the Erlenmeyer-Kimling et al. studies can be accounted for by restriction of the latter sample to intact families (and presumably less severely ill parents). Another important consideration in interpreting the high-risk data is that only a relatively small subgroup of offspring of one schizophrenic parent (10–15 percent) is expected to develop schizophrenic disorder. A high degree of genetic vulnerability is not expected in all, or even most, children with one schizophrenic parent (Hanson, Gottesman, and Meehl 1977). Therefore, comparison of group means is a weak method of detecting vulnerability indicators or

antecedents of schizophrenic disorder in a group of high-risk subjects (Nuechterlein 1982). A more appropriate strategy may be to test for the existence of a disproportionately large extreme-scoring subset of high-risk subjects on the measure of interest, as has been done with some measures of attentional performance (Erlenmeyer-Kimling and Cornblatt 1978; Nuechterlein 1983) and event-related potentials (Friedman, Frosch, and Erlenmeyer-Kimling 1979). Longitudinal followup of the high-risk sample to determine which subgroup eventually exhibits psychotic behavior is also very useful, because it helps to identify indicators that may contribute to breakdown. The followup data provided by Mednick, Schulsinger and their colleagues are interesting in this regard, because they indicate that high-risk subjects who eventually developed schizophrenia and other serious psychiatric disorders displayed more extreme electrodermal abnormalities than did high-risk subjects who did not develop these problems.

Questionnaire-Defined High Risk. A quite different approach to the identification of high-risk individuals involves the use of questionnaire measures of personality traits hypothesized to characterize persons who are at elevated risk for psychosis in general and schizophrenia in particular. This is the approach employed by Loren and Jean Chapman and their collaborators at the University of Wisconsin. Two of the traits for which they have developed questionnaire measures are physical anhedonia and perceptual aberration. Chapman, Chapman, and Raulin (1976) and Chapman and Chapman (1978) have developed a true/false questionnaire measure of physical

anhedonia, a deficiency in the ability to experience physical pleasures. Illustrative items include, "Sex is okay, but not as much fun as most people claim it is" (keyed true) and "When I have seen a statue, I have had the urge to feel it" (keyed false). Chapman, Chapman, and Raulin (1978) also developed a true/false questionnaire measure of perceptual aberration, involving primarily experiences of derealization and distortions in the perception of one's own body. Illustrative items include "Sometimes people whom I know will begin to look like strangers" (keyed true) and "I have never felt that my arms and legs have momentarily grown in size" (keyed false). Evidence from interview and Rorschach data supports the concurrent validity of these scales (Chapman, Edell, and Chapman 1980; Edell and Chapman 1979), indicating that individuals with high scores exhibit cognitive and perceptual characteristics believed to be associated with psychosis-proneness.

Simons (1981) measured SCR and heart rate orienting responses to a series of innocuous tones in three groups of college students: 18 subjects reporting high physical anhedonia, 22 subjects reporting frequent perceptual aberrations, and 22 subjects with scores near the mean of each of the two scales. He hypothesized that anhedonic subjects would exhibit hyporesponsivity while perceptual aberration subjects would exhibit hyperresponsivity. Consistent with the first hypothesis, 67 percent of the anhedonic subjects were SCR-OR nonresponders or fast habituators compared to 14 percent of the controls. Perceptual aberration subjects, on the other hand, did not differ from the controls in SCR-ORs. Similar effects were observed with the heart rate data; anhedonic

subjects were deficient in orienting whereas perceptual aberration subjects did not differ from control normals. Tonic arousal measures did not significantly distinguish the questionnaire-defined high-risk groups from the normal controls, although mean differences were in the predicted direction.

As Simons (1981) pointed out, the lack of SCR-OR effects with the perceptual aberration subjects may have been due to the use of innocuous stimuli. Recall that SCR hyperresponsivity was found in genetic high-risk samples primarily with strong, aversive noises (Mednick and Schulsinger 1968; Van Dyke, Rosenthal, and Rasmussen 1974; Prentky, Salzman, and Klein 1981). It will be important for future researchers to present stronger stimuli to determine whether autonomic hyperresponsivity to stressful stimuli characterizes perceptual aberration subjects.

Other psychophysiological abnormalities also have been found in anhedonic subjects. For example, anhedonic college students exhibit a smaller P300 component of the event-related brain potential (Simons 1982), particularly to stimuli which signal the presentation of hedonically related stimuli (pictures of nudes). Thus, groups of anhedonic subjects exhibit SCR-OR hyporesponsiveness, deficient heart rate orienting responses, and small P300s. Each of these dysfunctions has been reported to characterize a substantial proportion of schizophrenic patients, thereby adding to the construct validity of the physical anhedonia scale of psychosis-proneness.

Electrodermal hyperresponsivity, rather than hyporesponsivity, has been related to another questionnaire measure of schizophrenia-like behaviors and experiences in college students. Nielsen and Petersen (1976)

developed a 14-item true/false Schizophrenism Scale which emphasizes social withdrawal and attentional dysfunctions. All of the items are keyed "true" for schizophrenia and illustrative items include "I do not like to mix with many people" and "I am easily distracted when I read or talk to someone." The psychophysiological test session included 16 habituation trials, 8 classical conditioning trials (including four 105-dB white noise UCS presentations), and 8 nonreinforced extinction trials. Scores on the Schizophrenism Scale were positively correlated with frequency of NS-SCRs, amplitude and recovery rate of SCR-ORs to the innocuous habituation stimuli, and rate of habituation to the noxious UCS. Thus, high schizophrenia scores were associated with high electrodermal tonic arousal, high SCR-OR responsivity, fast SCR-OR recovery, and fast SCR habituation to the UCS. Nielsen and Petersen concluded that these results are similar to those obtained by Mednick and Schulsinger (1968) for offspring of schizophrenic mothers. At first glance, fast habituation appears contrary to Mednick and Schulsinger's findings. However, Nielsen and Petersen presented only four UCSs; thus, the results are not contradictory. Finally, it should be pointed out that scores on the Schizophrenism Scale were highly correlated with scores on Trait Anxiety, Fearfulness, and Neuroticism. Therefore, the electrodermal effects may not be attributable to schizophrenia alone.

Summary and Conclusions. Three of four relevant studies found electrodermal hyperresponsivity and/or slow habituation to mildly aversive loud noises in the offspring of schizophrenic parents (Mednick and Schulsinger 1968; Van Dyke, Rosenthal,

and Rasmussen 1974; Prentky, Salzman, and Klein 1981). The electrodermal hyperresponsivity was found even among children reared by nonschizophrenic foster parents, thus eliminating possible effects of childhood environments on the results (Van Dyke, Rosenthal, and Rasmussen 1974). Moreover, subjects who later exhibited serious psychiatric disorders showed the most extreme electrodermal hyperresponsivity (Mednick and Schulsinger 1968). These results suggest that sympathetic hyperresponsivity to aversive stimulation is associated with a genetic vulnerability to schizophrenia and with the later occurrence of psychiatric breakdown.

To an extent, the electrodermal hyperresponsivity found among genetically defined high-risk subjects resembles the pattern of responding observed in the subgroup of responder symptomatic schizophrenics. Gruzelier et al. (1981*b*) found more frequent than normal SCRs, with slower habituation, to a "conspicuous" 90-dB tone among unmedicated, recently hospitalized schizophrenics, especially among patients who were responders to previously presented innocuous tones. Horvath and Meares (1979) also reported slower than normal SCR habituation to a series of 100-dB tones in unmedicated nonparanoid schizophrenics, whereas paranoid schizophrenics did not differ from normal. Exceptions to these results are Bernstein's findings (1970; Bernstein et al. 1981) of faster than normal habituation to 90-dB tones in chronic schizophrenic patients. Granting that at least a subgroup of unmedicated symptomatic schizophrenic patients are hyperresponsive to aversive loud noises, important differences are nevertheless present between the results for these patients and those for the high-risk subjects.

Unlike the high-risk subjects, responder schizophrenics exhibit tonic sympathetic hyperarousal (e.g., heightened SCL and frequent NS-SCRs) even when exposed to mild innocuous stimuli. This suggests that hyperresponsivity to aversive stimulation may be a longstanding trait associated with the vulnerability to schizophrenia, whereas the tonic hyperarousal state develops later, perhaps when life events become too stressful and psychotic symptoms begin to emerge.

One of the most common electrodermal anomalies in symptomatic schizophrenic patients, SCR-OR nonresponsiveness to mild innocuous stimuli, has not been observed among genetically defined high-risk samples. Simons (1981) found that anhedonic college students who are hypothesized to be at elevated risk for later schizophrenia did exhibit excessive SCR-OR nonresponsiveness. Furthermore, both anhedonic college students (Simons 1982) and the genetically defined high-risk sample of Friedman, Vaughan, and Erlenmeyer-Kimling (1982) exhibited small P300 components of the event-related brain potential to task-significant stimuli. These results constitute evidence of hyporesponsivity in at least a proportion of high-risk subjects that may be related to the SCR-OR nonresponsiveness of many symptomatic schizophrenic patients.

These results are open to different interpretations. One hypothesis is that there are different specific vulnerabilities to different types of schizophrenic disorders. A genetic predisposition coupled with behavioral, emotional, and autonomic lability may represent one type of vulnerability to one form of schizophrenic disorder. Anhedonia, accompanied by behavioral, emotional, and autonomic

withdrawal, may represent another type of vulnerability to a different form of schizophrenia. Another plausible interpretation is that autonomic hyperresponsivity represents the primary vulnerability, while anhedonia and autonomic hyporesponsivity represent a secondary coping strategy (Straube 1980; Ohman 1981; Dawson, Nuechterlein, and Liberman 1983). Finally, another possible hypothesis is that deviant autonomic responsivity in either direction potentiates the specific vulnerability to schizophrenic disorder which is caused by a separate factor. Prospective, longitudinal, follow-through studies of high-risk subjects may help to determine which, if any, of these hypotheses is correct. In addition to correlational studies to establish further the predictive value of these variables for later breakdown and to track changes in these variables over time, preventive intervention attempts may serve as experimental manipulations to help determine the causal role of such vulnerability factors.

Studies of Remitted Schizophrenic Patients

If certain psychophysiological abnormalities reflect enduring traits associated with the vulnerability to schizophrenia, then these abnormalities should remain present during clinical remission. To test this hypothesis, psychophysiological recordings should be obtained from patients in a documented symptomatic state and a documented state of remission, without medication in either state, and with commensurate recordings obtained from appropriately matched normal controls. In addition, the tests in the different states should be conducted in a mixed order for both the patients and

controls to avoid confounding order effects with state effects. One could then determine whether the psychophysiological measures are stably abnormal across states (hence, suggestive of a vulnerability indicator) or are abnormal only during the symptomatic state (hence, suggestive of a symptom indicator). To our knowledge, no psychophysiological study meeting all of these criteria has been published. However, two recent studies contain at least some primary elements of the ideal experimental design and therefore may shed some light on the stability of psychophysiological abnormalities across different states (Zahn, Carpenter, and McGlashan 1981*b*; Iacono 1982).

Zahn, Carpenter, and McGlashan (1981*b*) studied unmedicated, good premorbid, schizophrenic patients at two times. The first session was approximately 3 to 4 weeks after hospitalization, when all the patients were symptomatic. The second session was 3 to 4 weeks before hospital discharge, when some of the patients were in a remitted state ("improvers") and some were in a relatively unremitted state ("nonimprovers"). Patients were divided into "improvers" and "nonimprovers" based on changes in ratings of psychopathology made by the psychiatric and nursing staff between admission and discharge. Improvers were characterized by relatively brisk and complete remission while nonimprovers showed a sluggish and incomplete recovery. The normal controls, who were tested only once, consisted of 118 twins matched to the patients for age, social class, and education. This control group was selected from a somewhat larger number of twins recruited from the community for a study of the genetic determiners of psychophysiological measures.

Difference scores (admission data minus discharge data) were computed on a variety of electrodermal, heart rate, and skin temperature measures. Analyses of these scores revealed very few significant changes despite the marked symptomatic change among the improvers. Thus, the results suggest that the psychophysiological measures are relatively stable and are not symptom-linked. These results are basically consistent with findings reported by Frith et al. (1979). However, the patients studied by Frith et al. were unmedicated while symptomatic but medicated while relatively remitted, and normal controls were not studied. Thus, the Zahn, Carpenter, and McGlashan results allow clearer interpretation.

While the Zahn, Carpenter, and McGlashan (1981*b*) data are consistent with a trait interpretation of schizophrenic psychophysiological measures, this conclusion must be considered tentative for several reasons. First, the normal controls were not retested. Therefore, one cannot directly assess the presence or degree of psychophysiological abnormalities during the second schizophrenic patient test. All that one can infer is that the mean value of the autonomic measures of the patients did not change significantly between the two tests, despite symptomatic changes. Acceptance of the null hypothesis is a weak basis from which to infer stability of measures. It is possible for the autonomic measures to show no mean changes, yet be highly unstable for individuals (e.g., random numbers would have these properties). Second, many of the autonomic measures obtained from the subgroup of improvers did not differ significantly from normal even when patients were symptomatic. Thus, one cannot infer stability of psychophysiological abnormalities in these patients

because the measures were generally not abnormal even during the symptomatic period. The autonomic measures of the nonimprovers, on the other hand, differed rather consistently and markedly from those of both normals and improvers, which indicates that the autonomic measures may have important and useful prognostic implications (see **Prognosis** section to follow). As evidence of trait-like stability of autonomic abnormalities, however, the Zahn, Carpenter, and McGlashan data should be considered only suggestive.

The second study involved cross-sectional comparisons of medicated remitted outpatient schizophrenics and normal subjects. Iacono (1982) measured SCR-ORs to a series of mild innocuous tones in a group of 24 remitted schizophrenic outpatients and 22 medical outpatient controls. The schizophrenic outpatients were interviewed with the lifetime version of the Schedule for Affective Disorders and Schizophrenia (SADS-L) (Spitzer and Endicott 1978). The guideline for inclusion was that a past episode met the Research Diagnostic Criteria (RDC) (Spitzer, Endicott, and Robins 1978) for probable schizophrenia. No patient met RDC criteria for current probable or definite schizophrenia at the time of the interview: The Global Assessment Scale (GAS, mean = 69.3) (Endicott et al. 1976) and the BPRS (with no psychotic symptoms rated more than "mildly present") were used to document remission status.

Before beginning the test session, all subjects were instructed to ignore the tones and concentrate on relaxing (Iacono and Lykken 1979). Iacono (1982) found a significantly higher proportion of SCR-OR nonresponders among remitted schizophrenics than among controls (46

percent versus 18 percent). The responder schizophrenics, relative to responder controls, exhibited significantly more frequent NS-SCRs and elevated SCL (the latter reached significance only during respiratory exercises and rest). The finding that nearly half of the relatively remitted schizophrenics were SCR-OR nonresponders, coupled with the fact that the responder schizophrenics exhibited higher than normal tonic electrodermal arousal, is strikingly similar to findings obtained with hospitalized symptomatic schizophrenics and suggests that these electrodermal anomalies are not simply correlates of symptomatic states but rather may be relatively stable traits. The limitations of this interesting study are: (a) the patients were not tested when symptomatic (hence, within-subject stability over time cannot be assessed), (b) all of the schizophrenic patients, but none of the control patients, were taking antipsychotic medication, and (c) while the patients were clearly not psychotic or severely ill at the time of testing, neither were they in a state of complete remission; BPRS and GAS ratings suggest the presence of some persisting mild symptoms and a low level of social functioning.

Iacono (1982) also found that the EEG spectra contained a greater proportion of delta (.1–2.9 Hz) and a lower proportion of alpha (8.0–12.9 Hz) in the remitted schizophrenic outpatients (both SCR-OR responders and nonresponders) than in the normal controls. Iacono points out that these EEG findings are in agreement with results obtained with adult schizophrenics and with children born to schizophrenic mothers (Itil 1977). Iacono, Tuason, and Johnson (1981) also found more smooth-pursuit eye tracking errors in this same sample of postpsychotic schizophrenic patients than in the

normal control subjects. These results are consistent with evidence that symptomatic schizophrenics and their first-degree relatives display deviant smooth-pursuit eye movements (Holzman et al. 1974; Holzman and Levy 1977). Thus, increased EEG delta, decreased EEG alpha, deviant smooth-pursuit eye movements, and electrodermal anomalies appear to be psychophysiological characteristics of schizophrenic patients in remission as well as during psychotic periods. It is of interest that the EEG (Iacono 1982) and smooth-pursuit eye movement abnormalities (Iacono, personal communication, November 1981) were not correlated with the responder/nonresponder electrodermal individual difference.

While the data of Iacono clearly support the continuing presence of schizophrenic psychophysiological anomalies beyond psychotic periods, a somewhat similar study by Tarrrier, Cooke, and Lader (1978) obtained negative electrodermal results. These investigators measured electrodermal responses from 18 partially remitted schizophrenics (nearly three quarters of whom were receiving neuroleptic medications), 18 matched normal controls, and 10 chronic schizophrenic inpatients. The criteria for "partial remission" were not specified, except to state that the patients were living in the community. The laboratory test consisted of three phases: rest, presentation of 15 innocuous nonsignal tones, and presentation of the same tones when made task-significant. The results are notable for the lack of effects: no differences were obtained between the partially remitted schizophrenics and the normal controls in SCL, NS-SCRs, SCR-OR frequency, or SCR-OR amplitude to the innocuous tones. Closer inspection of the data reveals an unusual finding among the

normal controls; between 40 and 60 percent of the controls were SCR-OR nonresponders even when the tone had task-significance. All subjects had been tested previously in their homes, but this seems unlikely to account for the highly unusual results among the control subjects. Whatever the reason, the aberrant SCR-OR data among the controls render interpretation of the data difficult.

The partially remitted schizophrenics studied in the laboratory by Tarrrier, Cooke, and Lader (1978) also had been studied in their homes by Tarrrier et al. (1979). As described above, the laboratory test included electrodermal measures obtained during rest and presentation of tones. The home test included electrodermal recordings for 20 minutes with only the experimenter present and then for 20 minutes while the patients discussed their illness with their relative. For purposes of data analysis, the patients were divided into those whose relatives were rated high on "expressed emotion" (EE) ($n = 11$) and those whose relatives were rated low on EE ($n = 10$). Both the high EE and low EE groups exhibited higher than normal rates of NS-SCRs when tested with only the experimenter present. To the degree that the patients were in remitted states, these results demonstrate heightened electrodermal arousal in the postpsychotic state. More important, the patients with high EE relatives continued to exhibit heightened electrodermal arousal in the presence of their relatives, whereas the patients with low EE relatives showed a gradual decline in arousal when in the presence of their relatives.

These interesting results indicate that social interaction with high EE relatives is sympathetically arousing to partially remitted schizophrenic

patients, compared to social interaction with low EE relatives, and this fact may be related to the higher rates of relapse observed among patients with high EE relatives (Brown, Birley, and Wing 1972; Vaughn and Leff 1976; Vaughn et al. 1982). Moreover, social interaction with relatives is more sympathetically arousing when the patient has recently experienced a life event (Tarrrier et al. 1979). However, we disagree with one of the conclusions reached by Tarrrier et al. (1979). Based on the significant effects obtained during the home test in contrast to the negative effects in the laboratory test, it was concluded that "the laboratory is an inappropriate setting for measures of schizophrenic patients' reactivity to their social environment" (Tarrrier et al. 1979, p. 315). This conclusion is not justified because the laboratory test did not involve manipulations of the subject's social environment. In fact, more recent research has demonstrated similar electrodermal effects of interactions with high EE and low EE relatives when tested in the laboratory (Sturgeon et al. 1981).

Summary and Conclusions. Two recent studies have obtained results which suggest that certain psychophysiological anomalies associated with schizophrenia may be relatively stable trait-like characteristics of the individual. Zahn, Carpenter, and McGlashan (1981b) observed that a variety of electrodermal, heart rate, and skin temperature measures did not change significantly when patients switched from a symptomatic state to a remitted state. Iacono and his co-workers (Iacono, Tuason, and Johnson 1981; Iacono 1982) found that remitted schizophrenic outpatients, compared to normal controls, exhibited a higher incidence of SCR-OR nonre-

sponsiveness, higher electrodermal tonic arousal among those who gave SCR-ORs, increased EEG delta activity, decreased EEG alpha activity, and more smooth-pursuit eye movement errors. These psychophysiological anomalies closely parallel those found in hospitalized symptomatic schizophrenic patients. Hence, the results suggest the continued presence of psychophysiological anomalies after the psychotic episode has subsided. Other research suggests that the electrodermal hyperarousal in remitted schizophrenics is displayed primarily under certain, stressful environmental conditions (TARRIER et al. 1979; STURGEON et al. 1981).

All in all, the results are consistent with the view that schizophrenic psychophysiological anomalies may reflect enduring traits rather than temporary states. More research is clearly needed, particularly prospective, longitudinal, repeated comparisons of normal controls with patients while floridly symptomatic and while in remission. Only in this way can the abnormalities be examined directly as a function of symptomatic status.

Whether the psychophysiological anomalies observed in remitted schizophrenics reflect the vulnerability to the initial onset of schizophrenic disorders is an unsettled issue. These anomalies might reflect the long-term aftereffects of the earlier psychotic episodes and/or their treatment. Research with remitted schizophrenic patients provides useful, but fallible, evidence regarding the existence of trait-like indicators of the initial vulnerability to schizophrenic disorders. Also, whether these anomalies reflect the vulnerability to future episodes is not determined at present. But certainly, if the study of prepsychotic (high-risk subjects), actively psychotic (sympto-

matic patients), and postpsychotic (remitted patients) individuals identifies the same anomaly, then one can have reasonable confidence that the anomaly is an indicator of vulnerability to psychosis. However, findings from each of these three populations considered individually provide only partial evidence regarding the status of such variables. Furthermore, parallel studies of the same variables in other psychiatric disorders will be necessary to determine whether such indicators reflect specific vulnerability factors for schizophrenic disorders or more generalized moderating or potentiating factors for several forms of psychopathology.

Prognostic Studies

If certain psychophysiological variables reflect an enduring vulnerability to schizophrenic episodes, then some of these measures might also be useful in the prediction of both short- and long-term outcome. That is, other factors being equal, subjects with higher vulnerabilities should have poorer prognoses in the sense that they will recover from the current episode more slowly and less fully and will have a greater chance of subsequent relapse. There is a paucity of research on this important issue. In fact, to our knowledge, only four electrodermal studies have addressed the question.

In the first of these studies, Stern, Surphlis, and Koff (1965) measured SCR-ORs to a series of tones and words from 63 acute schizophrenic patients. The patients were initially tested 1 to 3 days after hospitalization, before they began drug treatment. Of the 63 patients, 44 were retested after 5 weeks of hospitalization and treatment. The median number of weeks of hospitalization

before discharge for these 44 patients was 7 weeks. Therefore, the 23 patients who were hospitalized less than 7 weeks were classified as "good prognosis" while the 21 patients who were hospitalized for more than 7 weeks were classified as "poor prognosis."

The two prognostic groups were indistinguishable from each other during the first hospital admission test in the frequency of NS-SCRs and frequency of SCR-ORs. At the 5-week retest, the good prognosis group became significantly less responsive, both in comparison to their first test and in comparison to the second test of the poor prognosis group. However, these results are extremely difficult to interpret for a variety of reasons. First, length of hospitalization is a poor index of outcome since it can be influenced by many variables other than symptomatic change. Also, as Zahn, Carpenter, and McGlashan (1981*b*) have pointed out, testing 1-3 days after hospital admission may obscure real psychophysiological group differences because prehospitalization medication is not controlled and because subjects are adjusting to a new and stressful environment.

In the second study, Frith et al. (1979) measured SCR-ORs to a series of tones in 41 unmedicated, recently hospitalized, acute schizophrenics. Patients were then treated with α -flupenthixol (an active antipsychotic which blocks dopamine receptors), β -flupenthixol (neither an active antipsychotic nor a dopamine receptor blocker), or placebo. Since the electrodermal prognostic results did not interact with the type of drug treatment, this variable will not be mentioned further. Patients were assessed weekly for changes in positive symptoms (hallucinations, delusions, thought disorder, and incongruity of affect). Amount of

clinical change was calculated by subtracting the rating scores after 4 weeks of treatment from the pretreatment scores.

Patients were divided into two groups based on their initial pretreatment SCR-ORs: nonhabitulators ($n = 22$) and habitulators and nonresponders ($n = 19$). The two SCR-OR groups did not differ in severity of initial symptomatology. However, the two groups did differ in clinical change scores. Nonhabitulators exhibited significantly less symptomatic improvement than did the habitulators and nonresponders. The nonhabitulators also exhibited significantly higher SCL, more frequent NS-SCRs, and faster SCR recovery times. Thus, the Frith et al. findings indicated that slow SCR-OR habituation and high tonic electrodermal arousal are associated with, and predictive of, poor short-term outcome.

In the third study, Zahn, Carpenter, and McGlashan (1981b) measured a variety of autonomic responses in four different situations (rest, presentation of innocuous tones, a forewarned reaction time (RT) task, and a mental arithmetic task) from 46 unmedicated acute schizophrenics. All patients, who were selected on the basis of good premorbid adjustment, were then provided clinical care on a research ward at the National Institute of Mental Health (average stay = 3.5 to 4 months). Psychosocial treatment was emphasized, but about half the patients also received antipsychotic medication. As was indicated earlier, patients were divided into "improvers" and "nonimprovers" based on changes in ratings of psychopathology between admission and discharge. Of the 46 patients tested at admission, 35 could be reliably classified as either an improver ($n = 18$) or a nonimprover

($n = 17$).

The improver and nonimprover groups did not differ in premorbid status or psychopathology ratings made at admission. However, the groups differed significantly on a number of autonomic tonic arousal measures and phasic responsivity measures recorded during the first test (3-4 weeks following admission). The nonimprovers showed higher tonic sympathetic arousal than the improver group as indicated by significantly higher heart rate, higher skin temperature, and a tendency toward more frequent NS-SCRs ($p < .06$). SCL declined less during rest in the nonimprovers than the improvers which, as indicated previously, is often associated with high sympathetic arousal.

The SCR-OR responder/nonresponder distinction was unrelated to prognosis; the improver and nonimprover subgroups exhibited approximately the same proportion of nonresponders. However, the SCR-OR responders in the nonimprover group exhibited a slower rate of relative habituation (i.e., when each trial block of SCR-ORs is expressed as a percentage of the largest trial block of SCR-ORs). Slower relative habituation in the nonimprover group indicates that these poor prognosis patients had an irregular "stop and go" pattern of orienting, with relatively large SCR-ORs sometimes occurring late during the habituation session. During the RT task, the nonimprovers exhibited smaller heart rate deceleration during the RT foreperiod (an index of sustained goal-directed attention). During the mental arithmetic task, the nonimprovers also exhibited a smaller increase in NS-SCRs. A discriminant analysis including these three variables (rate of relative SCR-OR habituation, heart rate deceleration

during the RT foreperiod, and the increment in NS-SCRs during the mental arithmetic task) correctly classified 84.4 percent of the schizophrenic patients as either improvers or nonimprovers.

In summary, Zahn, Carpenter, and McGlashan (1981b) found that the poor short-term prognosis patients were characterized by high tonic arousal, slow relative habituation to innocuous stimuli, and less autonomic reactivity in task-demanding situations. The finding that high tonic arousal and slow relative habituation is associated with poor short-term prognosis is conceptually consistent with the results reported by Frith et al. (1979). Moreover, Zahn, Carpenter, and McGlashan (1981b) found that the nonimprovers were quite deviant from normal levels in virtually all of the measures, while the improvers differed only slightly from normal control levels.

Unfortunately, the generality of the Zahn, Carpenter, and McGlashan (1981b) findings is tempered by sex differences. Many of the autonomic differences between improvers and nonimprovers, particularly those involving tonic arousal during rest, were found with only male schizophrenic patients. The authors concluded:

Despite these puzzling sex differences, it is clear that the [improver] patients were generally less deviant in ANS [autonomic nervous system] functioning than the [nonimprover] patients. Since the difference is independent of clinical state at the time of testing, it is consistent with the hypothesis that deviant ANS functioning may represent a stable characteristic of a prognostically relevant subgroup of schizophrenics. [Zahn, Carpenter, and McGlashan 1981b, p. 265]

The fourth study examining the

prognostic value of electrodermal variables was reported recently by Schneider (1982). Unlike the previous studies reviewed in this section, the patients were elderly (age range 55–67) and had a history of chronic schizophrenia (hospitalized ≥ 20 years). Each patient first underwent a drug “washout” period ranging from 4 days to 4 weeks. At the end of this period, skin conductance was recorded bilaterally to a series of mild innocuous tones. Each subject was then administered neuroleptic therapy (either thiothixene or thioridazine) for a period of time ranging from 2 to 6 months. The patients were then classified as “neuroleptic responders” ($n = 18$) or “neuroleptic nonresponders” ($n = 8$) depending on whether there was symptomatic improvement or deterioration on the pretreatment-to-posttreatment changes on BPRS scores, Clinical Global Impressions ratings, and subtest scores of the Wechsler Adult Intelligence Scale.

On the pretreatment test, the neuroleptic nonresponders displayed lower SCL, fewer NS-SCRs (right hand only), and faster SCR-OR habituation (right hand only) than did the neuroleptic responders. Thus, poor therapeutic response to neuroleptics in chronic schizophrenic patients was associated with low electrodermal arousal levels and low electrodermal responsivity (fast habituation). These electrodermal-prognosis relationships are opposite in direction to those reported by Zahn, Carpenter, and McGlashan (1981*b*) and Frith et al. (1979). Schneider (1982) suggests that these discrepancies might be due, at least in part, to the extreme differences between the studies in the ages, prognoses, and symptom characteristics of the patients under study. Patients studied by Schneider were much older, much more chronic, and

exhibited more negative symptoms (e.g., emotional withdrawal) than did patients in the earlier studies. Given that electrodermal nonresponsivity tends to be associated with the presence of negative symptoms, one suspects that Schneider’s patients represent primarily the low-aroused, low responsive subgroups of schizophrenic patients. Schneider’s results suggest that the most abnormally low-aroused and low-responsive patients within this subgroup are neuroleptic nonresponders. Seen from this perspective, the patients with the more normal electrodermal data showed the better therapeutic response to neuroleptics which, in fact, is consistent with the results of Zahn, Carpenter, and McGlashan (1981*b*). Recall that Zahn, Carpenter, and McGlashan’s improvers were most normal electrodermally, while the nonimprovers were most abnormal (in Zahn, Carpenter, and McGlashan’s acute patients, the abnormality was one of hyperarousal and slow habituation). Thus, our interpretation is that the Frith et al. (1979), Zahn, Carpenter, and McGlashan (1981*b*), and Schneider (1982) studies all indicate that more extreme electrodermal abnormalities are associated with poorer short-term prognosis.

Summary and Conclusions. Three of four studies of the prognostic value of electrodermal studies have reported significant relationships between pretreatment electrodermal measures and short-term prognosis (Frith et al. 1979; Zahn, Carpenter, and McGlashan 1981*b*; Schneider 1982). In recently hospitalized, unmedicated, acute schizophrenic patients, both Frith et al. and Zahn, Carpenter, and McGlashan observed that poor short-term prognosis was generally associated with heightened electrodermal arousal and slow

SCR-OR habituation. Only Zahn, Carpenter, and McGlashan studied normal controls, and they found that good short-term prognosis patients were most like the normal subjects electrodermally. It should be emphasized that the autonomic correlates of prognosis were detected in the absence of pretreatment symptomatic differences between the good prognosis and poor prognosis patients.

In long-term, chronic patients, Schneider (1982) observed that poor short-term response to neuroleptic treatment was associated with low electrodermal arousal and fast SCR-OR habituation. At first glance, Schneider’s results seem directly opposite to those of Frith et al. and Zahn, Carpenter, and McGlashan. However, Schneider’s chronic patients exhibited principally negative symptoms, suggesting that those patients represented primarily the low-aroused, low-responsive subgroup of patients. Thus, the finding that the poor prognosis chronic patients exhibited lower arousal and lower responsivity implies that the better prognosis patients were more normal electrodermally, which is consistent with the Zahn, Carpenter, and McGlashan results.

Obviously, much more research is needed in this theoretically and clinically important area of psychophysiological prognostic indicators. Are the psychophysiological predictors of prognosis enduring trait-like characteristics of the individual or immediate precursors of symptomatic change? Do they reflect a genetic predisposition for chronic or nuclear forms of schizophrenia? Can these measures be used to predict the long-term likelihood of relapses? Can they serve a useful role in the early detection of impending clinical relapses among outpatients,

or in determining the proper type and dosage of medication? Do these measures reflect prognosis and treatment response in psychiatric disorders other than schizophrenia? Such issues are in urgent need of further research (see also Zahn 1980).

Overall Summary and Conclusions

Psychophysiological dysfunctions associated with schizophrenia, with an emphasis on electrodermal anomalies, have been reviewed in some detail. The present section will take the broader view, examine the forest rather than the trees, and address the central question regarding the functional role of these anomalies in the developmental course of schizophrenia.

In a seminal article, Zubin and Spring (1977) distinguished between markers of the symptomatic episode and markers of the vulnerability to schizophrenia. Episode markers are those measures that differentiate schizophrenic patients from normal subjects only as long as the episode persists. Vulnerability markers are those measures that differentiate schizophrenic patients from normal subjects before, during, and after the episode. Thus, episode markers index the presence of the psychotic state whereas vulnerability markers index a relatively permanent trait of the individual.

To determine whether the psychophysiological dysfunctions reviewed in this article qualify as episode indicators or vulnerability indicators, consider the two types of electrodermal anomalies identified earlier. The first electrodermal anomaly, SCR-OR nonresponsiveness to innocuous stimuli, has been found in a high proportion of anhedonic individuals who are hypothesized to be at risk for

psychosis in general and schizophrenia in particular (Simons 1981). This anomaly has also been found rather consistently in high proportions of symptomatic schizophrenics (Öhman 1981; Bernstein et al. 1982) and remitted schizophrenics (Iacono 1982). Thus, the evidence suggests that SCR-OR nonresponsiveness may be present before, during, and after schizophrenic episodes in some individuals, although further investigation is necessary to demonstrate that anhedonic individuals do later manifest schizophrenic disorders at heightened rates. The second electrodermal anomaly, SCR-OR responsiveness coupled with higher than normal tonic sympathetic arousal during the presentation of mild innocuous stimuli, has been found in a substantial proportion of symptomatic schizophrenics (Öhman 1981) and remitted schizophrenics (Iacono 1982), but not in genetically defined high-risk subjects. However, a related phenomenon has been observed in genetically defined high-risk subjects; specifically, at least some offspring of schizophrenic patients are hyperresponders and/or slow habituators to mildly aversive loud noises (Mednick and Schulsinger 1968; Van Dyke, Rosenthal, and Rasmussen 1974; Prentky, Salzman, and Klein 1981). A similar hyperresponsiveness and/or slow habituation to mildly aversive loud noises has been reported for symptomatic schizophrenic patients by some investigators (Horvath and Meares 1979; Gruzelier et al. 1981b) but not by others (Bernstein et al. 1981). This specific anomaly has not been examined, to our knowledge, among remitted schizophrenic patients.

It should be emphasized that the evidence reviewed above regarding the presence of electrodermal anomalies across different symptomatic states is based on cross-

sectional comparisons. No study to our knowledge has measured psychophysiological responses longitudinally from the same individual before, during, and after a schizophrenic episode. Nevertheless, the data suggest that electrodermal anomalies, as well as several other psychophysiological dysfunctions (see table 3), are possible vulnerability indicators. Certainly the evidence is sufficiently promising to warrant further research to examine whether these psychophysiological dysfunctions are valid indicators of vulnerability, whether the vulnerability being indexed is genetically determined, whether the vulnerability indicators have useful prognostic and treatment implications, and whether the vulnerability being indexed is specific to schizophrenia.

Regarding the specificity issue, there is considerable evidence that the two electrodermal anomalies associated with schizophrenia also occur in other psychiatric disorders. For example, abnormally high rates of SCR-OR nonresponsiveness have been found among unipolar and bipolar affective disorder patients, even when in clinical remission (Dawson, Schell, and Catania 1977; Iacono et al. 1983), whereas abnormally high electrodermal arousal has been found among anxiety neurotics (Lader and Wing 1966). These results would suggest that the electrodermal abnormalities may have nothing to do with schizophrenia *per se*, but rather may be correlates of depression and anxiety. This is not the total answer, however, because clinically asymptomatic remitted schizophrenics also exhibit the same electrodermal abnormalities. Thus, granting that the electrodermal anomalies are not specific to schizophrenia, they are nevertheless useful trait-like characteristics associated with the vulnerability to schizo-

Table 3. Summary of evidence regarding the presence of psychophysiological dysfunctions before, during, and after the psychotic episode

Time present	Psychophysiological dysfunctions				
	Skin conductance orienting nonresponsiveness	Heightened electrodermal arousal	Smooth-pursuit eye movement dysfunctions	Attenuated P300 component of the event-related potential	Attenuated EEG alpha & heightened EEG delta
Present before episode	With anhedonic subjects (Simons 1981), but not with genetic high-risk subjects (Mednick & Schulsinger 1968)	With subjects who score high on the Schizophrenism Scale (Nielsen & Peterson 1976)	Not tested	With anhedonic subjects (Simons 1981)	With genetic high-risk subjects (Itil 1977)
Present during episode	With symptomatic schizophrenics (Bernstein et al. 1982)	With symptomatic schizophrenics (Öhman 1981)	With symptomatic schizophrenics (Holzman & Levy 1977)	With genetic high-risk subjects (Friedman, Vaughan, & Erlenmeyer-Kimling 1982)	With symptomatic schizophrenics (Itil 1977)
Present after episode	With remitted schizophrenics (Iacono 1982)	With remitted schizophrenics (Iacono 1982)	With remitted schizophrenics (Iacono, Tuason, & Johnson 1981)	Not tested	With remitted schizophrenics (Iacono 1982)

A related dysfunction, hyperreactivity to mildly stressful stimuli, has been found in at least some genetically defined high-risk subjects (e.g., Mednick & Schulsinger 1968; Van Dyke, Rosenthal & Rasmussen 1974; Prentky, Salzman, & Klein 1981).

phrenia and other serious behavioral disorders.

While the evidence suggests that electrodermal anomalies may be indicators of a vulnerability trait, it is well documented that electrodermal measures also are sensitive to changes in psychological states. Psychophysiological measures in general are not static properties of the subject; instead, they fluctuate with psychological states. Thus, psychophysiological measures may be both vulnerability and episode indicators. For example, a vulnerable individual may have a somewhat heightened tonic sympathetic arousal in both the premorbid and remitted states, although the phenomenon may be observable only under mildly stressful test conditions. The same individual may then exhibit a more pronounced and more generalized heightened sympathetic arousal when, or somewhat before, psychotic symptoms begin to appear. If this picture is accurate, then the conceptual dichotomy between episode indicators and vulnerability indicators may not adequately describe the developmental course of schizophrenic psychophysiological anomalies. Instead, as developed more fully elsewhere in this issue (Nuechterlein and Dawson 1984), it may be necessary to distinguish between: (1) episode indicators (those which are abnormal only during psychotic episodes), (2) stable vulnerability indicators (those which are stably abnormal across all states), and (3) mediating vulnerability factors (those which are abnormal during nonpsychotic states and which become more extremely abnormal during psychotic states). Many of the promising psychophysiological measures may prove to serve as mediating vulnerability factors in the developmental course of schizophrenic disorders.

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