A Comparison of Psychiatric Patients and Normal Controls on the Integration of Auditory Stimuli

Harvey Babkoff, Samuel Sutton, Joseph Zubin, and Dov Har-Even

Received April 28, 1980; revised version received August 4, 1980; accepted August 23, 1980.

Abstract. Temporal processing of sensory auditory information was investigated in 27 psychiatric patients and 29 normal controls by measuring forced choice thresholds for the right ear to bursts of noise stimuli of three different durations—4, 32, and 128 msec. Psychiatric patients were found to be 5 dB less sensitive than normal controls. A subsequent analysis compared the normal controls with three subgroups of psychiatric patients differentiated according to symptom profile. Those psychiatric patients whose main symptoms were affective showed a shallower threshold duration integration function than did normal controls. Patients whose major symptoms were delusions of persecution and depersonalization showed a slightly steeper slope than normal controls, whereas patients whose major symptoms were hallucinations and lack of insight showed the steepest slope.

Key Words. Hallucinations, schizophrenic patients, affective patients, auditory temporal integration, visual temporal integration, reaction time.

Bazhin et al. (1975) reported differences between ears in temporal integration of auditory stimuli for hallucinating schizophrenic patients. The present study, a partial replication in another cultural setting, is an attempt to determine whether such findings are indeed culture free (Zubin and Kietzman, 1966). Two methodological refinements are introduced in the present study. First, a three-interval forced choice procedure is used to assure that differences among groups do not arise from differences in response criterion (Clark et al., 1967). Second, noise bursts rather than pure tones are used since reducing the duration of noise bursts does not produce systematic changes in the frequency spectrum, a complication which must have occurred for the stimuli used by Bazhin et al. (1975). This is important because it is at the shortest duration (1 msec) that the largest differences are found, and it is at the shortest duration that the spectrum is most distorted for pure tone stimuli. The slope of the integration function is known to be influenced by tonal frequency (Watson and Gengel, 1969).

As in the Bazhin et al. (1975) study, the present experimental design is multivalent, i.e., it involves the measurement of thresholds at multiple values of the independent variable, stimulus duration (Kietzman et al., in press). If the thresholds of a particular
group of patients are found to be more deviant from those of normal controls at one
stimulus duration than at others, i.e., a difference in slope, this finding can be more
easily interpreted as a difference in sensory processing than as an overall poorer level
of attention and/or motivation for that group (Sutton, 1973).

Finally, since the largest differences among groups in the Bazhin et al. (1975) study
were found for right-ear stimulation, only right-ear thresholds were obtained in the
present study.

Methods

Subjects. Twenty-seven male patients were selected from two psychiatric hospitals in
Israel, Ezrath Nashim in Jerusalem and the J. Abarbanel Mental Hospital in Bat-
Yam. The selection was restricted to cooperative patients between the ages of 18 and
50 years. The mean age of the patients was 33.75 (SD 8.6) years. A preliminary
screening of the patients based on information from hospital records excluded
patients known to be mentally retarded, brain damaged, or addicted to drugs or
alcohol.

The 31 normal controls, who were recruited through newspaper notices, ranged in
age from 22 to 61 years, with a mean age of 29.2 (SD 8.0) years. The normal controls
were paid at the rate of IL 25/hour.

Of the 31 normal subjects interviewed and tested, only 29 were included in the final
analyses as two had been hospitalized in the past with psychiatric illness.

Interview. Past research has documented the tendency of psychiatrists at service-
oriented institutions to overdiagnose schizophrenia and to underdiagnose affective
disorders (Cooper et al., 1972; Gurland, 1973). We therefore decided to obtain
information on patient symptomatology by using a semi-structured interview. The
U.S.-U.K. Mental State Interview Schedule, adapted from the Present State Exami-
nation, 8th edition (January, 1968; Cooper et al., 1969), was translated into Hebrew by
two clinical psychologists working independently. The final translation was adopted
after a series of meetings between the two translators.

Apparatus and Procedure. All auditory testing was performed with the subject
seated in a Medtecnik Silent Cabin. Stimuli were presented monaurally to the right
ear. Stimuli were trapezoid-shaped, 1 msec onset and 1 msec offset bursts of noise
generated by a General Radio type 1390-B random noise generator and shaped by a
Grason-Stadler Model 829 E electronic switch. The stimulus durations tested, includ-
ing onset and offset times, were 4, 32, and 128 msec. Stimulus duration was controlled
by locally designed timing and logic circuitry and calibrated by a Monsanto Type 120
A electronic counter to an accuracy of ±0.1%. Rise times were calibrated by a
Tektronix Type 454 A oscilloscope. Stimulus intensity was controlled by a Hewlett-
Packard 5-W 600 Ohm attenuator. The stimuli were transduced by the right earphone
of a pair of AKC K150 stereophonic earphones placed in Z61 cushions. Stimuli were
calibrated by a Bruel and Kjaer Type 2113 Audio-Frequency Spectrometer.

The order of presentation of stimuli, the onset and duration of the signal lights
identifying the three alternative intervals and the interlight intervals were controlled
by Massey-Dickinson logic units. The order of stimulus duration conditions (4, 32,
and 120 msec) tested was randomized across subjects. A three-interval temporal-
forced-choice adaptation of the Block Up and Down Two-Interval Forced-Choice
(BUDTIF) procedure was used to measure threshold (Campbell, 1963; Bruder et al.,
1975; Algom and Babkoff, 1978). The duration of the light signaling each of the
observation intervals, as well as the time between the interval warning lights, was 1 sec.
Intertrial interval (from the offset of the third interval warning light to the onset of the
first interval warning light for the next trial) was 10 seconds. A session lasted
approximately 40 minutes.

Feedback after each trial was given for correct responses. All three stimulus
durations were tested during a single session, with a rest period given between each
duration tested. Thus, an estimate of threshold for each duration was based on the
median of seven to eight blocks of trials after convergence of the "staircases" was
obtained for each subject for each condition.

All communication with the subjects was accomplished via an intercom system.

Results

Normal-Psychiatric Patient Comparisons. The initial analysis was a comparison
of normal controls with hospitalized psychiatric patients as a single group. These data
are plotted in Fig. 1 as the mean threshold in dB SPL for the noise bursts on the
ordinate as a function of noise burst duration on a logarithmic abscissa. Both the
normal and psychiatric patient functions decrease as noise burst duration increases.
The two functions appear parallel, with the patient function less sensitive than the
normal function by approximately 5 dB at all noise burst durations.

A two-way analysis of variance (ANOVA) with one-way repeated measurements of
the threshold duration data was performed. The results of this analysis indicated: (1)
For both groups, noise burst duration is a significant variable in determining thresh-
old ($F = 126.74; p < 0.0001$); and (2) the two groups differ from each other significantly
($F = 4.64; p < 0.05$). The interaction term is not significant, possibly indicating parallel
functions (Fig. 1).

Symptom Profile Group Comparisons. The second analysis compares normal
controls with subgroups of psychiatric patients differentiated according to symptom
profiles based on the Mental State Interview Schedule.

This analysis was performed in a sequential manner, the first step of which was to
tentatively identify patient clusters based upon their symptom profiles. The second

---

1. In this procedure, a block consisted of three trials. If the subjects correctly detected the stimulus on all of
the three trials, the intensity of the stimulus on the next block of three trials was reduced. If the subject
detected the stimulus on two of the three trials, the intensity of the stimulus in the next block of three trials
was the same. If the subject failed to detect the stimulus in two or three of the three trials in a block, the
intensity of the stimulus was increased in the next block of three trials. The procedure included both "up"
and "down" staircases whose order was randomized across blocks (Campbell, 1963; Bruder et al., 1975). The
"staircases" began from a level of 15 to 20 dB above estimated threshold and 15 to 20 dB below estimated
threshold and were altered by a 3 dB step at the beginning of the session. After two or three steps, the
attenuation step was reduced to 2 dB and then to 1 dB when "up" and "down" staircases converged. The up
and down staircases were continued for seven or eight blocks after convergence. An estimate of the signal
level yielding 67% correct responses (i.e., threshold estimate) is given by the median of the signal levels
revisited in the "up" and "down" staircases in the last seven or eight blocks after convergence.
step identified the major symptoms of these patient clusters and assessed the relative weights of these symptoms in the construction of a discriminant function. As a final step, the different clusters were compared with respect to their threshold performance. If differences between clusters emerged both in their major symptomatology and in threshold performance, this would support the meaningfulness of the clustering.

**Fig. 1. Threshold in dB SPL for normal controls and psychiatric patients**

![Graph showing threshold in dB SPL as a function of noise burst duration in msec.]

Threshold in dB SPL is plotted on the ordinate as a function of noise burst duration in msec, on a logarithmic abscissa. Data are shown for the normal controls (○) and for all of the psychiatric patients combined (●).

The U.S.-U.K. Mental State Interview Schedule contains 37 variables. Of these, 17 variables were excluded because the data did not distribute normally \(Z \geq \pm 1.96\) for either skewness or kurtosis. A symptom profile was generated for each patient based on the remaining 20 variables. A product-moment correlation was performed for the symptom profiles which were then subjected to Guttman (1968) Q-sort Smallest Space Analysis (SSA) in an effort to identify profile clusters. The number of symptom variables (20) and the number of subjects (27) are not in the appropriate proportions to permit evaluation of statistical significance of any cluster groupings. The purpose of the cluster analysis was not to generalize but rather to serve as a preliminary step to delineate patient groupings.

The resulting space diagram of the SSA is shown in Fig. 2.
Fig. 2. The space diagram constructed on the basis of the smallest space analysis

![Space Diagram]

Note four patient clusters, three of which are marked A, B, and C consisting of 10, eight, and six patients, respectively. The patients in the fourth cluster, unmarked, were considered as not associated with either of the three lettered clusters and not included in subsequent analyses. See text for explanation of the space diagram.

The structure of the space diagram can be described as containing three profile clusters: One includes 10 patients (cluster A), a second includes 8 patients (cluster B), and a third includes 6 patients (cluster C). By inspection it can be seen that cluster A is clearly different from clusters B and C; whereas the differences between clusters B and C are less clear cut. A fourth group of three patients did not appear to belong to either of the major clusters and was, therefore, excluded from further analyses.

The average group scores on the 20 symptoms in rank order of these symptoms for each of the patient clusters are shown in Table 1. In general, it seems that the patients in cluster A score highest on affective symptoms, and lowest on nonaffective symptoms, while those in cluster B and C score lowest on affective symptoms. Patients in cluster B score highest on anxiety, delusions, and depersonalization, while those in cluster C score highest on cognitive and perceptual symptoms, including hallucinations.

An SPSS Discriminant Analysis (Nie et al., 1970) was performed to find the functions describing the maximum differences between the three patient clusters. Nine statistically significant variables were found which differentiate the three patient clusters. These are shown in Fig. 3. Average symptom scores are plotted for each of the patient clusters to aid in comparison.
Table 1. Average group scores and rank order of the symptoms for each of the patient clusters

<table>
<thead>
<tr>
<th>Rank from highest to lowest</th>
<th>Cluster A</th>
<th>Cluster B</th>
<th>Cluster C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom</td>
<td>Mean score</td>
<td>Symptom</td>
<td>Mean score</td>
</tr>
<tr>
<td>1. Somatic dysfunction(^1)</td>
<td>57.4</td>
<td>Depersonalization(^1)</td>
<td>60.9</td>
</tr>
<tr>
<td>2. Tension(^1)</td>
<td>55.9</td>
<td>Situational anxiety</td>
<td>56.7</td>
</tr>
<tr>
<td>3. Lack of interest</td>
<td>54.9</td>
<td>Delusions of persecution(^1)</td>
<td>56.3</td>
</tr>
<tr>
<td>4. Depression</td>
<td>54.4</td>
<td>General anxiety</td>
<td>56.1</td>
</tr>
<tr>
<td>5. Lack of concentration(^1)</td>
<td>53.8</td>
<td>Worry</td>
<td>55.8</td>
</tr>
<tr>
<td>6. Lack of insight(^1)</td>
<td>51.4</td>
<td>Obsessions</td>
<td>55.2</td>
</tr>
<tr>
<td>7. Social discomfort</td>
<td>50.9</td>
<td>Self-deprecation(^1)</td>
<td>54.7</td>
</tr>
<tr>
<td>8. Physical health</td>
<td>49.2</td>
<td>Irritability(^1)</td>
<td>53.6</td>
</tr>
<tr>
<td>9. Worry</td>
<td>48.7</td>
<td>Social discomfort</td>
<td>53.3</td>
</tr>
<tr>
<td>10. Obsessions</td>
<td>48.4</td>
<td>Slowness</td>
<td>53.0</td>
</tr>
<tr>
<td>11. Slowness</td>
<td>48.0</td>
<td>Depression</td>
<td>51.4</td>
</tr>
<tr>
<td>12. Perceptual distortions</td>
<td>47.7</td>
<td>Thinking difficulties</td>
<td>51.3</td>
</tr>
<tr>
<td>13. Thinking difficulties</td>
<td>46.3</td>
<td>Tension(^1)</td>
<td>50.4</td>
</tr>
<tr>
<td>14. Irritability(^1)</td>
<td>46.0</td>
<td>Physical health</td>
<td>49.6</td>
</tr>
<tr>
<td>15. General anxiety</td>
<td>45.4</td>
<td>Perceptual distortions</td>
<td>49.3</td>
</tr>
<tr>
<td>16. Self-deprecation(^1)</td>
<td>45.4</td>
<td>Lack of interest</td>
<td>47.4</td>
</tr>
<tr>
<td>17. Hallucinations(^1)</td>
<td>45.3</td>
<td>Lack of concentration(^1)</td>
<td>47.1</td>
</tr>
<tr>
<td>18. Delusions of persecution(^1)</td>
<td>44.6</td>
<td>Somatic dysfunction(^1)</td>
<td>46.8</td>
</tr>
<tr>
<td>19. Depersonalization(^1)</td>
<td>43.6</td>
<td>Lack of insight(^1)</td>
<td>46.5</td>
</tr>
<tr>
<td>20. Situational anxiety</td>
<td>42.9</td>
<td>Hallucinations(^1)</td>
<td>45.0</td>
</tr>
</tbody>
</table>

1. Symptoms significant in differentiating the three patient clusters in discriminant analysis. (See text, table 2, and footnote 2 for explanation.)
Fig. 3. Discriminant analysis results for the classification of nine symptoms differentiating the three patient clusters

Cluster A contained 10 patients; cluster B, eight patients; cluster C, six patients. The average symptom scores are plotted on the ordinate for each of the patient clusters on the abscissa. The symptoms appear in the order of their differentiating ability, with hallucinations (upper left panel) the most significant, depersonalization, next (upper middle panel), and irritability (lower right panel) the least significant. The value of the Wilks Lambda index appears with each symptom. All Wilks Lambda values are significant ($p \leq 0.0001$).

The nine symptoms included in Fig. 3 are presented in the order of their significance: hallucinations (upper left panel), depersonalization, somatic function, self-deprecation, lack of insight, tension, lack of concentration, delusions of persecution, and irritability (lower right panel). The Wilks Lambda index, shown with each symptom (Fig. 3), reflects the cumulative extent of differentiation with the addition of
each of the symptom variables, noted by its decreasing value (Tatsuoka, 1971). All values of the Wilks Lambda index are highly significant ($p < 0.0001$). A comparison of the predicted classification of patients based on the discriminant functions with the actual empirical classification (SPSS discriminant analysis) shows that 100% of the "grouped" cases are correctly classified. Little correspondence was found between the hospital psychiatric diagnoses of these patients and their separation into the three clusters.

The threshold data for the normal controls and the three patient groups are plotted in Fig. 4 showing the mean threshold in dB SPL as a function of noise burst duration on a logarithmic abscissa. Note that the functions for the four groups differ in position along the ordinate as well as in slope.

Fig. 4. Threshold in dB SPL for normal controls and three patient clusters

Threshold in dB SPL is plotted on the ordinate as a function of noise burst duration in msec, on a logarithmic abscissa. Data are shown for the normal controls (N) and for patient clusters A, B, and C.

2. Under a (groups-1) rule to determine the number of discriminant functions, two functions were generated in this analysis. In a discriminant analysis, the weighting coefficients of the variables can be interpreted as in multiple regression or factor analysis, in that they identify the variables which contribute most to differentiating the groups along the respective dimension. The order of the four variables contributing most to the first discriminant function in the present analysis from highest to lowest is: depersonalization, self-deprecation, somatic dysfunction, and lack of concentration. For the second discriminant function, the order is: hallucinations, lack of insight, depersonalization, and somatic dysfunction. These six variables correspond to those having the largest $F$ to enter the discriminant analysis.
A two-way ANOVA (repeated measurements on one variable) of the threshold-duration data was performed to compare the four groups: normal controls, patient clusters A, B, and C. The main effect of duration in reducing threshold is highly significant ($F = 115.08; p < 0.0001$). The second main effect of groups almost reaches significance ($F = 2.74; p < 0.06$). The interaction term, however, is highly significant ($F = 4.55; p < 0.001$), indicating that the effect of noise burst duration in reducing thresholds differs across groups.

The sources of the interaction were analyzed using the Newman-Keuls Multiple Comparison tests and are summarized in Table 2 in the form of a comparison matrix.

In summary, the results of the ANOVA and subsequent Newman-Keuls analysis indicate that there are few if any major differences in the threshold-duration relationship between the normals and the patients in cluster B. The major differences are found between the normals and the patients in cluster C and between the patients in cluster C and the other two patient groups for the short duration stimuli. The difference between the normals and the patients in cluster A at the short duration approaches significance ($p < 0.10$). This difference increases and becomes significant at the longer durations.

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Duration (msec)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>1. Normals vs. cluster A</td>
<td>$p \leq$ 0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>2. Normals vs. cluster B</td>
<td>NS1</td>
<td>NS</td>
</tr>
<tr>
<td>3. Normals vs. cluster C</td>
<td>0.01</td>
<td>0.10</td>
</tr>
<tr>
<td>4. Cluster A vs cluster B</td>
<td>NS</td>
<td>0.10</td>
</tr>
<tr>
<td>5. Cluster A vs. cluster C</td>
<td>0.01</td>
<td>NS</td>
</tr>
<tr>
<td>6. Cluster B vs. cluster C</td>
<td>0.01</td>
<td>NS</td>
</tr>
</tbody>
</table>

1. For all NS $p > 0.10$.

The threshold-duration data were subsequently analyzed by a least squares technique in terms of the equation: $\log I (\text{dB}) = \log C (\text{dB}) - b \log t$ to obtain the constants of the integration equation. The least squares analyses indicate that for all groups, the linear term can account for 96 to 98% of the variance. All slope constants are significant ($p < 0.033; p < 0.0005$).

The slope of the function for the normal controls indicates a 6.68 dB decrease in threshold per decade increase in noise burst duration; for the patients in cluster A, the slope term is 5.07 dB per decade; for the patients in cluster B, the slope term is 7.92 dB per decade; while for the patients in cluster C, the slope term is 12.37 dB per decade. A multiple linear regression was performed on the log threshold-log duration data for the four groups. The results indicate that the coefficients (slopes and/or intercepts) differ significantly across the groups ($F = 5.304; df = 6.151; p < 0.0005$).
The individual log threshold-log duration data of each normal subject and patient were fitted by a linear function by the least squares technique to evaluate the slope and intercept. The slopes and intercepts of the members of the four groups were treated as dependent variables and separately analyzed by one-way analyses of variance. The results indicate that the slopes differ significantly across groups \((F = 5.145; df = 3.49; p < 0.0036)\). The major source of the significant difference (Scheffé Multiple Range Test) is between cluster A and cluster C and between cluster C and the normals. The intercepts also differ significantly across groups \((F = 5.732; df = 3.49; p < 0.0019)\). The major source of the significant differences is between cluster C and the normals.

In summary, the main differences in the slopes of the threshold-duration function are between normals, patients in cluster A, and patients in cluster C. Patients in cluster A tend to produce a shallower threshold-duration slope than normal controls, while the patients in cluster C produce a much steeper threshold-duration slope.

**Drug Dosage and the Threshold-Duration Function.** One of the effects of the hospital diagnosis of 23 of the 27 patients as schizophrenic was the drug regimen assigned to them. Almost all of the patients received antipsychotic (phenothiazine) drugs. Three patients received drugs other than phenothiazines. One patient received lithium and methyl t-dopa, one received haloperidol and Valium, while the third received trihexyphenidol HCl, an antispasmodic drug. Of the patients receiving phenothiazines, all but five also received trihexyphenidol HCl, which is generally used for the prevention of extrapyramidal symptoms caused by the phenothiazines. Three of the patients receiving antipsychotic drugs also received Valium.

The dosage levels for 2 to 3 weeks before testing were transformed to chlorpromazine equivalent units (Goodman and Gilman, 1975). This information was evaluated by a neurologist/psychiatrist, who grouped the patients into three chlorpromazine equivalent dosage groups: (a) low, less than 700 mg per day; (b) regular, 750-800 mg per day; (c) high, greater than 850 mg per day.

An ANOVA was performed on these data, i.e., threshold as a function of duration for the three drug dosage groups. Only duration is significant in lowering threshold \((F = 22.6, p < 0.001)\). There is no effect of groups nor is the interaction term significant. In summary, drug dosage does not affect the threshold-duration relation.

**Discussion**

A comparison of the symptom profile groups (patient clusters) differentiated by the discriminant analysis and the hospital psychiatric diagnoses indicated that approximately the same general diagnostic category (schizophrenia) and subcategories were used by the hospital psychiatric staff for patients in all symptom profile groups. Such a general diagnostic approach as utilized by the hospital psychiatrists justifies the initial comparison of all patients with normal controls regardless of the symptom profiles obtained by the discriminant analysis. The results of this comparison indicate two approximately parallel threshold versus noise burst duration functions, with an approximately 6-8 dB decrease per decade increase in duration. These slope values correspond well with recently published data (Bakoff and Gombos, 1976; Penner, 1978). The psychiatric patients show approximately a 5 dB higher threshold than do
normals at all durations. A higher threshold for psychiatric patients at all durations may be attributed to either sensory deficit or poorer motivation.

A different approach to interpreting such a finding, however, may be advanced. Perhaps the single linear function of a heterogeneous population of schizophrenic patients represents a composite of various patient subgroups, each contributing a different slope estimate whose averaged value is represented by the overall patient slope estimate.

Support for this latter interpretation is provided by the subsequent analyses. The data obtained, using the U.S.-U.K. Mental State Interview Schedule, were used to form symptom profiles which, when analyzed by the Smallest Space Analysis, suggested that there were three major profile clusters referred to as A, B, and C. The rank order of symptoms, as well as the discriminant analysis, indicated that the five highest ranking symptoms associated with patient cluster A were mainly affective. The five highest ranking symptoms associated with patient cluster B were typical psychotic symptoms, but hallucinations were absent. The major symptoms associated with patient cluster C were also typical psychotic symptoms, but these patients had hallucinations. (See Table 1 and Fig. 3). On the basis of the discriminant analysis and the average symptom profiles, patients in the A cluster will be referred to as the affective patients; patients in the B cluster will be referred to as the nonhallucinating psychotics; and patients in the C cluster will be referred to as the hallucinating psychotics.

The threshold duration data were found to differ among these groups, with some of the differences being clear cut and others being marginal or nonexistent. The normal controls differed from the affective patients and from the hallucinating psychotic patients; the hallucinating psychotic patients differed from both the affective patients and the nonhallucinating psychotics; the nonhallucinating psychotic patients differed from the affective patients but did not differ from the normal controls. When a linear equation (log I vs. log t) is fitted to the threshold-duration data of the normal and the three patient subgroups, the normals show a 6.68 dB reduction in threshold per decade increase in duration. The function for the affective patients is shallower (5.07 dB decrease in threshold per decade increase in duration). In contrast to these two groups, the slope of the function of the nonhallucinating psychotics is slightly steeper than the normal (7.92 dB per decade increase in duration). The steepest slope is produced by the hallucinating psychotic patients (12.4 dB per decade increase in duration).

These data indicate deviations from the normal in the processing of sensory information over short durations. Integration of stimulus energy occurs with both shallower than normal, and steeper than normal, types of summation, which are associated with particular types of patient symptom profiles. The shallower partial summation found for the affective patients can be interpreted as a relative loss of information as stimuli are increased in duration, i.e., increasing energy via duration instead of via intensity results in a loss of information. The very steep summation function found for the hallucinating psychotic patients can be interpreted as a relative loss of information as stimuli are shortened in duration. As duration decreases, more intensity must be added than is lost due to the decrease in duration. In both cases, the loss of information due to changes in duration is different than for the normals.

One question which may be raised concerns the effect of level on the slopes of the threshold versus noise burst duration functions. Since the absolute threshold, i.e., the
absolute level of the noise bursts, for the affective patients is higher than for the normals at every duration, perhaps the slope difference between the two groups is related to the absolute difference in level. Penner (1978) compared (for normal subjects) the results of the time-intensity trade in the presence of an uncorrelated continuous background noise to the time-intensity trade in the absence of a background noise. Although the results indicated a difference in overall absolute thresholds of approximately 20 dB, the slopes of the two functions were approximately equal. A similar experiment by Gengel (1972), in which relatively high masked threshold levels were used, also indicated no effect of high level background noise on the slope of the integration function. Gengel's (1972) and Penner's (1978) results argue against assigning the different slopes found among the various patient subgroups to the absolute differences in level.

**Affective Patients vs. Normal Controls.** The threshold-duration data of the affective patients imply an ineffective use of the energy available in a stimulus when that energy is spread over time, although the integration process is operative over these durations. Malone and Hemsley (1977) reported the results of an auditory signal detection study in 10 depressed patients who were not receiving antidepressants. Auditory detection was studied using a 1 second duration tone presented against a noise background. Although the design of their experiment did not allow for a quantitative (in dB) assessment of the differences in threshold, their data do indicate a significant decrease in d' for the depressed patients relative to the normal controls, as well as an improvement in d' when the patients received antidepressant medication. Their data support the findings of Bruder et al. (1975) that patients with affective disorders show lowered auditory sensitivity. In addition, their data also support our findings that the auditory thresholds of affective patients for longer duration stimuli are higher than those of normals and nonaffective psychotic patients.

Malone and Hemsley (1977) conclude that their results can be interpreted as reflecting differences in selective attention which could affect d' (Broadbent, 1971). Such an interpretation, as noted above, is possible for a bivalent (difference) result. The significant difference in slope between the affective patient auditory integration function and the integration functions of the normals and the nonaffective psychotics reported here militate against such an explanation for our findings. Lowered attention would presumably affect auditory thresholds in the same manner for all durations and would result in a displaced function with the same slope. However, it is conceivable that detecting a shorter duration stimulus is more difficult than detecting a longer stimulus, and "attentional" differences could account for the finding in the hallucinating psychotic patients. Such an explanation would not account for the reduced slope in the affective patients.

**Hallucinating Psychotic Patients vs. Nonhallucinating Psychotic Patients and Normal Controls.** The data of both groups of nonaffective patients indicate steeper threshold vs. noise burst duration functions than for the affective patients or normal controls. The slope of the threshold vs. noise burst duration function of the hallucinating psychotic patients is much steeper than for any other group.
In the study of Bazhin et al. (1975), the decrease in threshold for the tone as a function of its duration for the normal controls and paranoid nonhallucinating patients is the same for the two ears. Hallucinating schizophrenic patients, however, show a steeper rise between 1 and 10 msec for the function in the right ear than for the same function for the left ear. The ear differences in threshold are related to the extent of the hallucinations, being greater for "genuine" auditory hallucinations, than for "psychic" hallucinations. They report, however, that ear asymmetry in the threshold-duration function is found for all forms of perceptual delusion studied.

Bazhin et al. (1975) related their findings to previous work indicating similar asymmetry to be characteristic of left temporal lobe pathology (Gersuni et al., 1971). Patients suffering from temporal lobe pathology show a greater increase in threshold for short-duration signals presented to the ear contralateral to the lesion.

The data of the present study indicate a somewhat steeper slope for the nonhallucinating psychotic patients (7.92 dB) than for the normal controls (6.68 dB) and a much steeper slope for the hallucinating psychotic patients (12.39 dB) than for either normal controls or for the other two psychiatric groups. The patients with the steepest slope ranked highest on hallucinations, lack of insight, self-deprecation, and perceptual distortions—all mainly cognitive and perceptual dysfunctions. Our data for right ear thresholds thus seem to be quite consistent with the finding reported by Bazhin et al. (1975) for psychiatric patients suffering from hallucinations and perceptual distortions, i.e., a steeper than normal threshold-duration function for the short duration stimuli.

The findings of the present study, as well as those of Bazhin et al. (1975), are implicitly in conflict with the report by Bruder et al. (1973) that for short duration stimuli (clicks to the right ear) thresholds for schizophrenic patients were not different from those of normal controls. However, since they did not explicitly segregate hallucinating from nonhallucinating patients in their analysis, it is difficult to evaluate whether their findings are in fact in conflict with the present study and that of Bazhin et al. (1975).

**Temporal Integration in the Visual System.** Collins (1972) and Collins et al. (1978) reported findings which involved comparison of the reaction time to a 2 msec light pulse with the reaction time to a 4 msec light pulse. They referred to this comparison as the "energy effect." It can be considered as an estimate, based on two points, of the slope of the reaction time-stimulus duration function. Collins (1972) reports that four of the 10 patients diagnosed as schizophrenic reported hallucinations; the other six had reported no hallucinations (CAPP'S; Endicott and Spitzer, 1972). Of the nine patients diagnosed as nonschizophrenic, two had reported hallucinations, and one had no reported symptom of depression, leaving six patients with mainly affective symptomatology without hallucinations.

We undertook a reanalysis of Collins' data in which we related "energy effect" (i.e., the estimated slope of the reaction time-stimulus duration function based on the difference between the reaction time to the 4 msec stimulus and the reaction time to the 2 msec stimulus) to the following three patient subgroups, formed on the basis of the reported psychiatric diagnoses and CAPP'S symptomatology: a group of six patients diagnosed as schizophrenic but having no hallucinations, a group of four patients
diagnosed as schizophrenic with hallucinations; a group of six patients diagnosed as non schizophrenic with affective symptoms. These groups were compared to Collins' 10 normal controls.

The results of a one-way analysis of variance indicate a highly significant difference between the groups ($F = 4.61; p < 0.012$). The mean reaction time difference score for the normals was 58.5 msec; for the nonhallucinating schizophrenic patients, 50.00 msec; for the non schizophrenic (affectives) patients, 35.17 msec; and for the hallucinating schizophrenic patients, 80.75 msec. These group mean reaction time difference scores were subsequently analyzed by a $t$-test for contrasts (Dixon and Massey, 1969). The results indicate that the affective patients have a significantly smaller reaction time difference score than either the normals ($p < 0.030$) or the hallucinating schizophrenics ($p < 0.0015$). The hallucinating schizophrenics have a significantly larger difference score than the non hallucinating schizophrenics ($p < 0.02$), and the comparison with the normals almost reaches significance ($p < 0.06$). The difference score of the nonhallucinating schizophrenics does not differ from that of the normals ($p < 0.4$). To the extent that the reaction time difference score represents an estimate of the slope of the reaction time vs. stimulus duration function, the hallucinating schizophrenics show a steeper slope than the normals, while non schizophrenic affective patients show a shallower slope than the normals. Non hallucinating schizophrenics have the same slope as the normals.

It is quite tempting to compare the results of the present study, which indicate significant differences in the slopes of our threshold-duration function for auditory stimuli, with the reanalyzed data of Collins (1972) for reaction time to visual stimuli. In both studies, hallucinating patients yielded steeper slopes of the behavior-duration function than normal controls while psychiatric patients with predominantly affective symptomatology yielded much shallower slopes. Such congruence of results may imply a generalizable finding across the sensory modalities of specific types of deviations in stimulus integration associated with specific types of symptoms. However, some caution is indicated because of the differences in the dependent variable used in the present study (psychophysical detection) and that of Collins (reaction time). This analysis of the visual reaction time data points toward the need for a direct comparison of threshold for visual stimuli of different durations among normals and subgroups of psychiatric patients differentiated according to symptomatology with auditory thresholds as in the present study.

Braff et al. (1977) have also presented visual evoked potential data which they interpret as indicating dysfunction of the short time constant information processing system in schizophrenia. These authors propose that this deficit reflects a relatively increased sensitivity (overactivity) of fast neurons with concomitant dysfunction of short time constant processing of information.

In summary, the data reported here indicate differences in stimulus integration for the auditory system between normal controls and affective patients, as well as between hallucinating psychotic patients and normals and between hallucinating psychotic patients and affective patients. The fact that patient subgroups formed on the basis of symptom profiles differ from each other and from the normal controls on an auditory energy integration function points to the importance of considering dysfunction in short time constant phenomena in psychopathology.
Acknowledgment. This research was supported by grant #770 from the United States-Israel Binational Science Foundation. The authors are extremely grateful for the aid, encouragement, and cooperation of Dr. O. Haker, Director of the J. Abarbanel Mental Hospital, Bat-Yam, and Dr. R.H. Belmaker, Clinical Research Director at Ezrath Nashim Hospital, Jerusalem, for providing the psychiatric patients and hospital facilities for this study. Without their active support, this study could not have been accomplished. In addition, the authors wish to express their gratitude to Mr. J. Gutgold for aid in building and maintaining the equipment; to Mrs. Y. Edward (Honig) and to Dr. M. Snyder for their aid in the research and data analysis. We would like to thank Dr. B.J. Gurland for helpful discussions with respect to patient classification and Drs. M.L. Kieftzman and P. Collins for making available the reaction time-duration data for their normal and psychiatric populations.

References


Guttman, L. A general nonmetric technique for finding the smallest coordinate space for a configuration of points. Psychometrika, 33, 469 (1968).


