the electrodermal psychophysiology of schizophrenics
and children at risk for schizophrenia: controversies
and developments*

Peter H. Venables

Introduction

A fairly comprehensive review of the psychophysiology of schizophrenia has recently been presented
by Venables (1975); however, the opportunity offered here to write a somewhat more idiosyncratic review of
work on the autonomic physiology of schizophrenia provides the chance of looking in as wide a context as
possible at some areas of research that appear to have provided a certain degree of controversy. The con-
troversy is, however, the stuff out of which progress is made, and although undoubtedly some readers will
view this paper as having elements that are too specula-
tive, it is possible that the consequent irritation will
provide the spur for future research.

This personally biased review will therefore take as
its starting points three interlocking sets of findings and
will attempt to extend its coverage from them. The
three points are all initially concerned with electro-
dermal activity and are (1) the reports in the work of
Gruzelier and Venables (e.g., 1972) of a bimodal dis-
tribution of responsivity of skin conductance in a
heterogeneous group of schizophrenics, (2) the findings
of Mednick and Schulsinger (e.g., 1968) that the fast
recovery of the skin conductance response exhibited
(in the premorbid state) by offspring of schizophrenic
mothers is predictive of their later schizophrenic break-
down and that this fast recovery appears to be char-
acteristic of some adult schizophrenics (e.g., Ax and
Bamford 1970 and Gruzelier and Venables 1972) but not of others (e.g., Maricq and Edelberg 1975),
and (3) the finding (e.g., Gruzelier 1973) of bilateral
asymmetry in the skin conductance levels and respon-
sivity of schizophrenics that has been interpreted to
indicate a deficiency of left hemisphere activity in
these patients.

These points have been listed, to some extent, in their
order of controversy, but they are interlinked and can-
ot be dealt with in a particularly tidy fashion; the
arguments, therefore, will necessarily proceed on a
“knight’s move” basis.

The Responder-Nonresponder Dichotomy

In 1970, before the start of the work which resulted
in the publication in 1972 of a report by Gruzelier and
Venables of an apparent bimodal distribution of skin
conductance (SC) responsivity, the data that were then
available appeared to arrive at two incompatible posi-
tions. Zahn, Rosenthal, and Lawlor (1968) provided
data to show that schizophrenics exhibited larger skin
conductance responses (SCRs) which did not readily habituate. SC responsivity than normals. This
finding was in accord with that of Dykman et al. (1968)
and, if high risk data are also included, is in line with the
work of Mednick and Schulsinger (1968), who showed
that one of the prime features that distinguished
children of schizophrenic mothers who later became
psychiatrically disturbed from those who remained
well was that the former had larger SCRs which did not
readily habituate. In contrast, Bernstein (1964 and 1970)
provided data suggesting that schizophrenics habituated
at a faster rate than controls, a position that appeared
to be in accord with the work of Russian investigators
reported by Lynn (1963).
Because we wished to examine the notion of limbic dysfunction in schizophrenia, Gruzelier and I were disturbed by this discrepancy in the findings. The reasons for wishing to examine limbic dysfunction are outlined in detail in Venables (1975, pp. 108-110); in summary three points were evident. These were, firstly, the suggestions of Mednick (1970) that anoxic damage at birth interacted with genetic predisposition to raise the probability of breakdown in these doubly disadvantaged persons, and that anoxic effects were most likely to be found in subsequent malfunction of the hippocampus. Secondly, neurological studies on the association between temporal lobe epilepsy and psychosis (e.g., Flor-Henry 1969) and the schizophrenic symptomatology in patients with tumors located in the limbic system (Malamud 1967) suggested that at least at a phenomenological level there was an association of schizophrenic symptoms with limbic dysfunction. Finally, the argument was concentrated on the idea that the commonly accepted finding of attentional dysfunction in schizophrenia was explicable in terms of the dysfunction of the sorts of limbic mechanisms outlined by Douglas (1967), Douglas and Pribram (1966), and Kimble (1968).

The motivation for looking at data on the orientation and habituation of the SCR in relation to limbic dysfunction arose because of the direct relevance of the work of Bagshaw, Kimble, and Pribram (1965), which showed that amygdalectomy in monkeys produced a marked diminution of the SCR to tone stimuli, while ablation of the hippocampus and inferotemporal cortex apparently had no effect either upon the appearance of the SCR or its habituation. Bagshaw and Kimble carried out a reanalysis of their 1965 data, which had originally been presented in terms of percentage responding in five 10-trial blocks, and represented them in the form of percentage responding and mean amplitude of response as a trial-by-trial analysis of the first 20 trials. (The data were thus in a form comparable to that in which experiments on human subjects were most often presented.) This reanalysis showed a deficit in habituation in 7 hippocampal animals in relation to 14 control animals. Of the six animals with amygdaloid lesions, two were hyperresponders, suggesting the possibility of some discharging foci in these cases; however, the other four animals were markedly underresponsive, two subjects showing no responses at all and two showing small responses only to the first and second stimuli presented.

The suggestion is thus that there is a possibility that high amplitude, nonhabituating patterns of response are related to hippocampal dysfunction and that non-responding or minimal responding is related to amygdaloid dysfunction.

With these findings in mind the data of Zahn, Rosenthal, and Lawlor (1968) and Bernstein (1964 and 1970) did not allow clear interpretation of the limbic status of schizophrenics. In a series of studies Gruzelier and Venables (1972 and 1974) and Gruzelier and Hammond (1976 and in press) have shown that there appears to be a bimodal distribution of SC responsivity in heterogeneous populations of schizophrenics and that the characteristic responsivity or lack of it does not immediately accord with regularly used diagnostic subcategories. All told, Gruzelier and his colleagues, working in two separate hospitals and having tested 127 unequivocally diagnosed schizophrenics, find that there is a more or less equally distributed bimodal split of electrodermal responsivity.

These are initial findings; they require further examination for a variety of reasons but mainly because others (e.g., Zahn 1976) have called the existence of the phenomenon of bimodality of responding into account.

The Definition of Nonresponding

Clearly the recorded existence or nonexistence of a response depends upon the gain setting of the measurement system. In the Gruzelier and Venables studies a response was defined as a change in conductance greater than 0.05 micromhos and, consequently, lack of response was anything smaller than this. Skin conductance nonresponding can be brought about by peripheral factors such as low manual skin temperature, but informal studies carried out by Gruzelier and Venables and by Patterson showed that nonresponding was not altered in the majority of subjects by the raising of hand temperature.

Is There a Real Phenomenon of Nonresponding?

Regardless of any arguments about the numbers of nonresponders in the schizophrenic population there seems to be little doubt that there is a genuine phe-
nomenon of electrodermal nonresponding. Informal assessments suggest that nonresponding is found in about 7 percent of adult normal subjects and that it is characteristic of a number of women in the post-ovulation phase of the menstrual cycle. In the psychophysiological assessment of 1,800 3-year-old Mauritian children (see the section on the Mauritian high risk study on p. 43), 145 of these were found to give no SCRs at any time during the course of testing and in these subjects the absence of SCRs was confirmed by a parallel absence of skin potential responses (SPRs), which are less subject to peripheral interference by low skin temperatures. The percentage of nonresponders in this sample, 8 percent, is close to the figure found in the general population of adults suggested above. The important consideration in the present context is the extent of the phenomenon in abnormal subjects and the conditions under which it is shown.

**Incidence of Nonresponders Among Schizophrenic Groups**

In the original 1972 study of Gruzelier and Venables, 43 out of 80 schizophrenics gave no responses whatsoever to 85-dB, 1,000-Hz, 1-sec tones. Lobstein (1974) using patients from the same hospital found that out of 48 schizophrenic patients 26 were nonresponders. In this instance Lobstein’s criterion of nonresponding was of no responding in the first three trials of an 85-dB, 1,000-Hz, 1-sec tone series, the tones having a 25-msec rise time. Patterson (1976b), using 75-dB, 1,000-Hz, 1-sec tones with a 25-msec rise time and testing chronic patients in two different hospitals, reported that out of 52 patients tested, 24 were nonresponders. Mirkin (personal communication), using 100-dB, 1,000-Hz, 1-sec tones with uncontrolled onset and testing 32 schizophrenics in a different hospital from those above, reported 11 nonresponders. Thus out of 212 patients tested, 104 gave no responses whatsoever, and it should be noted that this includes a group stimulated at an intensity of 100 dB. This figure of 49 percent nonresponders does not accord with the figures of from 0 to 14.8 percent of nonresponding in five groups of schizophrenics tested by Zahn (1976) and consequently is in need of further examination. All the patients in Zahn’s groups were drug free, while all those from the British studies were on varying doses of neuroleptic medication. An important aspect to consider therefore is to what extent the phenomenon of nonresponding is a function of medication. (This will be dealt with in the section on attempts at explanation of the responder-nonresponder controversy; see p. 31.) Bernstein (1964) in a study of the electrodermal orienting response to visual stimuli reported that of his “regressed” schizophrenics “almost half failed to respond at all on trial one.” The phenomenon of nonresponding was thus noted, but did not arouse particular interest for some years before the Gruzelier and Venables (1972) report.

**Minimal Responding and Nonresponding**

Gruzelier and Venables (1972 and 1974) found a clear dichotomy of patients who were nonresponders and patients who oriented but did not habituate within 15 trials (the responders). Patterson (1976b), however, reported further classes of responsivity among his patient groups. One group was what he termed “fast habituators,” who responded to only the first or second stimuli and formed 17 percent of those tested. Bernstein (1964, 1969, and 1970) in a series of studies has reported that nonresponding was exhibited in a high proportion of schizophrenics at low levels of stimulus intensity (visual, 5-ft. candles; auditory, 60 dB) and that other patients, particularly those classed as “confused,” also showed very fast habituation—only responding for one or two trials. However, the responding of these same “confused” patients is also reported by Bernstein as being particularly determined by stimulus intensity. Bernstein (1970) provides data to show equal numbers of responders and nonresponders to 60-dB stimuli among the “confused” patients, while the nonresponder percentage drops to 12.5 for 75-dB tones and to 4 for 90-dB tones. This is in contrast to informal data from Gruzelier and Patterson (personal communication), both of whom report no change from nonresponsivity to responsivity with increases in auditory stimulus intensity even as high as 100 dB.

One question that can be asked in this context is whether there is any similarity between subjects who are minimal responders and those who are nonresponders. Firstly, it is pertinent to know whether nonresponding is an extreme end of a continuum of responsivity or whether subjects who do not respond are in a separate category; secondly, at a theory-constructing level, it would be useful to be able to speculate on the length of the recovery limb of skin conductance nonresponders if they did respond. Thus, if there is a continuum for
minimal responding to nonresponding and the characteristics of the SCR recovery limb are known for minimal responders, some not too unwarranted theoretical extrapolation is possible for the nonresponders. Thirdly, if for instance a limbic dysfunction point of view of schizophrenic disorder is to be considered, the suggestion that both minimal responders and nonresponders are of the same kind is important. The unpublished data of Bagshaw and Kimble referred to earlier (see p. 29) do in fact suggest an answer to this last point. Of the four hyperresponsive amygdalectomized animals, two were nonresponders and two minimal responders.

One point of issue is whether the minimal responders are unusual in the sense that they give few responses and habituate very quickly, or that they give very small responses—which then have only to delay rather little in order to appear to habituate.

Data now being collected in this laboratory suggest that the former is the case, and data from Bernstein (1969 and 1970) appear to support this contention. The term “fast habituator” used by Patterson (1976b) thus may be more appropriate for this class of responsivity. Data from Patterson (1976b) show that if recovery time of the SCR to 75-dB tones is used as a criterion, then this is significantly longer for the fast habituators than for those schizophrenics who showed the other extreme pattern of nonhabituation, or for those who habituated during the tone series. The last two groups were not differentiated by their recovery times.

Hyperresponding and Nonhabituation

Nonhabituation, like nonresponding, is an operationally defined category. In the Gruzelier and Venables studies, which form the starting point of the discussion, habituation was defined as being reached when three successive nonresponses were shown to stimuli in a 15-stimulus sequence. In the 1972 study, while the mean number of trials to criterion in a normal and nonpsychotic patient control group was 4.40, of those schizophrenics who responded, noninstitutionalized schizophrenics showed 13.4 and institutionalized schizophrenics showed 12.9 trials to criterion. Data from a methodologically comparable experiment by Bernstein (1969) show that no schizophrenic patients in his “confused” groups exhibited the phenomenon of nonhabituation over 20 75-dB trials using a 2-trial habituation for criterion, and only 1 out of 17 in the “clear” group showed the pattern of response. The data summarized by Zahn (1976) are presented in the form of a series of histograms giving numbers of subjects showing different numbers of SCRs from four experiments. The SCRs were all to 20 tones of 72-75 dB and were either of 300 or 500 Hz. If the data for only male subjects are extracted from the histograms (to make them comparable to the remainder of the data covered in this review), then the mean number of responses shown by schizophrenics in Zahn’s samples was 7.3 and that shown by his normal groups was 8.7. Only 7 male schizophrenics out of the 78 tested showed no responses. Zahn’s data thus show a slightly smaller degree of responsivity in his schizophrenic than in his normal group, and by no means the hyperresponsivity of the responding schizophrenics studied by Gruzelier and Venables.

When Bernstein (1969) raised the stimulus intensity to 90 dB, 8 out of 26 “confused” and 5 out of 27 “clear” schizophrenics responded and did not habituate. However, the greatest amount of nonhabituation was shown by the normal controls of whom 10 out of 18 did not habituate to criterion. To stimuli of a slightly higher intensity (100 dB) Mirkin (personal communication) reported 11 out of 32 schizophrenic subjects who responded to every one of 15 stimuli.

The data on hyperresponsivity thus appear to be as difficult to draw together as those on hyporesponding.

Attempts at Explanations of the Responder-Nonresponder Controversy

In order to proceed from the position reached in the last section, it is important to make the assumption that the lack of consistency in the data does not result from error on the part of the investigator. Rather, one must assume that either recognized but not controlled factors, or alternatively, unrecognized factors enter as important variables in the determination of the results and that the challenge of attempted reconciliation may be informative rather than otherwise. The following discussion will involve (1) the consideration of such factors as the influence of medication and the characteristics of the stimuli used (e.g., intensity and relevance); (2) the methods of recording, particularly with relevance to laterality of measurement; (3) the instructions given to the subject and other “hidden” methodological variables; (4) the type, or diagnosis of
the subject; and (5) the interaction between these variables.

The Effect of Drugs

The examination of samples of patients on and off major tranquilizing medication has more than psychopharmacological implications. It has been common practice for patients to receive medication very early in their first contact with medical/agencies following the onset of psychotic disorder. Obtaining patients for research who have not previously been medicated is in consequence a difficult procedure. Once a patient has been successfully treated with a major tranquilizer there are often ethical objections to removing him from medication, particularly for the period of about a month which is required for traces of the tranquilizer to be eliminated. If some patients in a group tend to become clinically worse when drug therapy is withdrawn, there is ethical and practical nursing pressure to restore it. If other patients in the group tend not to relapse on the withdrawal of medication, then clearly there is an operational difference in diagnosis between the two groups of patients. A third group of patients are those who form a drug-free group in some hospitals and who are subjected to considerable experimentation; these are often patients for whom medication appears to have had no beneficial effects. Itil and his colleagues (Itil, Keskiner, and Fink 1966 and Saletu, Saletu, and Itil 1973) have compared on EEG measures patients defined as “therapy responsive” and “therapy resistant” (depending on the extent to which medication does or does not effect clinical improvement) and have shown electrophysiological differences between the groups. Curry (1971) has shown, however, that patients may differ in the extent to which they metabolize phenothiazines and that they thus may differ in the extent to which the medication is actively available to them for therapeutic purposes.

In summary, there may be a range of reasons why some patients are on medication while others are not; while undoubtedly there are variations due to therapeutic practice, there may also be a degree of self-selection, for the sorts of reasons outlined above, which may accentuate already existing differences between patient groups. Furthermore, even though patients are on similar, matched amounts of drugs, there may be interactions between subdiagnosis and the effect of medication that result in differential effects of these drugs.

Tecce and Cole (1972) presented a major review of the effects of major tranquilizers on psychophysiological variables, and this review was extended by Venables (1975).

The general outcome of the two reviews was to suggest that while medication has an effect on levels of tonic activity, there is limited direct effect on phasic activity. This is a bald statement that requires more extensive elaboration.

Bernstein (1964), whose data on electrodermal phasic hyporeactivity have been referred to above, included patients both on and off drugs in his sample; in none of his results were there any differences due to drugs. On the other hand, in a later study Bernstein (1967) showed an effect of medication upon tonic electrodermal levels; and where there were indications of drug-determined differences in phasic reactivity, he suggested that these were related to the drug-influenced differences in tonic level with which they were associated.

Spohn, Thetford, and Cancro (1971) carried out a study starting with a group of 32 schizophrenics of whom 29 were receiving phenothiazine medication. Medication was withdrawn from 20 of the patients and replaced by placebo. Of this group of 20, 15 remained without medication for 3 months. Results showed that SCL increased on withdrawal of medication to a level higher than that of a normal control group. Frequency of response was proportional to drug dosage when the patients were on drugs; but when the relation between SCR and SCL was partialled out, the effect of drug dosage on SCR was not significant. These data thus substantiate those of Bernstein. No evidence was found for an effect of medication on SCR amplitude.

A study of direct relevance to the present problem of the status of the responder-nonresponder dichotomy has been carried out by Gruzelier and Hammond (in press). This investigation was carried out on 18 patients and occupied 12 weeks—4 weeks on drug, 4 weeks on placebo, and 4 weeks reinstated on drug. Chlorpromazine was the only type of medication given, but the dosage was adjusted to the clinical requirements of the individual patient. Stimuli were 1,000-Hz, 85-dB, 1-sec tones with rise and fall times of 250 msec. Eight patients were nonresponders during all three phases of the experiment; three further patients who were nonresponders under medication became responders under
placebo. Two patients were responders (i.e. responded but did not habituate) throughout all three periods, and three patients who were initially responders later showed patterns of nonresponding. For three patients it was not possible to determine orienting response data over the three trial periods. These results make it apparent that there is no clear effect of medication upon responding and nonresponding states and therefore the results are in accord with the previous studies showing no effect of medication upon phasic responses. Also in accord with the other studies cited above, Gruzelier and Hammond showed that mean SCL increases significantly upon withdrawal of medication.

All the patients whose data were summarized by Zahn (1976), in which no evidence of bimodality of responding was apparent, were unmedicated at the time of testing, and the possibility of the difference between his results and those of Gruzelier and Venables could thus arise from this variable. After reviewing several pieces of evidence, however, Zahn suggests that it is unlikely that the differences in results could be directly due to differences in drug status.

The data reviewed so far suggest that the effects of medication on phasic responding are minimal. However, the possibility of the differential action of medication on different classes of patients needs to be considered; examination of a patient group taken as a whole may possibly confound such effects. There is some evidence to support this view.

Stern, Surphlis, and Koff (1965) examined the electrodermal orienting response to 500-Hz, 75-dB tones of patients before and after 5 weeks of hospitalization and phenothiazine medication. The patients were divided into “good” and “poor” prognostic groups. The tests given before medication showed little difference in responsivity between the good and poor groups. Approximately 70 percent of the good and 60 percent of the poor subjects responded to the first tone, and about 40 percent in each group responded to the second tone. Tests given after medication, however, showed that the responsivity of the good group was markedly reduced, while that of the poor group was relatively unchanged. A similar pattern of responding was found when electrodermal responding to words in a word association task (where presumably the stimuli had significance) was examined. This result is in contrast to a study by Goldstein et al. (1972) who examined the effect of thioridazine on acute newly admitted patients. In this study the “goods” became more reactive on medication, while the “poors” became less reactive. In a similar study by Magaro (1973) the effect of medication was to reduce the electrodermal reactivity of patients rated as poor premorbid, while there was no effect of medication on those rated as good premorbid. In both the Goldstein et al. and Magaro studies the stimuli were meaningful and, consequently, may be considered similar to the word association stimuli of Stern, Surphlis, and Koff (1965). The discrepancy in results is therefore difficult to resolve and does not appear to be replicable on the basis of the meaningfulness of the stimuli used. Meaningfulness, relevance, or significance of stimuli does, however, appear to be an important factor in the determination of responsivity and this will now receive further consideration.

Stimulus Relevance and Intensity

Gruzelier and Venables (1973) reported an experiment in which the presentation of a series of neutral tones to which the subject had to make no response was followed by a discrimination sequence in which the subject had to press a button to a 1,000-Hz, but not to a 2,000-Hz, 75-dB, 1-sec tone. Whereas in the initial habituation series the pattern of electrodermal responding and nonresponding previously reported was shown, in the second part of the experiment, previously nonresponding schizophrenics responded to the tones requiring response, but not to the neutral tones. This experiment exemplifies one of the major sorts of problems that are involved as intervening variables in this field. The determination of the significance of stimuli is a subtle and ephemeral characteristic which may underlie the discrepancies between studies from different laboratories.

The use of stimuli requiring reaction is one means of assuring signal value; however, the reaction may itself produce a response and confuse the issue. Other methods require more difficult manipulation and necessitate the supposition that whatever means are used to ensure significance for normals are also effective for schizophrenics.

Bernstein (1969 and 1970) has consistently reported an increase in responsivity with an increase in stimulus intensity. For instance, 52 percent of his “confused” schizophrenic patients responded to the first presentation of a 60-dB tone, and 89 percent to a 75-dB tone;
the increased responsivity to the first presentation of a 75-dB tone was not maintained, however, and there was no difference in responsivity to a second tone of either 60 or 75 dB when only about 20 percent of patients responded. However, in response to a 90-dB tone, 96 percent of confused patients responded to tone 1, and the percentage responding was above 40 to the 15th tone in the series. Bernstein’s formally presented data are thus in opposition to the informal reports of Gruzelier and Patterson, who reported no appearance of responding in nonresponders even when the tone intensity was raised to 100 dB. As stated earlier (see the section on incidence of nonresponders among schizophrenic groups on p. 30), Mirkin (personal communication) also noted about 30 percent of nonresponders to a 100-dB sharp onset tone.

Bernstein’s work on the orientation response (Bernstein 1968 and 1969 and Bernstein et al. 1971) has suggested that the significance of a stimulus is related to its intensity insofar as loudness may indicate an approaching stimulus. Bernstein’s own data on the increase in responsivity with louder stimuli are thus in accordance with the idea that responsivity increases with the significance of the stimulus. The more informal data of Gruzelier, Patterson, and Mirkin on the effect of stimulus intensity do not, however, fit with this explanation and it is difficult to suggest an explanation for the discrepancy other than a procedural one.

All experimenters working with schizophrenics as subjects are particularly aware of their sensitivity to the experimental situation in which the studies are carried out. One large element in this situation is that of the experimenter himself. It is not unlikely that the nuances in tone of voice with which he gives the “neutral” instructions such as “You will hear a series of tones; you need not pay attention to them; just sit and listen” are interpreted in a variety of ways by different patients. It is possible, for instance, that almost by definition, no instructions could be neutral for paranoid patients.

The instructions are also important to the extent that they prepare the subject for the stimuli and do or do not eliminate startle responses. A particular instance of this is reported by Gruzelier (personal communication).

In the initial series of studies (i.e., in Gruzelier and Venables 1972 and 1973), the subject was seated in the experimental room, reassured, the headphones adjusted, and the experimenter left the room and gave the “neutral” instructions through the headphones. Those instructions were followed shortly by the first of the orientation tones. Under this procedure, the clear dichotomy of responders and nonresponders is reported. In the later studies (Gruzelier and Hammond 1976 and in press) the procedure was modified slightly, so that the instructions to the subject were given before the headphones were placed on the subject’s head and the tones were then presented without further comment when the experimenter had left the subject’s room. Under these experimental conditions Gruzelier and Hammond reported that in addition to the clear responder-nonresponder dichotomy, they also found a proportion of subjects who were “fast habituators” and responded to the first one or two stimuli and not thereafter. Gruzelier and Hammond, in these later experiments, used 85-dB, 1,000-Hz stimuli with a 250-msec rise and fall time, and consequently the possibility of startle by the stimuli is minimized. He does, however, suggest that the omission of the immediately preceding auditory message through the headphones may have resulted in the responsivity in patients who otherwise would have been nonresponders and a form of startle may have been the cause.

Bernstein and Taylor (1976) report a study on adolescent schizophrenics using stimuli in which the experimental arrangement generated information value for the stimuli and a verbal praise or scold comment preceded the first five tone trials of the series. The response to the voice was in all cases very much larger than that to the tones. It may therefore be important, in the usual experimental procedure, when some instructions are given before a tone series, to pay particular attention to the time between the end of the instructions and the onset of the first tone since there is a possibility of an interaction at the response level if the response to the instruction is large—even if that response is not measured. There may, however, be a particular function of speech stimuli in this instance which needs to be considered.

**The Nature of the Auditory Stimulus Used**

In the examination of the results reported by Zahn in relation to those by Bernstein, Gruzelier and Venables, Patterson, and others, one feature which may be noted is that Zahn uses 72- to 75-dB, 300- or 500-Hz stimuli, while the other workers use 1,000-Hz stimuli. Is there any possibility that this frequency difference is respon-
sible for the differences in the studies? Stern, Surphils, and Koff (1965), whose work was referred to earlier, also used 500 Hz at 70-dB intensity and report results which appear to show a similar amount of responsivity to that reported by Zahn. There is thus a possibility of a differential frequency-responsivity that could be a factor in the different results reported. Gruzelier and Hammond (1976) report data in accord with this suggestion, showing that in a study of the absolute auditory thresholds of schizophrenic patients and controls, “schizophrenics had superior hearing at low frequencies up to 1,000 or 2,000 Hz” (p. 47). There is a suggestion in these data that this effect is only consistent at 500 Hz and that on a second occasion of testing, the thresholds of schizophrenics and controls at 1,000 Hz do not differ. It is also very provocative that Gruzelier and Hammond report that it is the right ear which shows the lowest threshold on the first occasion of testing and that this lateral difference disappears on the second occasion. The evidence is therefore slightly suggestive that differential responsivity in schizophrenics may in fact be a function of the frequency of the stimuli used and that there may be some interaction with laterality of brain function in addition. The data concerned with differences in lateral function in schizophrenics can now be added to the growing list of factors involved in disturbances of responsivity. The possibility of greater responsivity to low frequency stimuli in schizophrenics suggests that these stimuli fall within the range of fundamental voice frequencies and consequently add to the importance of considering lateral functions in this context.

Lateral Dysfunction in Schizophrenia

Venables (1966) described work on two-flash threshold and two-click threshold in schizophrenics. The two-click threshold used in this study was the mean of thresholds obtained separately for each ear. The data obtained from each ear separately were used in a tentative way, however, and the results were briefly mentioned in Venables (1969). In normal subjects it had been found that there was a lower threshold for the left ear than for the right (a finding subsequently more accurately replicated by Murphy and Venables [1970]). There was a suggestion that this pattern was reversed in schizophrenics and that the extent of the reversal was related to the degree of incoherence of speech shown by the patient. It was this tentative finding at the behavioral level which prompted the studies on the bilateral measurement of electrodermal activity that gave rise to the findings published by Gruzelier (1973) and Gruzelier and Venables (1974). In general these data show that while there is no difference in the responsivity of the two hands among normal control subjects under the conditions employed in the studies, the responsivity of the right hand is higher than that of the left in electrodermally responding schizophrenics; moreover, in the data of Gruzelier (1973) there is a higher SCL on the right hand in these patients. In nonresponsive patients, however, the SCL is higher on the left than on the right hand. The neuroanatomical data on the pathways from eccrine sweat glands on the hand to the brain are not good, but Luria and Homskaya (1963) and Sourek (1965) nevertheless provide data which suggest that the pathway is ipsilateral. Further suggestive evidence may be derived from the conjunction of the proposals of Edelberg (1973) that electrodermal activity may be considered as an accompaniment of motor movement and the data, for instance, of Brinkman and Kuyper (1972) that arm movements are controlled ipsilaterally. Thus, deficiency in left hand responding in schizophrenics would be suggestive of left hemisphere dysfunction in these patients. It should be noted that unilateral nonresponding was reported in a small number of patients (18 percent) by Gruzelier (1973) and Gruzelier and Venables (1974). Thus the phenomenon of nonresponding, to which attention has been paid in previous sections, can appear as a unilateral feature.

The finding of left hand (left hemisphere?) dysfunction in schizophrenics does not immediately fit with the two-click data introduced at the beginning of this section; however, a tentative argument proceeds as follows. In normals a lower left ear threshold suggests (in a binaural stimulation situation as used by Murphy and Venables [1970]) that the right hemisphere is better than the left for dealing with this material. Kimura (1964) reported left ear superiority in a dichotic listening task using melodies as stimuli for recall and in addition she found a similar laterality effect in a task requiring the perception of numbers of clicks presented dichotically. The tentative finding of an opposite superiority in schizophrenics suggests that the left hemisphere is better than the right for the resolution of clicks. Two possibilities (at least) exist here for the explanation of this finding. One would be the suggestion of depression of
specialized function in schizophrenics; thus the inferior performance by the right hemisphere in the resolution of temporal difference between clicks might be due to the depression of this specialized function. Similarly we might expect a depression of left hemisphere function for speech stimuli or stimuli having some characteristics of speech. The other type of explanation, and one which appears plausible on the basis of evidence to be reviewed, invokes the idea that the hemispheres differ in patterns of “strength of the nervous system” to use the terminology of Pavlovian and neo-Pavlovian workers (Nebilytsin and Gray 1972).

Murphy and Venables (1971) suggested, following work with normal subjects in which the effect of caffeine citrate on two-click thresholds was examined, that the left hemisphere displayed weak nervous system characteristics, while the right hemisphere had features more characteristic of a strong nervous system.

Under weak stimulation, by the use of clicks at about 60 dB it might be expected that in schizophrenics—in whom, overall, the characteristics of a weak nervous system are seen in a number of studies (see the section on stimulus intensity and paradoxical effects on p. 39)—that the left hemisphere might be more sensitive and resolve the pairs of low intensity clicks more readily, hence giving the appearance of right ear superiority.

If this sort of model is at all feasible, then it may serve to generate explanations of other findings. It has already been noted in the experiment of Gruzelier (1973) that among nonresponding patients the SCL of the right hand is lower than the left (this is the opposite to the state of affairs with responding patients). These data (Gruzelier 1973 and Gruzelier and Venables 1974) also replicate the findings of Gruzelier and Venables (1972) in showing that there is an overall lower level of tonic activity among nonresponders than among responders. These data are extended to other than electrodermal measures in Gruzelier and Venables (1975). Thus, if we adopt the notion that at low levels of “arousal” the “weak” left hemisphere shows a higher level of activity than the “stronger” right hemisphere, then at the lower level of general arousal exhibited by the nonresponders the idea that the left hemisphere has a “weaker” nervous system than the right would suggest a higher left-hand SCL than a right-hand SCL. In the case of SC responders where the general level of arousal is higher, the model fits the data if it is suggested that the weaker left hemisphere shows transmarginal inhibition and shows a lower effective level of arousal than the right and hence the left hand shows a lower SCL than the right. Gruzelier and Venables (1974) found the same directionality of SCL in responders and nonresponders. A difference between the hands which was, however, not significant during a tone habituation series became significant during a tone discrimination task. If the Gruzelier (1973) and the Gruzelier and Venables (1974) tone habituation series are compared, it is possible that the shorter interstimulus interval used in the latter experiment might have led to higher arousal levels in this experiment than in the 1973 one, and thus both nonresponders and responders reached the point of crossover of the operating characteristic of the weak left and stronger right hemispheres. With the tone discrimination studies both the responders and the previously nonresponding patients might be sufficiently “aroused” to be at the point where the left hand was showing the effects of transmarginal inhibition. These arguments are illustrated in graphic form in figure 1. Data in some support of a transmarginal effect on tonic activity on the left hand are to be found in Gruzelier, Lykken, and Venables (1972). In this experiment, heart rate, skin conductance, skin potential, and two-flash threshold were measured under three induced arousal levels manipulated by pedaling an exercise bicycle under different loads. The subjects were paranoid and nonparanoid schizophrenics and normal controls. All subjects showed increased heart rate over the three conditions. Skin conductance level (SCL) was measured from the left hand and skin potential level (SPL) from the right. Nonparanoid schizophrenics, in contrast to paranoid schizophrenics and normal controls, showed a paradoxical decrease in SCL over three arousal conditions while this was not shown in SPL. The data are thus in accord with the idea of a “weak” left hemisphere/hand, but unfortunately it is not possible to say whether the lack of paradoxical effect on the right hand is due to its absence or to the fact that the measure in this instance was SPL and not SCL. It is suggested that the latter may not be the explanation as the mean levels of SPL between 20 and 25 μV are just above those at which electrolyte junction effects take place (Venables and Christie 1973) and are thus involving the same sudorific mechanisms as those involved in SCL. In a later experiment in the same set (Gruzelier, Lykken, and Venables 1972) supposedly involving a higher level of arousal on which the bicycle ergometer conditions were superimposed, the...
previous results were basically replicated, but in this instance right-hand SPL in nonparanoid patients showed a paradoxical fall only on the highest arousal condition. This suggests that in nonparanoid patients the right hemisphere/hand may show transmarginal inhibition, given conditions that are sufficiently arousing.

One question that poses itself at this point is whether nonresponding can be considered to be a transmarginal effect on phasic responsivity of the same kind as that which appears to be the case for tonic levels and responses.

At the empirical level the answer appears to be No. It has been shown above that the SCL of nonresponders is lower than that of responders in experimental situations that are intrinsically of low impact. There is in general an increase in SCL with increase in situational arousal, and this includes conditions in which stimulus significance invokes phasic responding. It does not therefore immediately appear that the increase in situational arousal which produces paradoxical effects particularly in left-hand measures could be responsible for the production of both responding and nonresponding.

However, the mechanisms responsible for phasic and tonic responsivity are not the same. The classic work of Sharpless and Jasper (1956) suggests that tonic responses are mediated via the brain stem portion of the reticular formation while the phasic orientation response is mediated by the more rostral diffuse thalamic system. (The role of the limbic system had not been so well investigated at the time of this study.) Gray (1967) suggests that the relative level of activity of the reticulo-cortico-recticular negative feedback loop is responsible for weak/strong nervous system differences. The suggestion at this point would thus be that differences in phasic responsivity are not immediately the result of brain mechanisms that have been involved in “strength
of nervous system” explanations of function outlined above.

It is possible, however, in an increasingly speculative manner to extend the argument further. Redding (1967) showed that the hippocampus has an inhibitory effect on the brain stem, but also a partial facilitatory effect on the nonspecific thalamic systems.

In suggestions put forward earlier (see the section on the responder-nonresponder dichotomy), it was proposed, following the work of Bagshaw, Kimble, and Pribram (1965) and Bagshaw and Kimble (1972), that electrodermal hyperresponsivity resulted from hippocampal lesions and hyporesponsivity from amygdalactomy. Hippocampal inactivity would lead, on the basis of Redding's work, to lack of inhibitory control of the brain stem reticular formation and hyperactivity of that structure, which would lead in turn (if Gray [1967] is correct) to the operation of transmarginal effects by the involvement of the cortex. The concomitant withdrawal of partial excitatory influence on the diffuse thalamic system would result in smaller phasic responses, but this effect might be balanced by the tendency to amygdaloid dominance with lack of hippocampal control. Thus while not allowing specific statements to be made about phasic activity, the sorts of tonic activities outlined above are in line with the suggestions of limbic involvement mentioned earlier.

In spite of the evidence and arguments produced above, which suggest left hemisphere involvement in schizophrenia, the position remains unclear. That this should be so is evident (a) when the result of a disturbance of one hemisphere is a disturbance of the relative activity of both, and (b) if (as the evidence above suggests) paradoxical effects are involved and the relative balance between the hemispheres varies (in addition to intrinsic laterality) in a way that depends upon the “arousal” level imposed by internal or external circumstances.

It is necessary, therefore, to seek other evidence to suggest which hemisphere is involved in the disturbances seen in schizophrenia.

There are a variety of sources of information: At the neurological level Davison and Bagley (1969) in their extensive review of “schizophrenia-like psychoses associated with organic disorders” provide an analysis of the association between psychotic symptoms and sites of CNS lesions on the basis of data abstracted from an extensive range of sources. No significant relations were found between right hemisphere lesions and psychotic symptoms. Left hemisphere and particularly temporal lobe lesions were associated with primary delusions and catatonic symptoms. Interestingly, too, in the light of the preceding discussion on the role of the brain stem reticular formation, lesions in this area were associated with thought disorder and Schneider’s (1959) first rank symptoms.

At the behavioral level, Klonoff, Fibiger, and Hutton (1970), Flor-Henry et al. (1975 b), and Gruzelier and Hammond (1976) have shown that when using the Wechsler Adult Intelligence Scale, subtests which are chosen as best revealing lateralized deficits indicate a left-centered dysfunction.

These sorts of data thus support the interpretation of left-sided deficits in electrodermal activity as indicating left cerebral dysfunction. Perhaps the strongest case for left-sided dysfunction is made by Flor-Henry in two reviews (1972 and 1974). His own empirical work (Flor-Henry et al. 1975 a) showing a significantly greater amount of power in the 20- to 30-Hz band in recordings from the left temporal region in schizophrenics is not entirely easy to interpret to indicate left temporal dysfunction. Data of a similar nature were gathered by Itil et al. (1974) on the sample of children at high risk for schizophrenia selected from the cohort of 9,006 children in Denmark born between 1959 and 1961 and studied by Mednick and Schulsinger. EEG recordings were made from occipital, parietal, temporal, and central leads, but the configuration which showed the greatest difference between high risk and low risk samples was the right temporal to parietal pair (T4 1 P4). The features that distinguished high from low risk samples were more slow beta activity (1.3-3.5 Hz), more fast beta activity (> 18 Hz), and less alpha activity in the former group. The finding of more fast beta activity in a temporal lead is in line with the Flor-Henry data, but the side of the abnormality is different in this high risk sample. In a further study with these same subjects, however, Gruzelier and Mednick (personal communication) report data on subtests of the Wechsler Adult Intelligence Scale that are in line with that on adults quoted above, indicating a left cerebral dysfunction. The position is thus unresolved, but does suggest that close attention to lateral differences is sufficiently important to require investigation in future studies.

At least one potential source of variability in the work discussed is in the nature of the stimuli used in the
experiments described. The variable of frequency has already been raised—Zahn in his work using lower frequencies (300-500 Hz) than most other workers who use 1000-Hz stimuli. Workers in the area of speech perception (e.g., Cutting 1974, Cutting and Rosner 1974, and Wood 1975) have indicated that certain aspects of auditory stimuli of a nonspeech nature behave in the same manner as speech stimuli (e.g., in showing categorical boundaries in perception) and consequently may involve specific lateral mechanisms in processing. Cutting and Rosner (1974), for instance, have shown that rise time cues categorical differences in both speech and nonspeech stimuli. The importance of this variable thus needs to be taken into account in future work and systematic parametric studies performed before anything firm can be added to our knowledge of lateral functions by the use of psychophysiological techniques.

Stimulus Intensity and Paradoxical Effects

The discussion of lateral differences of function has already prompted discussion of the idea of disturbances of control of the sensory aspects of stimulation in schizophrenics. The hypothesis that the left hemisphere was a “weaker” system than the right need not be taken to imply that the right hemisphere is “strong” (in that it never shows transmarginal effects) but rather that it is stronger than the left.

Pavlov (1941) suggested that schizophrenic withdrawal and negativism are examples of paradoxical phenomena in subjects with weak nervous systems. Venables and Tizard (1956 and 1958) provided data on this in work on reaction time where it was shown that chronic unmedicated schizophrenics tended on the first occasion of testing to show paradoxical effects with visual but not auditory stimuli. However, Venables and O'Connor (1959) showed that in contrast to normals, schizophrenics tended to show longer auditory than visual reaction times, and the suggestion was made (Venables 1971) that this phenomenon of longer auditory reaction time was a function of more pronounced and continuous transmarginal inhibition in this modality.

Two aspects of this work may have relevance in relation to psychophysiology. One is in relation to the stimulus modality used in experiments carried out on schizophrenics. It is interesting to note in relation to the paradoxical results with visual stimulation cited above that the reports of Buchsbaum and his colleagues (Buchsbaum 1975, Buchsbaum and Silverman 1968, Silverman, Buchsbaum, and Henkin 1969, and Landau et al. 1975) that schizophrenics tend to show “reducing” behavior (exemplified by the reduction of averaged evoked responses with increases in stimulus intensity) have been based on work using visual stimuli. On the other hand, Shagass (1976), in his extensive review of work on electrophysiology in schizophrenia, reports that these patients, compared to normals, show consistent overall reduction in the amplitude of the evoked response to auditory stimuli. It is difficult on the basis of available results, using electrodermal measurement, to indicate whether there are any parallels to these suggestions concerned with modality effects. Bernstein’s (1969) data appear to indicate that there is a monotonic increase in responsivity with increase in intensity over the visual and auditory modalities. However, the two visual intensities used would probably not have reached the range where paradoxical effects would be shown. Smith (1967), in contrast, did provide data to show that skin conductance response amplitude to a series of 110-dB tones was less than that to 70-dB tones.

The area has recently been reviewed by Jordan (1974) and Depue and Fowles (1976) and need not be expanded additionally here; however, it should also be noted that the original Venables and Tizard (1956 and 1958) results were obtained on the first occasion of testing. This result was interpreted as indicating that the arousal generated by the subject’s first exposure to the laboratory, in addition to the stimulus intensity dynamism of the more intense stimuli, exceeded the margin and paradoxical effects were shown. There is thus, as suggested earlier, a large area of uncertainty where situational effects may influence results.

Subdiagnosis

The explanation of inconsistency of findings within schizophrenic populations by the invocation of differences in subdiagnosis has become almost a required ritual before an experimental paper or review can be written. There is not sufficient space at this point to reiterate the sorts of statements that have been made. It is, however, probably reasonable to suggest that it is possible to isolate a group of nuclear, poor premorbid, nonparanoid, hebephrenic patients who behave in similar sorts of ways on the types of variables that have been considered. It is possible to set against this core group
others labeled as paranoid, good premorbid, or reactive patients who have the common feature of behaving differently from the core group although not necessarily in the same way.

Rather than to pursue this well-worked ground further, it is proposed at this point to step out onto less completely assessed territory. Gruzelier and Venables (1972) noted that the electrodermal responder-nonresponder dichotomy did not parallel any of the more classic subdiagnostic types, who tended to be more or less equally distributed among the categories of responsiveness. Using the Wittenborn Psychiatric Rating Scale, however, noninstitutionalized responders were found to have higher ratings on scales of manic behavior, psychotic belligerence, anxiety, and attention-demanding behavior. This set of variables does perhaps fit with sorts of symptomatology that could be predicted on the basis of dysfunction of the hippocampus and consequent hyperactivity of the amygdala. Stevens (1973) also interprets disturbances of emotional behavior in schizophrenic patients of this kind as disturbances of limbic function and, in addition, points to the disturbances of attention that can follow from limbic dysfunction, an area covered in a review by Venables (1973). Stevens, however, also suggests that from a clinical point of view the disturbances of attention include “not only delusions of interpretation but most characteristically the uncontrollable intrusion of unwanted memories and thoughts into the stream of consciousness” (p. 178).

This sort of clinical picture might very well be thought to be exhibited by those patients showing Schneiderian first rank symptoms (Schneider 1959). It is perhaps interesting that Taylor (1972), in reviewing the records of 78 male patients who were diagnosed schizophrenic and admitted to a closed psychiatric ward (and who hence must have had symptoms with presumably severe characteristics), found that 34 had positive Schneiderian symptoms while 44 had not—a proportion not too different from the responder-nonresponder dichotomy.

Flekkøy (1975) in his review of psychophysiological-neuropsychological aspects of schizophrenia, contrasts the florid symptomatology of the electrodermal responder with a suggestion that the electrodermal nonresponders exhibit residual or deficit states. He posits that the responder with florid symptoms exhibits the failure of a basic inhibition system and the nonresponder the reduced functioning of a noradrenergic system.

It is possible to suggest other ways in which the sorts of hypotheses being considered may be linked. Venables (1957) proposed the use of a dimension, “activity-withdrawal,” primarily at that time as a means of providing coherence in data then being collected. A recent review (Depue 1976) resurrects this dimension and provides data that appear to indicate its usefulness. An early set of studies (Venables and Wing 1962) suggested that withdrawn schizophrenics were more “aroused” than active patients, when using the measures skin potential and two-flash threshold. It is important to note that (1) these patients were unmedicated and (2) they were all familiar with the laboratory in which they had been tested since they had taken part in several earlier experiments. The level of situationally induced arousal might therefore be conceived to have been low. Depue and Dubicki (1974) report that withdrawn schizophrenics show a higher degree of delusions and hallucinations than active patients. On the basis of earlier arguments it can therefore be suggested that there is a possibility of identification of the withdrawn patients with the electrodermal responders, since the responding patients show the higher level of tonic arousal. It is difficult to reconcile this position with data reported by Bernstein (1967). He reports that LoMRS (Montrose Rating Scale) patients, who are described as “wholly or partially disoriented, regressed, disorganized, incoherent” (p. 229), have lower tonic levels of arousal than the HiMRS patients. If it is suggested that the LoMRS patients are akin to the withdrawn, hallucinating, and deluded patient group, then the direction of level of arousal is inconsistent. Two factors should be noted in Bernstein’s work: firstly, that an assistant always sat with the patient, and secondly, that the data (figure 2, p. 226) show that the level of electrodermal arousal to the higher intensity visual stimuli was lower than that to the lower intensity stimuli. These two facts together suggest that the patients may have been at a level of stimulation at which they exhibit paradoxical effects and that the source of that stimulation was possibly the presence of a social stimulus. Williams (1974) has shown in an experiment on direction of gaze that schizophrenics tend to avoid persons more than things and clinical experience suggests that social stimuli are more disturbing to patients than nonsocial stimuli. The presence of the assistant in Bernstein’s experiments may thus possibly be the factor partially responsible for a paradoxical reversal of arousal levels, with the LoMRS patients being at a lower tonic level than the HiMRS patients for this reason. In the
Venables and Wing (1962) studies the patients were very familiar with the situation and were sitting in the experimental room alone.

The suggestion that electrodermal responders can be classified as withdrawn and exhibit weak nervous system characteristics is in line with data from Depue (1976, p. 182) showing that withdrawn patients were more responsive to low intensity stimuli, and that the actives were more responsive to high levels of stimulation.

There are, as must be immediately evident, wholesale gaps in the knowledge required to do more than speculate about the present position, and our understanding remains excessively incomplete. It is, however, often by the consideration of apparently unlikely conjunctions, such as that of withdrawal and responding, that a possible further set of studies can be suggested.

The Recovery Limb of the Skin Conductance Response

It was stated at the beginning of this review that in addition to hyperresponsivity and hyporesponsivity and the disturbances of laterality that are evident in schizophrenia, the controversial topic of the recovery limb of the skin conductance response would be discussed.

In a review in 1974, Venables discussed the measurement and features of the aspects of the recovery limb of the skin conductance response in some detail, and consequently these points need not be covered in extenso here. Briefly, it can be said that in addition to its amplitude characteristics, the skin conductance response has three temporal characteristics—latency, rise time, and recovery. Because the recovery has an approximation to an exponential form, it is not appropriate either theoretically or practically to measure complete recovery. Instead, the most usual measure has been time to half recovery, although, because many responses do not reach that value before some succeeding disturbance intervenes, some workers have used one-third recovery time or assessment of the percentage of the response recovery in a fixed time as appropriate measures. Data reviewed by Venables (1974) suggested that there were differences in recovery time between schizophrenics and normals, the schizophrenics having the shorter recovery time. There were also differences due to the nature of the stimuli that elicited the response; under neutral conditions recovery tended to be slower than under signal conditions. Under unpleasant conditions (e.g., the cold pressor test—Edelberg [1972]), recovery limbs tended to be long. Furedy (1972), for example, reports longer recovery limbs for responses to stimuli that signal unpleasant shocks.

Since the 1974 review other data have appeared which suggest that the position is more complex than it appeared. In confirmation of earlier findings Zahn, Carpenter, and McGlashan (1975) showed the recovery time of the SCR to 72-dB, 500-Hz tones of two groups of schizophrenics, who did or did not improve on treatment, to be significantly slower than normal and not to differ between each other. In contrast, Maricq and Edelberg (1975) report data which show that to 78.5-dB tones, schizophrenics exhibited longer recovery times than normal. Both the Zahn, Carpenter, and McGlashan and the Maricq and Edelberg patients were off medication at the time of testing and the latter authors report testing another group of patients on medication and replicating their results. Maricq and Edelberg suggest the use of a lower stimulus intensity than that used by Gruzelier and Venables (1972) as being a factor which could be responsible for the difference in results. Gruzelier and Venables (1974), however, used stimuli with 75-dB intensity and still showed shorter recovery times for schizophrenics than for normals; neither stimulus intensity nor medication appears, therefore, to account for the difference in the results. Maricq and Edelberg’s schizophrenics were, however, allocated to two groups on the basis of their Plexus Visualization Scores (PVSs), a rating of blood capillary patterns of the nailfold believed to distinguish between biologically different subgroups of schizophrenics (Maricq 1970). Schizophrenics designated as having high PVSs are thought to resemble the process type of patient, while those with low PVSs “appear to be a mixed group including ‘reactive’ patients and those with borderline diagnoses” (Maricq and Edelberg 1975, p. 631). It was the high PVS or process patient who had significantly slower recovery than the controls, whereas the low PVS patients did not differ from the normals.

At this point it is worthwhile recalling the data of Bagshaw, Kimble, and Pribram (1965) and Bagshaw and Kimble (1972) referred to in the section on the responder-nonresponder dichotomy. In this study, the results of hippocampectomy were to produce animals that were hyperresponders, and poor habituators with SCR recovery times shorter than those shown by control animals. In the case of amygdalectomy the animals were either
nonresponders or hyporesponders and, in the latter case, had recovery times that were slightly longer than normal.

Bearing in mind species and procedural differences, one might speculate that the low PVS patients of Maricq and Edelberg were like the hippocampectomized animals, and the high PVS patients like the amygdalectomized animals. This probably unwarranted conceptual jump should, however, be taken with data from Patterson (1976a and 1976b) in mind. Patterson (1976b) found in a group of 31 schizophrenic subjects that 11 were nonresponders and that the remainder could be split into long and short recovery groups. The long recovery group had a mean half recovery time of 13.9 sec—a value not too different from the value of 11.2 sec found by Maricq and Edelberg for SCR to 78.5-dB, 1-sec tones. Patterson’s stimuli were 75-dB, 1-sec tones with controlled rise time. The value of 4.1-sec recovery time for the short recovery group is very similar to the figures of 4.7 sec for noninstitutionalized and 3.5 sec for institutionalized schizophrenics found by Gruzelier and Venables (1974) for SCRs also to 75-dB, 1,000-Hz, 1-sec controlled rise-time tones. It appears possible, therefore, to find within the same schizophrenic population data which are consistent with both the slow and fast recovery positions. Patterson’s (1976a) data are particularly interesting in that he carried out pupillometric work in conjunction with the measurement of skin conductance recovery. Pupil area was measured under conditions of 15-min adaptation to white light, in 1 min of darkness and for a subsequent 10 sec in light. Measures of initial area, dilatation after 1 sec, extent to dilatation, time to maximum dilatation, constriction after 500 msec, extent of constriction, and time to maximum constriction were taken. It was found that the most significant variable distinguishing the SCR fast and slow recovery group was the time to maximum pupil constriction in the final period of exposure to light. The fast SCR recovery time was associated with slow time to maximum constriction and vice versa.

Patterson chose to examine pupillometric and SCR recovery variables at the same time because he was using the pupillometric measures as indicants of adrenergic-cholinergic balance.

Following the data already fully discussed in this paper which suggested that hyperresponding and short SCR recovery are a product of hippocampal dysfunction, Patterson used the arguments put forward by Douglas (1972) to the effect that the results of hippocampal lesions can be obtained by cholinergic depletion. If slow time to maximum pupil constriction can be interpreted as resulting from cholinergic depletion and, as demonstrated, is associated with fast SCR recovery, then the Douglas (1972) suggestion appears confirmed, and a further basis of explanation for some of the electrodermal data on schizophrenic subjects is put forward.

Patterson (1976b) has shown that those of his subjects who show responsivity can be categorized as “nonhabitutators” (called in the rest of this paper responders or hyperresponders), “responders” who habituate halfway through the tone series and thus display a normal process, and “fast habitutators” who respond only to the first and/or second stimuli and are thus the hyporesponders referred to elsewhere. The data on the SCR recovery times of these groups show that the fast habitutators exhibit long recoveries (mean 15.3 sec) while the other two groups do not differ between themselves and show short recovery (mean 5.6 sec). If it is at all reasonable to suggest, as has been done above, that hyperresponding includes both nonresponding and minimal responding (fast habituating), then it could be suggested that this group, previously thought of as akin to amygdalectomized animals, could be showing excess of inhibition due to cholinergic overactivity. Further supportive data have been produced by Lobstein (personal communication), who found that the SC nonresponders tended to show a more marked and earlier heart rate (HR) decelerative pattern to loud tones than was shown by SC responders. The vagal, cholinergic activity, which would be thought to be responsible for HR deceleration, is thus more marked in the nonresponding than the responding patients.

This area of work, although producing results that appear to be of interest, is still fraught with interpretative difficulties. Venables (1974) has already suggested an interpretation—that fast SC recovery indicated openness to the environment and inability to filter. Stevens (1973), as discussed in the section on subdiagnosis, has suggested that delusional and hallucinatory behavior follows from defective filtering capacity. It is thus of considerable interest that Mednick (1976) in his most recent report on work from the Psykologisk Institut, Copenhagen, has reported that 34 subjects of the original 1962 high risk sample of 204 now have a schizophrenia spectrum diagnosis and that within this group shortness of SCR recovery in the data collected 14 years previously...
correlated \((r = .49, p < 0.005)\) with the presence of hallucinations and delusions now exhibited. Those subjects who now have a schizophrenia spectrum diagnosis, but without delusions, did not have fast recovery SCRs. The data from this source also therefore support the notion of association of hyperresponsivity and fast recovery electrodermal responses with florid forms of symptomatology.

The distinction between nonresponders and short recovery hyperresponders is apparent even in very young children in the high risk study in Mauritius and some of the data from this project will be briefly described.

The Mauritian High Risk Study—
Some Preliminary Findings

It is not the intention at this point to give an extensive account of the Mauritian study, but rather to present some findings which suggest that the principles discussed in the earlier parts of this paper can legitimately and with profit be extended to work on a very disparate sample, namely 3-year-olds on a tropical island and of different racial origins than those studied before in high risk research. The study also differs from other high risk investigations in that the definition of “risk” used in this instance is not based on genetic variables but is determined solely by abnormality of electrodermal responsivity.

In 1967 a World Health Organization (WHO) Scientific Group met in Geneva to consider research in the field of neurophysiology and psychiatry (WHO Technical Report No. 381, 1968). One of the primary recommendations of this group was that research of a cross-cultural nature should be carried out following the “high risk” design. WHO further implemented the recommendations of this report by inviting the Psykologisk Institut, Copenhagen, to begin such a project in Mauritius.

The work has been carried out on the island under a specially created legal entity, “The Joint Child Health Project,” for which Mednick, Schulsinger, and Venables of the Psykologisk Institut in Copenhagen are coinvestigators, together with Dr. A. C. Raman, the island’s chief psychiatrist, and Professor B. Sutton-Smith of Teachers College, Columbia University, New York, who was involved in developmental assessment procedures applied to the sample. The opportunity was also used by Drs. Ulett and Itil of the Missouri Institute of Psychiatry to gather EEG data on a subsample of the population of children. A preliminary report on the study has been given by Bell et al. (1975).

From vaccination records, lists were prepared of the 1,800 3-year-old children living in two representative communities. The cooperation of the families was obtained and during the year August 1972–July 1973 these children were brought into the laboratory for assessment. Playroom observation of the children enables psychological assessment of their developmental status to be made in controlled conditions.

The assessments of the sample included the following procedures:

- Field report on home visit, with detailed interview of parents
- Brief pediatric examination
- Standardized coding of obstetric records
- Detailed psychological assessment including observations of play behavior and child/parent interaction
- Psychophysiological measurement of skin conductance, skin potential, and heart rate during orienting and conditioning procedures
- Assessment of child’s behavior during psychophysiological procedures
- Electroencephalography

Complete data were successfully collected on 93 percent of the population of 1,800 children with the exception of the obstetric material where some 60 percent of the data were available in suitable detail. EEG data are available on approximately 50 percent of the children.

The psychophysiological procedures were a modification and reduction of the methods used successfully in the Copenhagen high risk studies and employed a highly standardized testing procedure. Stimuli were presented to the children via headphones from a tape recorder; the sequence consisted of 24 trials. The first three stimuli were 75-dB, 1,000-Hz, 1-sec tones with 25-msec rise time; in the second three the frequency of the stimuli changed to 1,311 Hz. The next 12 trials constituted a conditioning procedure with a CS+ consisting of a 60-dB, 1,000-Hz, 12-sec stimulus paired in the last 2 sec with a 90-dB unpleasant noise UCS. CS− was a 500-Hz stimulus unpaired with a UCS. The final six stimuli were test trials consisting of unreinforced CS+ and CS− stimuli.
From the 1,800 children tested, 200 were selected for further study in four matched groups of 50. Two groups of 50 were each taken into two nursery schools and two groups remained in the community and were not exposed to the nursery school experience. Within each group of 50 there was an approximate allocation as follows: 26 children who had the same hyperresponsive pattern of electrodermal activity as the children who became "sick" in Copenhagen were diagnosed as "high risk." In detail, on 12 selected responses there were SCR amplitudes greater than 1 micromho and recovery times less than 2.5 sec. Fourteen subjects in each group of 50 were selected as controls by having midrange values of amplitude and recovery (amplitude > 0.4 and < 0.9 micromho, recovery > 2.5 and < 9.0 sec). Ten subjects were selected as nonresponders, as they exhibited no responses on either skin conductance or skin potential channels. The sample of children extensively studied thus contains two abnormal responsivity groups—hyperresponders and hyporesponders—having the same features that have been the major points of discussion in the earlier parts of this paper. It should, however, be remembered that in contrast to any earlier studies, the subjects were children aged 3 years at the time of testing and of a racial mix reflecting the population from which they were drawn (39 percent Hindu, 20 percent Moslem, 10 percent Tamil, 26 percent Creole, and 5 percent other races).

In January 1976 the children entered the island's primary school system. Before this took place, however, a final assessment of their behavior was undertaken in which they were observed in groups of four in a standardized play situation. Each group of four consisted of a child from each nursery school and from each of the two community control groups. Each child was dressed in a similar uniform to prevent identification of his sample status, and the observers used for the study were specially recruited and trained and did not know the children. The testing was carried out in a place other than the two nursery schools.

Three timed measures of behavior proved to be particularly informative. These were: (a) "constructive play alone," a category that was recorded when the child played constructively with a toy or toys by himself; (b) "positive interaction," a category that included talking, cooperative play, and helping or accepting help from a peer; (c) "watching," a category in which a child was timed when watching a peer or adult while not otherwise interacting. The results showed that the nursery school experience had no effect on "constructive play alone" in the hyperresponsive and the nonresponder groups. However, in the control (medium responsive) group the amount of constructive play was, in the nursery school children, approximately double that displayed by community control children. Although the nursery school experience had no effect on the abnormal groups in that the nursery school and community children did not differ, the hyperresponsive children showed significantly more constructive play than the nonresponding children and the control children who had remained in the community. It is possible that in these hyperresponsive children is being seen the creativity that might be expected in the relatives of schizophrenics or in certain patients in their premorbid state.

Children from the community group in both abnormal and control samples showed a lot of "watching" and did not differ from each other. The nursery school experience significantly reduced "watching" in the hyperresponsive and control samples, but not in the nonresponder group.

Not very much time was spent in "positive interaction" by any of the groups. The nursery school experience, however, increased "positive interaction" in the two abnormal groups but reduced it in the control group largely because so much time was spent in "constructive play alone."

This very preliminary description of some of the research for this study is presented here to suggest that even in very young children the abnormal hyperresponsive-hyporesponsive dichotomy does appear to be a viable distinction. It is perhaps remarkable in this instance that children selected in a very brief psychophysiological testing procedure at the age of 3 showed distinctive patterns of behavior 3 years later as a result of their experience in the intervening period. It is also not unreasonable to suggest that the sorts of behavior shown are in accord with the patterns that might be expected to be associated with the psychophysiological types of behavior measured.

A considerable amount of data are now available on these children. Three further psychophysiological assessments have been made, and the behavior of the nursery school children has been continuously monitored and rated. Psychophysiological data are also available on 372 parents of the 200 children intensively studied. Reports on this material will appear over succeeding years.
Conclusion

The material discussed in this paper has concentrated largely on results and controversies arising in the measurement of electrodermal variables in the study of schizophrenia. This is perhaps inevitable insofar as (with the exception of work on the EEG) this area of electrophysiological investigation has received most concentrated attention. It has also perhaps been the case in the past that because of its relative ease of measurement, electrodermal activity has been assessed by hand and “eyeball” techniques before the time-consuming data reduction of cardiovascular variables has been undertaken. With the advent of computer techniques, however, the position is likely to change, and the great gains that can accrue from the consideration of many channels of data may benefit our knowledge of the field. In the meantime the author apologizes for largely concentrating on electrodermal work—an area, however, that in itself produces results sufficiently exciting to indicate their potential usefulness.

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**The Author**

Peter H. Venables, Ph.D., is Professor of Psychology, University of York, Heslington, York, England.