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CENTRAL AUDITORY PROCESSING OF SPEECH AND NON-SPEECH
STIMULI IN AFFECTIVE PSYCHOTICS AND SCHIZOPHRENICS:
A NEUROPSYCHOLOGICAL INVESTIGATION

by

ALLAN YOZAWITZ

A dissertation submitted to the Graduate
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Abstract

CENTRAL AUDITORY PROCESSING OF SPEECH AND NON-SPEECH STIMULI IN AFFECTIVE PSYCHOTICS AND SCHIZOPHRENICS: A NEUROPSYCHOLOGICAL INVESTIGATION

by

Allan Yozawitz

Advisor: Professor Louis D. Costa

This study was designed to uncover characteristic differences in central auditory processing between carefully defined psychiatric subgroups of affective psychotic patients and schizophrenic patients to enhance the validity of their independent classification and to help resolve the locus within the central auditory nervous system (CANS) that is responsible for these perceptual differences.

Twenty psychiatric inpatients, ten non-patient controls and two right temporal lesioned controls were tested on a carefully selected battery of speech and non-speech measures which have been proven to be valid indicators of CANS dysfunction. The speech measures consisted of a word discrimination test (CID W22), a staggered spondaic word test (SSW), a test of the binaural fusion of filtered speech (DBF) and a dichotic competing sentence test (Binaural Separation Test). The non-speech measures con-

sisted of forced-choice audiometry and a forced-choice measure of the binaural energy summation of click pairs presented at threshold intensity levels and dichotic for each ear leading with respect to interaural onset time.

Independent study diagnoses based upon semi-structured interviews were provided by a psychiatrist who was blind to the nature of the study. Of the twenty inpatients who had all received hospital diagnoses of schizophrenia, nine were reclassified as affective psychotic while eight retained the diagnosis of schizophrenia. The acoustosensory performance of these two patient groups was contrasted with each other and with the two non-patient control groups.

This study successfully demonstrated that clinical dissimilarities between affective psychotic patients and schizophrenic patients underlie predicted differences in their CANS perceptual functioning. Affective psychotic patients displayed evidence of lateralized right temporal lobe dysfunction for dichotic measures employing both speech and non-speech stimuli. The direction of their interaural asymmetries was consonant with the performance of the two right temporal lesioned controls and with predicted performance based upon Flor-Henry's hypothesis that affective psychosis is associated with predominantly non-dominant limbic-temporal lobe dysfunction. The schizophrenic patients, in contrast, did not display evidence of lateralized cortical dysfunction. Furthermore, the hypothesis of an association between the functional psychoses and generic brain stem dysfunction at or below the level of the superior olive received no support.

However, the finding that the averaged pure tone sensitivity for both patient groups was reduced by approximately 5 dB in both ears suggests that the hypothesis of upper brain stem dysfunction cannot be ruled out.

The implications of these findings for effective psychiatric treatment are discussed.

CHAPTER I

INTRODUCTION

Since Kraepelin (1919) isolated the nosological concepts of dementia precox and manic-depressive insanity, on the basis of differential patterns of recovery, psychiatrists have been struggling to achieve greater nosological differentiation within the functional psychoses in an attempt to improve the treatment outcome for their patients. In recent years, the development of new and more effective psychopharmacological therapeutic agents (i.e., tricyclic antidepressants, MAO inhibitors and lithium carbonate) for the treatment of manic-depressive illness has underscored the desirability of improving the diagnostic detection of affective psychotic patients from the totality of schizophrenic patients.

Ollerenshaw (1973) contends that if one utilizes pharmacological and prognostic criteria, much of what is currently classed as acute schizophrenia is really manic-depressive psychosis. The manic phase of the manic-depressive cycle produces florid symptomatology which is often schizomimetic and thus increases the difficulty of differential diagnosis. This is attributable, in part, to the mistaken belief that some symptoms often associated with schizophrenia do not also occur in affective disorders.

This problem was substantiated by the data of the US-UK diagnostic project (Cooper, Kendell, Gurland, Sartorius and Farkas, 1969) in a study of admissions to public mental hospitals in London and New York. Compared to the symptom ratings and diagnoses

made by the project's research psychiatrists which were shown to be cross-nationally reliable, hospital psychiatrists in both London and New York had a much wider concept of schizophrenia and a much narrower concept of affective disorder. New York hospital psychiatrists applied the diagnosis of schizophrenia 26.9% more often than project psychiatrists and used the diagnosis of affective disorder 20% less often than project psychiatrists. Similarly, London hospital psychiatrists applied the diagnosis of schizophrenia 12.4% more often than project psychiatrists and used the diagnosis of affective disorder 12.4% less often than project psychiatrists. Moreover, Abrams, Taylor and Gaztanaga (1974) found that only two of a sample of 41 patients admitted to an acute treatment psychiatric inpatient unit with a diagnosis of paranoid schizophrenia satisfied a rigorous diagnostic research criteria for schizophrenia. Half of the total sample of these patients were reclassified as manic and were found to be similar to patients who were admitted to the unit with the diagnosis of mania, for demographic, genetic and pharmacological treatment response variables.

Morrison, Clancy and Crowe (1972) in a 25-35 year follow-up study using research diagnostic criteria similar to Abrams et al. (1974), excluded 63% of their original sample of schizophrenics for failing to satisfy the new stringent criteria. The validity of these new diagnostic criteria were demonstrated by the achievement of a clear separation of family members in a blind family history assessment that compared the relatives of schizophrenic and affective psychotic probands. Numerous other studies have

reported the presence of schizophreniform symptomatology for groups of patients who were both responsive to lithium carbonate and who had a longitudinal prognostic course that was consonant with affective psychosis (Carlson and Goodwin, 1973; Carpenter, Strauss and Muleh, 1973; Lipkin, Dyrud and Meyer, 1970; Ollershaw, 1973; Taylor, Gaztanaga and Abrams, 1974; and Gershon and Yuwiler, 1960).

The clinical solution to the problem of diagnostic ambiguity is not easily resolved. For example, it has been well established, on the one hand, that manic-depressive psychotics respond to lithium carbonate treatment (Goodwin and Ebert, 1973; Peet, 1975; Schou, 1973). Affective patients who have been misdiagnosed as schizophrenic will inevitably have a prolonged course of illness and suffer unnecessarily by not having had the opportunity to benefit from such treatment. On the other hand, it has been reported (Johnson, Gershon, Hekimian, 1968; Shopsin and Gershon, 1973) that lithium carbonate may be neurotoxic in some schizophrenic patients. Therefore, any simple attempt to increase the proportion of diagnoses of affective psychosis without careful validation would be both counterproductive and unwarranted.

One area of investigation that has attempted to achieve validation for discrete diagnostic categories has focused upon distinctive modes of central nervous system functioning in mental illness (see Akiskal and McKinney, 1975; and Mirsky, 1969). Similar suggestions of a possible organic etiology for the functional psychoses had been considered even prior to the pioneering work of Kraepelin (Flor-Henry, 1969). However, despite the great

technological developments that have led to progress for the assessment of CNS functioning, this avenue of investigation has been impeded by the same diagnostic imprecision that has precluded the achievement of clinical validation based upon conventional prognostic criteria.

The primary requisite of any scientific investigation is the objective standardization of the criterion (see Sutton, 1973). It has long been recognized that apparent contradictions between the results of some studies investigating CNS functioning for psychiatric patients may have reflected the diagnostic heterogeneity of the patient groups that were selected (Shakow, 1962; Zubin, 1966; Mendels, 1970; Noble and Lader, 1971). This study aims to investigate central auditory nervous system (CANS) functioning for carefully defined and relatively homogeneous samples of patients to test the hypothesis that clinical dissimilarities between affective psychotic patients and schizophrenic patients underlie predicted differences in their central auditory perceptual functioning. The clinical benefit that might be derived from such an investigation is considerable; to render objective and unequivocal diagnostic indicators that may be effectively used to separate these psychiatric subgroups for differential treatment. To the extent that etiological dissonance is implied by discordant diagnostic indicators, these objective indices may also have utility for the assessment of vulnerability to specific psychiatric disorder (see Zubin and Kietzman, 1966; Buchsbaum, 1976).

Limbic-Temporal Lobe Hypothesis

A good deal of attention has been devoted to ascertaining the primary locus of dysfunction within the brain that may be fundamentally responsible for functional psychiatric disorder. The problem of localization of higher mental functioning within the cerebral cortex was brought into modern perspective with the work of Hughlings-Jackson (1869). Jackson first recognized that circumscribed brain lesions result in a disorganization of function that is often manifested as abnormal performance rather than as the complete loss of a particular function. Although higher mental functioning may be disturbed by a lesion to one of many cortical areas which are linked within the "functional system," the characteristic nature of such a disturbance is dependent upon the location of that lesion (Luria, 1973). Furthermore, Luria (1973) noted that "...a lesion of a single, circumscribed area of the cerebral cortex often leads to the development, not of an isolated symptom, but of a group of disturbances, apparently far removed from each other [p. 74] " (i.e., a syndrome).

One of the most widely accepted hypotheses concerning the etiological basis of affective psychosis is that the metabolism of biogenic monoamines may be disturbed at some functional site within the brain (Frazer, 1975). Monoamines, functioning within the CNS as neurotransmitters, mediate electrochemical synaptic neural activity. The homeostatic regulation of such neural activity is thought to be disturbed during the depressive stage of affective psychosis either through insufficient levels of catecholamines (i.e., norepinephrine or dopamine) or through excessive

levels of indolamine (i.e., serotonin) or acetylcholine in the CNS (Baldessarini, 1975). Indeed, the successful antidepressant action of psychopharmacological agents has been attributed to their efficacy in increasing catecholamine levels at postsynaptic receptor sites by either preventing their reuptake by presynaptic receptors (e.g., tricyclics) or by preventing their catabolism (e.g., MAO inhibitors) (Schildkraut and Kety, 1967).

Mirsky (1969) has suggested that subtle "biochemical-metabolic lesions," which may be undetectable with conventional histological techniques, may be implicated in the pathogenesis of psychiatric disorder. A good deal of research with animals has indicated that major changes in brain monoamine levels may be induced by social stress (e.g., see Barchas and Freidman, 1963; Bliss and Zwanziger, 1966). It is not inconceivable that chronic monoamine homeostatic imbalance, which may be sustained by prolonged social stress, may be neurotoxic and thus lead to the genesis of these "biochemical-metabolic lesions" (see Shaywitz, Yager, and Klopfer, 1976; Sporn, Harden, Wolfe and Molinoff, 1976). Moreover, this may be especially marked during critical periods of neural maturation.

Several behavioral disturbances associated with the diagnostic syndrome of affective psychosis such as variability of mood, appetite, libido and sleep patterns suggest hypothalamic involvement. Recent evidence supports the hypothesis that monoaminergic neural pathways regulate the neuroendocrine cells which secrete the hypothalamic releasing hormones. Citing this evidence, Sachar (1975) suggests that the widely known hypersecretion of cor-

tisol by many depressed patients (Gibbons, 1964; Sachar, Hellman, Fukushima and Gallagher, 1970; Carrol, Curtis, Davies, Mendels and Sugerman, 1976) may therefore "...provide support for the current hypothesis that depressive illness is associated with diminished hypothalamic catecholaminergic activity [p. 126]."

It has been demonstrated, in studies with animals, that lesions which sectioned the medial forebrain bundle (MFB) have been associated with decreased brain monoamine levels (see Wender, 1971). Conversely, Stein (1971) has postulated that a catecholamine deficiency in the brain can influence behavior by decreasing the synaptic neural activity within the MFB. Termed the neuroanatomical substrate of reward (see Wise, Berger and Stein, 1973), the MFB is a nerve tract which runs through the hypothalamus from the brain stem to the cerebral cortex.

Mednick and Shulsinger (1968) found evidence which suggested that severe psychiatric breakdown is related to perinatal complications involving anoxia. Penfield (1954) postulated that during anoxic parturition, the fetal head is moulded so that the anterior choroidal and the posterior cerebral arteries are compressed against the incisura of the tentorium. He further proposed that this resulted in damage to mesial temporal lobe structures which sometimes ripened into an epileptogenic focus. Windle (1969) demonstrated with monkeys that, subsequent to birth anoxia of sufficient duration to necessitate resuscitation, severe lesions of the brain stem, basal ganglia, thalamus, and inferior colliculus were permanently inflicted despite the transitory nature of the behavioral handicaps. Towbrin (1969) has also shown that brain

damage resulting from anoxia is located primarily sub-cortically in the periventricular system (PVS). The PVS, as the neuroanatomical substrate of punishment, is the antithetical regulatory counterpart of the MFB.

It appears conceivable, therefore, that disturbed function within mesial temporal or limbic structures may be generated either by severe lesions resulting from perinatal anoxia or by functional "biochemical-metabolic lesions" related to disturbed monoamine metabolism. Abundant evidence from investigators, with both animals and humans, has revealed the function of the mesial temporal and limbic structures to be the modulation of emotional and cognitive function (e.g., Klüver and Bucy, 1937; MacLean, 1949; Penfield and Jasper, 1954; Olds, 1959; and Valenstein, 1973). Such a proposed locus of dysfunction would be compatible with the nature of the behavioral disturbances associated with functional psychiatric disorder.

Falconer (1971) has stated that the epitome of a lesion affecting the limbic lobe is manifested by temporal lobe epilepsy. Psychomotor seizures arising from temporal lobe epilepsy are considered to be the expressions of a paroxysmal functional disturbance within the limbic system (Mignone, Donnelly and Sadowsky, 1970). It is not surprising, therefore, that the functional psychoses have had a long history of being linked to the occurrence of temporal lobe epilepsy (see Flor-Henry, 1969).

In a study to test this hypothesis, Gibbs (1951) found that psychiatric disorders were three times more common in patients with anterior temporal seizure foci than in those with seizure

foci located elsewhere in the brain. Slater and Beard (1963) reported that of 69 psychotic epileptics in their study, 80% showed evidence of temporal lobe dysfunction on the basis of a history of psychomotor seizures and temporal spiking on their EEG. Although numerous other studies have confirmed these results (e.g., Malamud, 1967; Horowitz and Cohen, 1968; Falconer and Taylor, 1968; and Flor-Henry, 1969), some controversy exists regarding the specific types of psychopathology associated with differential epileptic foci (Mignone, et al., 1970). Moreover, some studies which have failed to replicate the strong association between temporal lobe epilepsy and functional psychosis have questioned whether the strength of that association was a spurious effect due to either sampling problems or other methodological issues (Mirsky, Primac, Ajmone-Marsan, Rosvold and Stevens, 1960; and Small, Small and Hayden, 1966).

Laterality Hypothesis

Flor-Henry (1969) compared 50 temporal lobe epileptics who had also been classified as psychotics with 50 temporal lobe epileptics who had never experienced psychiatric symptoms. He concluded that: 1) Psychosis for temporal lobe epileptics was not etiologically associated with structural cerebral damage but was related to underlying patterns of abnormal neuronal activity within the temporal lobe and its limbic projections. 2) An epileptic focus within the dominant temporal lobe was associated with diagnoses of schizophrenia. 3) An epileptic focus within the non-dominant temporal lobe was associated with diagnoses of manic-depressive psychosis.

Flor-Henry (1976) further developed his hypothesis concerning differentially lateralized temporal lobe dysfunction between schizophrenia and manic-depressive psychosis based upon both a diverse review of the literature and new evidence from an original double blind investigation. Employing neuropsychological test data to independently validate psychiatric research diagnoses, a multiple step-wise discriminant function analysis yielded an 85% correct classification for schizophrenia and a 94% correct classification for affective psychosis. Proposing a slightly modified hypothesis, Flor-Henry (1976) stated that the functional psychoses appear to be manifestations of bilateral, although predominantly lateralized, asymmetrical neuronal disorganization in the anterior temporal-limbic regions. Specifically, schizophrenia was proposed to be a consequence of predominantly left anterior temporal dysfunction, while affective psychosis was proposed to be a consequence of right anterior temporal dysfunction.

Hommes and Panhuysen (1971) have suggested that there is a negative correlation in affective psychotic patients between the severity of their depression and the degree to which speech is unilaterally represented in their left hemispheres, as determined through the use of the Wada (1949) technique of intracarotid sodium Amytal injection. Similarly, both Slater (1953) and Gottesman and Shields (1972) have observed a higher than normal percentage of mixed lateral preference in pairs of monozygotic (MZ) twins who were discordant for schizophrenia compared with normal levels of mixed lateral preference in pairs of MZ twins who were

concordant for schizophrenia.¹ These data are intriguing, for they not only support the notion that asymmetrical neural functioning influences the phenotypic expression of psychotic states, but suggest that lateralized neural functioning may also be a trait variable that could potentially serve as a measure of psychiatric vulnerability.

Much of what is known about the differences in cognitive function between the cerebral hemispheres has been provided by studies of patients with disconnected hemispheres or with unilateral cortical lesions (e.g., see Sperry, Gazzaniga and Bogen, 1969; Nebes, 1971; Hécaen, 1962; Milner, 1971; Milner and Taylor, 1972; Zangwill, 1967). Recently, a number of studies with normals have added to this knowledge (e.g., see Schwartz, Davidson and Maer, 1975). As Teuber (1975) has stressed, the concept of dominance of the left over the right hemisphere has been replaced by the notion of complimentary specialization. The function of the left hemisphere has come to be primarily described as "analytic," subserving language functioning, while the function of the right hemisphere has come to be primarily described as "configurational," subserving impressionistic functioning.

Certainly, the hypothesis proposed by Flor-Henry (1976) conforms to these conceptions. Schizophrenic speech disturbances have been phenomenologically linked with aphasic speech distur-

¹The theory suggested by Satz, Fennel and Jones (1969) was that opposite handed twins are heterozygous for alleles determining cerebral dominance and are thus susceptible to incomplete penetrance of lateralization. If environmental factors impinge on these two different CNS structures, they may differentially react so that only one may become psychotic.

bances for many years (e.g., Kleist, 1960; Geschwind, 1964; Critchley, 1964). Moreover, it has also been long recognized that while propositional speech was characteristically impaired with aphasic speech disturbances, affective speech was usually spared (Hughlings-Jackson, 1879). In a recent study confirming these observations, Heilman, Scholes and Watson (1975) reported that affective speech was, in fact, impaired for patients with right temporal lesions.

The findings of a number of psychophysiological studies measuring evoked responses (Perris, 1974), EEG's (d'Elia and Perris, 1973, 1974; Flor-Henry, 1976; Goldstein, 1975) or skin conductance (Gruzelier and Venables, 1973, 1974) also point to lateralized hemispheric dysfunctions in schizophrenia and in manic-depressive psychosis, although there is some disagreement in the interpretation of these findings with respect to which hemisphere is malfunctioning (see Bruder, 1975 for a review of these studies). The same ambiguity is conveyed by the literature on whether unilateral non-dominant electro-convulsive therapy (ECT) is more effective than conventional bilateral ECT (see Galin, 1974).

Assessing the aggregate body of evidence which supports his hypothesis, Flor-Henry (1976) concluded that "...the association between schizophrenia and the left hemisphere is more powerfully established than that of the lateralization to the right hemisphere of the affective syndromes [p. 788] ." It is, therefore, one of the goals of this study to clarify that association between lateralized right hemisphere dysfunction and the affective psychoses. Since the temporal lobe includes both the nuclear and the extranuclear auditory cortical zones, measures of central auditory nervous system (CANS) functioning may be of particular value in testing for later-

alized temporal lobe dysfunction in schizophrenia and in affective psychosis.

Brain Stem Hypothesis

An alternate hypothesis concerning the locus within the brain that may be fundamentally responsible for functional psychiatric disorder is that the functional integrity of brain stem structures may be impaired. Some behavioral concomitants of brain stem dysfunction such as level of arousal (see Mednick and Schulsinger, 1968; Venables, 1963), sleep disruption and affective blunting are certainly consonant with psychotic disturbance. For example, the reported absence of stage IV sleep in affective psychosis (see Whybrow and Mendels, 1969) corresponds with the well known observation that lesions of the raphe nuclei of the brain stem may alter sleep patterns by reducing stage IV sleep (see Mirsky, 1969). Moreover, tricyclic and MAO inhibitor antidepressant agents have been shown to inhibit the firing of presynaptic serotonergic neurons in the raphe system of the brain stem (Sheard, Zolovick and Aghajanian, 1972).

Baldessarini (1975) has suggested that the site of monoamine neurotransmitter action involves both the diencephalon and the brain stem. Certainly, the development of histochemical fluorescent techniques have shown that the cell bodies which are the sources of either the serotonergic or the noradrenergic neural tracts are located at various sites along the brain stem (e.g., the lower raphe nuclei of the pons and the reticular formation of the medulla) (Ungerstedt, 1971). Additionally, Guth and Bobbin (1971) have summarized recent evidence for the cholinergic innervation of the olivocochlear bundle. It should also be recalled that the extent of

the anoxic damage demonstrated by Windle (1969) was rather diffuse and included some brain stem areas. Therefore, it is another goal of this study to help clarify this issue of localization within the CNS concerning the primary site of dysfunction for schizophrenia and manic-depressive psychosis. The employment of measures of CANS functioning may be particularly valuable in this regard because of the development of new techniques for evaluating the integrity of the CANS (Berlin, 1976).

Auditory Perceptual Dysfunction Associated with Temporal Lobe

Lesions

The auditory cortex is divided into primary (projection) and secondary zones within the lateral portion of the temporal lobes. The organization of the cortical projection zones, however, differs from that for the visual system in that complete representation for each ear is not restricted to the contralateral hemisphere. Thus, auditory perceptual deficits arising from unilateral temporal lobe lesions are compensated to some extent by the functional integrity of the intact temporal lobe. It is for this reason that unilateral temporal lobe lesions of Heschl's gyrus (i.e., the topographical locus of the auditory projection zone) do not result in central hearing loss as measured by pure tone audiometry (Karaseva, 1972; Hodgson, 1967). However, recent studies (Blinkov and Karaseva, 1967; Gersuni, Baru, Karaseva and Tonkonogii, 1971; Karaseva, 1972) have demonstrated, using both brief tone audiometry and suprathreshold RT measures, that unilateral superior-temporal lobe lesions (i.e., including primary auditory cortex) lead to impaired perception of transient (i.e., 1 msec.) auditory stimuli (e.g., clicks) in the ear contralateral to the lesion. Moreover, these same pa-

tients who demonstrated a loss in auditory sensitivity to brief stimuli, produced normal audiograms and improved their reaction times when the auditory stimuli were of long duration (i.e., 120 msec.).

Pavlov, working with animals, first showed that temporal cortical lesions produced a functional disturbance in their ability to form differential reflexes to combined acoustic stimuli (see Luria, 1973). Numerous other studies with temporal lobectomized animals (e.g., Butler, Diamond and Neff, 1957; Masterson, Jane and Diamond, 1967) and with temporal cortical lesioned patients (Ax and Colley, 1955; Bender and Diamond, 1965, 1975; Swisher and Hirsh, 1972; Carmon and Nachson, 1971; Efron, 1963; Lackner and Teuber, 1973) have confirmed that it is the integrity of the secondary zones of auditory cortex that is essential for the kind of veridical temporal perception that permits the resolution of combined acoustic stimuli. Such perceptual resolution is important, for it has been proposed that fine time discriminations underlie the perception of speech (Liberman, Cooper, Shankweiler and Studdert-Kennedy, 1967; Studdert-Kennedy and Shankweiler, 1970).

It has even been suggested that the perceptual inability to correctly discriminate certain phonemic features, such as may result from a failure to resolve rapid formant frequency transitions (Darwin, 1971), could produce a profound effect upon the development of internalized speech (Vygotsky, 1962) and may subsequently alter the development of adaptive cognitive processes (Allen, 1969). It is thus interesting that Tallal (1974) has demonstrated that developmental aphasics, without other evidence of neurological impairment, have shown significant improvement in their ability to

discriminate between stop consonants when the initial formant transitions were lengthened. Lowe and Campbell (1965) and Rosenthal (1970, 1971) have similarly reported that developmental aphasics displayed increased time constants for the perception of both the successiveness and the temporal order of tonal and of speech stimuli.

A major focus of recent psychophysiological research has been the interpretation of the role of hemispheric specialization in the mediation of temporal processing. Some investigators, who have studied unilateral temporal lobe lesioned patients, have conjectured that only the left temporal lobe was responsible for the processing of temporal sequencing (e.g., Efron, 1963; Swisher and Hirsh, 1972; Carmon and Nachson, 1971; Albert, 1972). However, others have postulated the presence of differentially specialized² auditory areas in each hemisphere to independently subserve the temporal processing of speech and non-speech stimuli (e.g., Shankweiler, 1966; Kimura, 1964; Milner, 1962). Numerous other investigations with normals which have employed either behavioral measures (e.g., Murphy and Venables, 1970; Halperin, Nachson and Carmon, 1973; Morais and Darwin, 1974; Papçun, Krashen, Terbeek, Remington and Harshman, 1974) or electrophysiological measures (e.g., Cohn, 1971; Wood, Goff and Day, 1971; Neville, 1974; Freidman, Simson, Ritter and Rapin, 1975) have also failed to provide conclusive evidence that complex auditory stimuli are unilaterally

²Phasic cells in the auditory cortex may be involved in the detection of the onset and the offset of acoustic signals and may play a specific role in detecting repetitive transient sequences (see Sovijärvi, 1975).

processed by the left temporal cortex. In view of these divergent opinions, this study will utilize binaural paradigms for both speech and non-speech stimuli so that the combined function of the two cortical hemispheres may be assessed with respect to the mediation of temporal processing.

A particularly valuable binaural paradigm for assessing the perception of speech and non-speech stimuli has been the method of dichotic stimulation. By definition, the method consists of the binaural presentation of disparate acoustic information to each ear. A variant of this procedure is the case where the disparate acoustic information is not the content but, instead, an interaural onset time difference. Studies which have employed this variant of dichotic stimulation with unilateral temporal lesioned patients have studied auditory localization (e.g., Bender and Diamond, 1965; Sanchez-Longo and Forster, 1958) and the perceptual resolution of successive clicks (Lackner and Teuber, 1973; Bender and Diamond, 1975).

The results of the localization studies have generally been that patients would either ignore or mislocate stimuli which should have otherwise been perceived in the auditory half space contralateral to the affected hemisphere (see Benson and Teas, 1976 for a suggested neurophysiological model for this misperception). There is as yet, however, no consensus regarding the results of the two click fusion studies. Although Lackner and Teuber (1973) and Bender and Diamond (1975) agree that two click resolution was impaired by unilateral left temporal lobe lesions, only Bender and Diamond have presented evidence of such impairment following right temporal lesions. Moreover, Bender and Diamond presented

evidence that two click resolution was differentially impaired depending upon the order of click presentation. They attributed this to a functional right sided bias for right temporal lesioned patients and to a functional left sided bias for left temporal lesioned patients. They theorized that when a click was presented to the side ipsilateral to the affected hemisphere, it "predominated" (i.e., a bias existed) over the perception of the click to the side contralateral to the affected hemisphere. Thus, when the initial click was presented to the ipsilateral or favored side, poorer resolution resulted for the perception of the binaural click pair (i.e., a greater interaural delay was necessary for the independent perception of the contralateral lagging click).

The most frequently applied variant of the dichotic stimulation method has been the case where the disparate acoustic information consisted of a difference in interaural content. Studies which have employed this procedure with unilateral temporal lesioned patients have generally studied the perception of speech stimuli. The results of these numerous studies, utilizing dichotic speech discrimination tests of many varieties, have also demonstrated impaired performance for the ear contralateral to the affected hemisphere, with the greatest asymmetrical impairment observed with right temporal lesions (e.g., Kimura, 1961; Berlin and Lowe, 1972; Jerger, 1964; Katz, 1962; Lynn and Gilroy, 1972).

Rosenzweig (1951) has suggested that the measurement of such perceptual impairment for the contralateral ear is enhanced with the method of dichotic stimulation because it results in the partial occlusion of the ipsilateral neural pathways by the contra-

lateral neural pathways. The left ear suppression seen with commissurotomed patients (Milner, Taylor and Sperry, 1968; Sparks and Geschwind, 1968) similarly attests to the suppression of the ipsilateral neural pathways during dichotic stimulation.

If the mechanism of dichotic stimulation does indeed result in the suppression of the ipsilateral neural pathways, one might expect that temporal lobectomized patients might perform better than normals with their strong ear (i.e., the ear contralateral to the intact hemisphere) because of the diminution of competing input through ipsilateral connections from their weak ear to their intact hemisphere. Although most investigations stress the perceptual deficits accrued to temporal lobe dysfunction, it is not unreasonable to suspect that as in many other instances of perceptual loss, some adaptive advantage or compensatory mechanism could be operable. The freeing of the intact hemisphere from the competing information of the ipsilateral pathways may be such a mechanism. Indeed, compared to the best ear performance of normals, which averages approximately 70% to 80% correct, right temporal lobectomized patients have been shown to generate near perfect (i.e., 90% to 100% correct) strong ear performance (Milner et al., 1968; Berlin, Cullen, Hughes, Berlin, Lowe-Bell and Thompson, 1975; Berlin and McNeill, 1976). Perhaps it was a similar improvement in the performance of the ipsilateral ear for temporal lesioned patients that was noted by Bender and Diamond (1975) with their description of ipsilateral ear "predominance" for binaural temporal resolution.

Another common observation from dichotic studies with either

lobectomized or temporal lesioned patients has been their failure to show a lag effect (i.e., the observation from dichotic studies with normals that the trailing message is recalled better than the leading message) (see Berlin and McNeill, 1976). Porter (1974) has postulated that the lag effect in normals results from an interruption in the acoustic processing of the initial stimulus by the trailing stimulus, during a critical period just prior to the initiation of phonetic processing. Since the lag effect has been shown to reach an asymptote at approximately 60 msec. following the offset of the initial stimulus, it has been inferred that the lagging signal has its maximum disruptive effect at this moment³ which also corresponds to the end point for the processing of transitional phonetic components (e.g., see Porter, Shankweiler and Liberman, 1969; Berlin, Lowe-Bell, Janetta and Kline, 1972; Berlin, Lowe-Bell, Cullen, Thompson and Loovis, 1973; Porter, 1974).

It is of interest to note that the asymmetrical performance decrement for the contralateral ear of temporal lobectomized patients and particularly for right temporal lobectomees reaches an asymptote when it is lagging behind the strong ear at an interaural asynchrony of approximately 60 msec. and then begins to decline thereafter (see Berlin, 1976). It appears, therefore, that the suppression of the ipsilateral neural pathways by the contralateral neural pathways that was generated by the dichotic method of stimulation, extends at least until the end of the proposed

³This explanation is analogous to the delayed backward masking functions described by Kolers (1962) and by Weisstein and Haber (1965) for visual stimuli.

60 msec. critical processing period. At an interaural asynchrony of approximately 60 msec., the ipsilateral input begins to be processed by the intact hemisphere as evidenced by both an improvement in the performance of the weak ear and a diminution in the performance of the strong ear.

It is theoretically possible that such an acoustically discrete mechanism of contralateral neural dominance, somewhat of an anatomical analog to the filter mechanism proposed by Treisman (1960), may contribute toward the absence of the lag effect for temporal lesioned patients. It should be recalled that for normals, under conditions of ipsilateral ear suppression, it has been suggested that processing of the initial stimulus may be interrupted by the competing input from interhemispheric channels. Conversely, temporal lesioned patients may be expected to benefit from the uninterrupted processing of the initial stimulus under similar conditions of ipsilateral ear suppression, when the contralateral ear is lagging, because of the degraded intelligibility of interhemispheric input from the lesioned hemisphere.

Auditory Perceptual Dysfunction Associated with Brain Stem Lesions

Circumscribed brain stem lesions have generally been found to result in variable auditory dysfunction (see Berlin and Lowe, 1972; Hodgson, 1972). However, Calcareo and Antonelli (1968) have defined a specific pattern of bilateral auditory impairment which characterizes generic brain stem dysfunction. Among those auditory deficits are a bilateral pure tone impairment, particularly for high frequencies, and a bilateral impairment for the discrimination of distorted speech. Subsequently, the application of pure tone audiometric evaluation and tests of the binaural fusion

of filtered speech, in comparative auditory perceptual studies, have successfully differentiated between patients with generic brain stem lesions and cortical lesions (Matzker, 1959; Smith and Resnick, 1972; Lynn and Gilroy, 1972; Ohta, Hayashi and Morimoto, 1967; Palva and Jokinen, 1975).

Specifically, audiometric anomalies have been found to mostly characterize patients with low brain stem dysfunction at the level of the cochlear nuclei and of the eighth nerve including the olivocochlear bundle (Calearo and Antonelli, 1968; Berlin, 1976). Bocca and Calearo (1963) originally stated that tests of the binaural fusion or resynthesis of filtered speech must be considered specific to the level within the brain stem where primary decussation occurs and where the efferent inhibitory pathways originate. Subsequent research has targeted the superior olive as the point where messages from the two ears are combined and as the origin of the olivocochlear bundle which is a major inhibitory pathway (Langford, 1970). Moreover, this assumption has been supported with post mortem histopathological studies of patients who have demonstrated an inability to resynthesize frequency filtered speech (see Matzker, 1959). These patients were found to have suffered histological changes within the brain stem and particularly within the olivary region.

Antonelli and Calearo (1968) proposed that the ascending reticular formation of the brain stem was capable of influencing the time constant of sensory integration by altering the conduction time of afferent neural impulses (also see Rosner and Heise, 1954; Lindsley, 1968; Rose and Lindsley, 1965). However, such function of upper brain stem structures is neuro-otologically in-

distinct from the function associated with secondary cortical zones (e.g., see Berlin, Cullen, Berlin, Tobey and Mouney, 1975). Therefore, this study, being limited to measures of CANS functioning, can attempt to only partially test the hypothesis of generic brain stem involvement in functional psychiatric disorder with respect to only lower brain stem structures (i.e., at the level of the superior olive and below).

Application of Measures of Auditory Perceptual Dysfunction to Psychiatric Populations

The major focus of this investigation is the application of measures which have been proven to be valid indicators of CANS dysfunction, in organic populations, to well defined psychiatric populations. Through the implementation of a carefully selected battery of these speech and non-speech measures, it is anticipated that a greater understanding may be derived with respect to the level within the CNS that may be fundamentally responsible for functional psychiatric disorder. Moreover, with the derivation of bilateral indices of CANS functioning, it will be possible to test the hypothesis that lateralized CNS dysfunction underlies the clinical dissimilarity between affective psychotic patients and schizophrenic patients. The speech measures consist of a word discrimination test (CID W22), a staggered spondaic word test (SSW), a test of the binaural fusion or resynthesis of frequency filtered speech (DBF) and a dichotic competing sentence test (Binaural Separation Test). The non-speech measures consist of forced-choice audiometry and a forced-choice measure of the binaural energy summation of click pairs presented at threshold intensity levels and dichotic for each ear leading with respect

to interaural onset time.

Methodology

It should be recalled that studies measuring the binaural resolution of paired click stimuli in patients with unilateral temporal lobe lesions have found these patients to need considerably longer interaural delays than controls to resolve two separate clicks (Lackner and Teuber, 1973; Bender and Diamond, 1975). However, the interpretation of a potentially similar finding for psychiatric patients could pose a problem because of the difficulty in separating sensory from non-sensory variables such as response criteria or motivation (e.g., see Clark, Brown and Rutschman, 1967; Wagoner, 1960). The forced-choice measurement of the binaural summation of click pairs was designed as a modification of the two click resolution paradigm for use with psychiatric populations to permit control for the effects of response criterion variables and thus permit an independent measure of binaural sensitivity (d') (see Bruder, Yozawitz and Sutton, 1977; Botte, 1976).

Moreover, for this study, the substitution of the measurement of two click resolution with the measurement of binaural summation eliminates the need to question the contribution of motivational differences that would otherwise be raised following a potential finding of poorer two click resolution for psychiatric patients. With a summation paradigm, patients who have difficulty resolving two clicks as separate should perform "better" (i.e., at a higher level of accuracy) than controls by showing greater enhancement in sensitivity (more summation) when a click is presented to both ears rather than to either ear alone.

Furthermore, the implementation of a detection paradigm at threshold levels to measure binaural summation explores, through a much simpler task, the same underlying perceptual ability as does the task of binaural resolution. Namely, the burden of deciding what the experimenter means by "twoness" is eliminated and all the subject need do is to simply respond to the presence of the stimulus from among three observation intervals.

Sutton (1973, 1975) has stressed the importance of careful experimental design for application to psychiatric populations. In general, measures that are intended to discriminate the performance of psychiatric patients and non-patients with respect to their CNS functioning should incorporate a means of isolating peripheral (receptor) function from central function. An own-control design, which generates difference scores for each session, permits each subject's CNS sensitivity to be evaluated apart from his peripheral sensitivity. This design also facilitates the partialling out of extraneous differences between groups (e.g., motivational differences, practice effects or diurnal variation) since these factors should affect both peripheral and central performance equally. For this study, the concurrent determination of single click thresholds along with paired click thresholds permits an own-control determination of difference scores for each session. Likewise, the design of the SSW test, employing both competing and non-competing conditions, and the design of the DBF test, employing both dichotic and diotic conditions (i.e., where the resynthesis of filtered speech occurs at the input to each earphone), also permits an own-control determination of difference scores for each session. Additionally,

forced-choice audiometry provides a means of parametrically assessing the peripheral sensitivity of each subject to non-transient auditory stimuli, while the CID W22 word discrimination test similarly serves as a standard for each subject against which dichotic speech perceptual performance may be contrasted.

Auditory Perceptual Functioning in Psychiatric Populations

The approach toward the study of temporal resolution in psychiatric patients was originally initiated to test the hypothesis that psychiatric patients display an altered state of cortical excitability (e.g., see Venables and Wing, 1962). In a series of studies, Venables (1963, 1964, 1966, 1967) presented reaction time and threshold data suggesting that withdrawn schizophrenics had impaired auditory temporal resolution ability which was particularly marked in comparison to their visual temporal resolution ability. However, the interpretation of these data was restricted as the result of numerous methodological limitations both for the derivation of sensory indices and for the specification of psychopathology (see Payne, 1970). Notwithstanding, a number of other investigators have also stressed the value of studying temporal processing in psychiatric populations (e.g., Zubin, 1963; Zubin and Kietzman, 1966; Yates, 1966; Ihamon and Goldstone, 1973; Johnson, 1975). Unfortunately, to date, there has been only a very limited application of measures of binaural temporal processing and laterality to psychiatric populations.

Bruder, Sutton, Babkoff, Gurland, Yozawitz and Fleiss (1975), employing a monaural paired click paradigm, have recently differentiated, from a heterogeneous group of hospital diagnosed schiz-

ophrenic patients, two homogeneous patient populations on the basis of differential auditory perceptual processing and an independent assessment of behavior pathology. One group, the reclassified schizophrenics, did not differ from a group of non-hospitalized controls in either their auditory sensitivity (d') to a single click or in their degree of reaction time facilitation to paired clicks for a range of interclick intervals from two to fifteen msec. The other group, the affective psychotics, differed from both of these groups by displaying an average of 6 dB lower auditory sensitivity to a single click and by benefiting more from the presence of the second click in the pair. This was evidenced by a greater degree of RT facilitation that was most pronounced at the longest interclick interval (i.e., they showed greater reduction in their reaction times to a click pair relative to their reaction times to a single click) (also see Bruder and Yozawitz, 1976).

Interestingly, this pattern of distinctive auditory perceptual processing for affective psychotic patients is similar to a pattern of augmentation that was observed in other sensory modalities for affective psychotic patients (primarily bipolar depressive patients) with an averaged evoked response measure (Baron, Gershon, Rudy, Jonas and Buchsbaum, 1975; Borge, 1973; Borge, Buchsbaum, Goodwin, Murphy and Silverman, 1971; Buchsbaum, 1975). These studies have defined augmenters as characterized by displaying lower than normal sensitivity to stimuli at threshold levels of intensity yet showing greater than normal sensitivity with increasing stimulus intensity. The degree of augmentation for these patients has also been shown to be re-

duced following treatment with lithium carbonate. Moreover, other studies which have measured the averaged evoked response to paired stimuli have reported the parallel finding that affective psychotics showed reduced cortical recovery periods (see Shagass, 1972). Accordingly, Henkin and Daly (1968) have theorized that stimulus integration should be at a maximum level when stimulus input is controlled by a system set at a "low gain."

In general, methodological problems such as the selection of inappropriate sensory measures and the inadequate specification of diagnostic subgroups has characterized the literature regarding the auditory perceptual functioning of psychiatric patients. For example, a number of studies using classical psychophysical techniques have found no difference between schizophrenic patients and controls for pure tone sensitivity (Bartlett, 1935; Ludwig, Wood and Downs, 1962; Rappaport and Hopkins, 1969; Bull and Venables, 1974). Contrastingly, other studies using classical psychophysical techniques (Levine and Whitney, 1970; Polidoro, 1970) or measures of signal detection (Emmerich and Levine, 1970; Rappaport, Hopkins, Silverman and Hall, 1972) have reported lower pure tone sensitivity for schizophrenics compared to controls. Most recently, Gruzelier and Hammond (1976) reported that schizophrenics showed a slight enhancement in their pure tone sensitivity with increasing frequency and that this was most evident for their right ears. Soviet researchers, measuring threshold vs. duration functions for a 1000 Hz tone have differentiated the auditory perceptual performance of schizophrenics with auditory hallucinations from schizophrenics without auditory hallucinations (Bazhin, Wasserman and Tonk-

onogii, 1975). They reported that schizophrenics with auditory hallucinations performed similarly to patients with left temporal lobe pathology by displaying impaired perception of brief (i.e., 1 msec.) tonal stimuli in their right ears.

The long association between schizophrenic speech disturbance and aphasic speech disturbance was noted earlier. Bull and Venables (1974) have recently found evidence of impaired perception of speech sounds in schizophrenic patients which was most pronounced at low intensities and when the redundancy of speech was reduced by filtering out high frequency portions of the speech spectrum. However, they found no evidence that this was a unilateral effect. Similarly, other studies have reported that speech sound discrimination in schizophrenics may be particularly impaired when the perceptual task is made more difficult by adding background speech or by presenting distracting words to the opposite ear (Ludwig et al., 1962; Maloney, Sloane, Whipple, Razani and Eaton, 1976). Namely, poor premorbid (process) schizophrenics have been shown to display a greater speech perception deficit under such conditions in comparison to good premorbid (reactive) schizophrenics, but no ear differences suggestive of lateralized hemispheric dysfunction were found (Polidoro, 1970; Maloney et al., 1976).

Recently, other studies which have reported evidence of interhemispheric asymmetry for psychiatric patients suggest that a reduction in the magnitude of these asymmetries may parallel clinical improvement for these patients following appropriate pharmacotherapy. An asymmetrical right ear (left hemisphere) perceptual impairment that was found for schizophrenics both on

an auditory temporal discrimination task and on a reaction time task was reported to have been reduced following the administration of antipsychotic medication (Gruzelier and Hammond, 1976; Gruzelier, 1976). Similarly, interhemispheric asymmetries for EEG (Goldstein, 1975) and for evoked responses (Perris, 1974) have also been reported reduced for affective psychotic patients following the administration of antidepressant medication.

Hypotheses to be Tested by the Present Investigation

This investigation aims to further resolve such findings of distinctive acoustosensory perception for carefully defined psychiatric subgroups through the employment of valid measures of CANS dysfunction. In contrast to the Bruder et al. (1975) investigation, where diagnosis was conceptualized as a dependent variable (i.e., apriori predictions could not be made concerning the auditory perceptual performance of specific diagnostic subgroups), this study will specify diagnosis as an independent variable. The successive alternation in the specification of the independent and the dependent variable has been suggested as the approach for ultimately obtaining valid relationships between psychophysiological criteria and diagnostic classification (Sutton, 1973; Gurland, 1973).

Schizophrenics, who were found not to differ in their auditory perceptual processing from non-patient controls in the Bruder et al. (1975) study, will, apriori, not be expected to differ from non-patient controls on similar measures for this study. Likewise, affective psychotics will, apriori, be expected to differ from both schizophrenics and non-patient controls on these same measures. In addition to non-patient controls, two

right temporal lobe lesioned controls will also be evaluated on these measures. According to Flor-Henry's (1976) hypothesis concerning differentially lateralized temporal lobe dysfunction between schizophrenia and manic-depressive psychosis, only the affective psychotics will, *apriori*, be expected to perform similarly to the right temporal lesioned controls on these measures of auditory perceptual processing.

The design of this study, including the selection of tests which have successfully differentiated patients with lower brain stem lesions from patients with cortical lesions, will permit the testing of a number of contemporary hypotheses concerning the neuropathology of affective psychosis and schizophrenia.

If a lower brain stem focus is etiologically implicated, one might expect: 1) uniform bilateral threshold elevation for clicks and for pure tones, especially for the high frequency region of the audiogram; 2) abnormal scores for the Dichotic Binaural Fusion Test; 3) poor bilateral word discrimination performance on the CID W22 test as well as on both the competing and the non-competing conditions of the SSW test; 4) poor bilateral performance on the Binaural Separation Test; 5) lower than normal levels of binaural energy summation for click pairs at all interaural asynchronies and bilaterally for each ear leading.

If a unilateral temporal lobe focus is etiologically implicated, one might expect: 1) unilateral threshold elevation for clicks for the ear contralateral to the cortical dysfunction (*i.e.*, if the locus of dysfunction includes primary auditory cortex); 2) normal pure tone thresholds; 3) normal scores for

the Dichotic Binaural Fusion Test; 4) normal word discrimination performance on the CID W22 test as well as on the non-competing conditions of the SSW test; 5) poor performance on the competing conditions of the SSW test for the ear contralateral to the cortical dysfunction (see Katz, 1968; Lynn and Gilroy, 1972 for independent validations of the SSW for both anterior and posterior unilateral temporal lesioned patients; 6) poor performance on the Binaural Separation Test for the ear contralateral to the cortical dysfunction; 7) normal levels of binaural energy summation for click pairs at simultaneity; 8) a greater magnitude of binaural energy summation for dichotic click pairs when the lag click is presented to the ear contralateral to the cortical dysfunction compared to when the lag click is presented to the ear ipsilateral to the cortical dysfunction. This should be particularly evident at an interaural asynchrony of 60 msec. (see Babkoff, 1975).

CHAPTER II

APPARATUS

Click Production

The apparatus employed in this study to generate clicks was designed to:

- 1) permit independent forced-choice measurements of the monaural click threshold for each ear;

- 2) permit independent forced-choice measurements of binaural click summation for each ear leading in a dichotic paradigm with respect to interaural onset times.

Specifically, the design of the apparatus allowed for physical independence and separate attenuation of the electrical pulses to be transduced as clicks and control of the temporal interval separating the clicks. The apparatus is described with reference to a functional block diagram (Fig. 1).

(A) Programmed Pulse Generator. The programmed pulse generator consisted of a bank of timers with power supplies (Analog and Digital Instrument Company Type TG-700 Digital Time Generator with Power Supply and a General Radio Type 1217-B Pulse Generator with a Type 1203-B Power Supply) which controlled:

- 1) the duration of each 500 msec. red flash which marked the observation intervals.

- 2) the 700 msec. temporal separation between each of the three observation intervals for each trial.

- 3) the 7 sec. intertrial response interval during

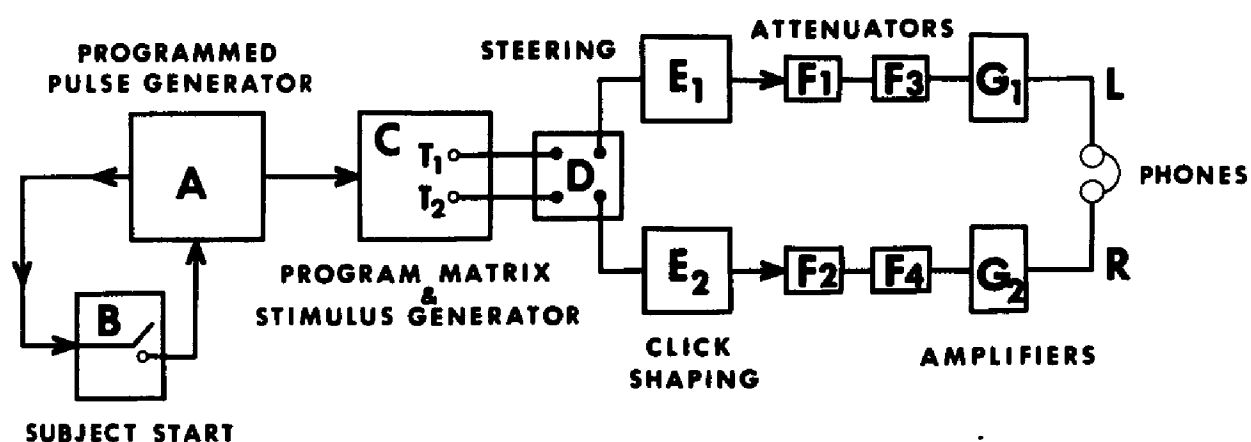


Figure 1. A schematic diagram of the experimental apparatus used to generate clicks and to control the temporal interval separating binaural click pairs.

which the three response buttons and the blue feedback light were operative.

(B) Subjects' Initiated Start. The end of the 7 sec. intertrial response interval was marked by a red flash which signalled to the subject that he could initiate the next trial when ready. The subject's touch of a telegraph key was necessary to initiate the next trial and could occur at any time after the occurrence of the signalling flash.

(C) Program Matrix and Stimulus Generator (local design). Single pulses were generated by programming one pulse at T_1 . The pair of pulses, dichotic with respect to interaural onset time, were generated by programming one pulse at T_1 and another pulse at T_2 . The interval between the pulses at T_1 and T_2 (i.e., Δt) could be varied from .01 to 99.99 msec. This interval was generated by a crystal-controlled timer (local design) calibrated and monitored with a Systron Donner counter timer model 1034. Error was found not to exceed 0.05%.

(D) Steering Switch. Either pulse generated at T_1 or T_2 could be steered into one of two channels, to the right earphone or the left earphone. Thus it was possible, by manipulating this switch, to produce a pair of pulses dichotic with respect to a preset Δt with either the right or left channel leading.

(E_{1&2}) Click Shaping (local design). The pulses directed to either channel were shaped as negative-going pulses with exponential return to base. The time constant of the exponential return to base of each electrical pulse, i.e., the time required to reach $1/e$ of peak amplitude, was 0.1 msec. The rise time was

.0125 msec.

(F_{1-4}) Attenuators. Each pulse was attenuated in each channel by cascaded sets of attenuators. F_3 and F_4 (Hewlett-Packard, 5W, 600 Ω) were adjustable in 1 dB steps over a range of 110 dB and F_1 and F_2 (local design) were adjustable in 0.1 dB steps over a range of 111 dB.

($G_{1\&2}$) Amplification (local design). The pulses were amplified at G_1 and G_2 and transduced as clicks by a set of Sharpe MK-II-S circumaural earphones. This set of phones was calibrated at the factory on request and was selected on the basis of a flat and uniform frequency response across the right and left phones.

Calibration of Click Production Apparatus

Six types of calibrations were required to permit control over the stimulus complex. These were performed:

1) to monitor the shape of the peak amplitude of the pulses and to measure and equate the peak amplitude of the pulses at the two channels. This was performed once prior to the initiation of testing for each subject and once at the completion of each subject's testing.

2) to monitor the temporal intervals separating the dichotic clicks.

3) to monitor the frequency response for each channel of the circumaural phones.

4) to monitor the shape of the click transduced by the right and the left phone and the peak amplitude of each click.

5) to calibrate the spectral composition of the click

transduced by the right and the left phone.

6) to specify the intensity of the click transduced by the right and the left phone in dB SPL.

The spectral analysis of the clicks was performed at the completion of the study. The other calibrations were performed once prior to the initiation of the study, once during the study and once at the completion of the study.

Monitoring of Peak Amplitude of the Pulses

The peak voltages of the right and the left channel pulses were monitored with an oscilloscope (Tektronix Type 561 with a Type 3A72 Dual Trace Amplifier) at the input to the phones. The readings were made with the phones connected and the circuit loaded. It was found that with an attenuator setting of 10 dB on each channel, the peak voltage output of the right channel was 555mv. and the peak voltage output of the left channel was 660 mv. The two channels were balanced by attenuating the left channel by 1.5 dB. This procedure was repeated at several other levels of attenuation and provided a check for the performance of the attenuators. At all levels, the observed change in peak voltage on the oscilloscope trace corresponded with the change in the attenuator setting.

Monitoring of the Temporal Intervals Separating the Dichotic Clicks

The intervals between T_1 and T_2 on the Program Matrix and Stimulus Generator were set at either .01 msec., 30 msec. or 60 msec. for this study. These Δt intervals were monitored during the study on a Tektronix Type 561 oscilloscope with a Type 67

time base. Figure 2 illustrates the actual output of each earphone for the case of the right ear leading. For illustrative purposes, the interaural Δt was set at 0.5 msec. and the time sweep of the oscilloscope was 0.2 msec./cm. Rarefaction clicks were used to further insure experimental control over the time of stimulation since it is known that the auditory neurons fire on the upward deflection of the basilar membrane. This upward displacement occurs as a result of an outward movement by the stapes caused by a pressure decrease in the external auditory meatus (see Wever, 1949; Babkoff and Sutton, 1966).

Calibration of the Frequency Response of the Phones

The procedure employed to calibrate the frequency response of the phones was similar to that described by Babkoff and Sutton (1966). The sinusoidal frequency output of a Hewlett-Packard Function Generator, model 3310A, was set at discrete frequencies ranging from 100 to 10,000 Hz with the aid of a Hewlett-Packard Electronic Counter, model 522B. The sinusoidal voltage was attenuated (Hewlett-Packard 350D attenuator), amplified (G_1 in Figure 1) and passed to either the right or left earphone where it was transduced as a pure tone. The peak to peak sinusoidal voltage was monitored with an oscilloscope (Tektronix Type 561 with a Type 67 time base and a Type 3A72 amplifier) and with a True RMS meter (Ballantine, model 320A) for all frequency settings at the input to the phones. A constant input of 100 mv. peak to peak and 34 mv. rms was, therefore, maintained for all frequency manipulations.

A half inch Brüel and Kjaer condenser microphone (Type 4134)

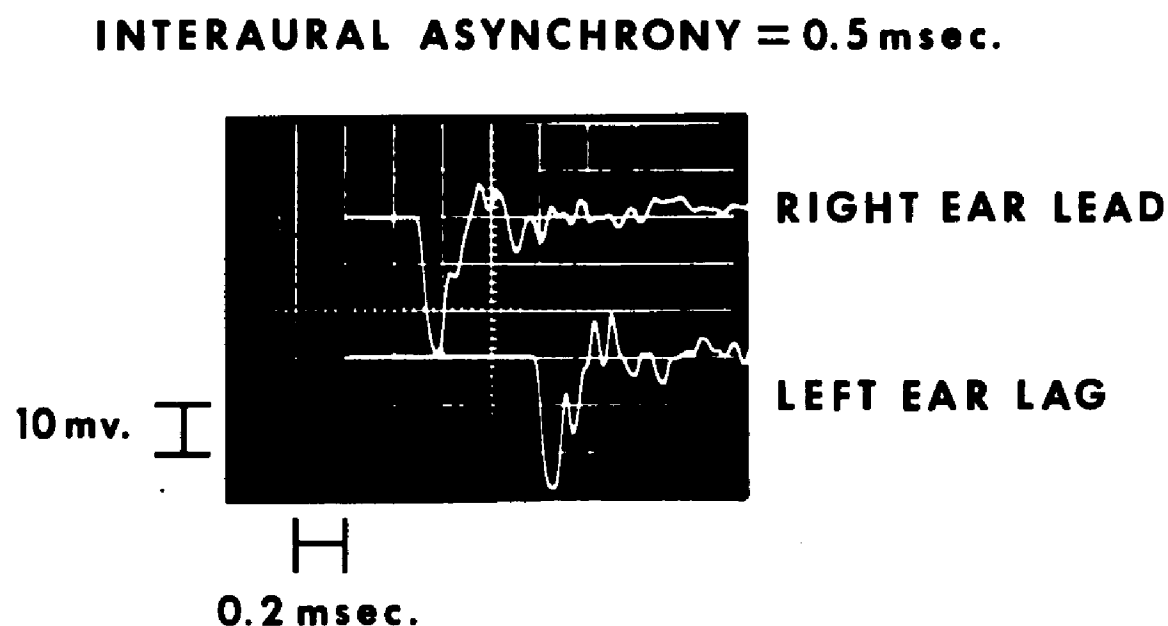


Figure 2. An oscilloscope photograph of the acoustic (rarefaction click) response of each earphone illustrating the temporal onset asynchrony of binaural click presentation for the right ear leading condition.

was snugly fit into the center opening of a flat plate lucite coupler which was mounted on a stand. The microphone was mounted flush with the coupler surface and was connected to a B&K Type 2615 cathode follower and to a B&K Type 2801 power supply.

Each earphone, in turn, was carefully placed and tightened onto the coupler surface so that the earphone diaphragm was aligned over the center of the microphone. Two specially designed brackets enabled the earphones to be securely clamped flush to the coupler surface without the need for weights.

For each pure tone response of each earphone the voltage output of the B&K instrumentation was monitored on the oscilloscope and read in rms voltage on the True RMS meter. Conversion of rms voltage readings into dB SPL⁴ were appropriately corrected for that error which was attributable, by its factory calibration, to the B&K instrumentation.

Figure 3 shows the obtained frequency response of the right and left phones in dB SPL. The curves for the two phones reflect how truly well matched and flat were this set of phones frequency responses. Over the range of frequencies from 250-

⁴Conversions were accomplished using this equation.

$$\text{dB SPL} = \left[20 \log \left(\frac{\text{obtained mv. rms}}{\frac{1.25 \text{ mv.}}{.0002 \text{ dynes/cm}^2}} \right) \right] + 9.9 \text{ dB}$$

where 1.25 mv. = 1 dyne/cm²
and 9.9 dB = The open circuit correction factor of 12.1 dB minus the 2.2 dB absolute value of the gain of the cathode follower. These values were determined by a calibration at the factory.

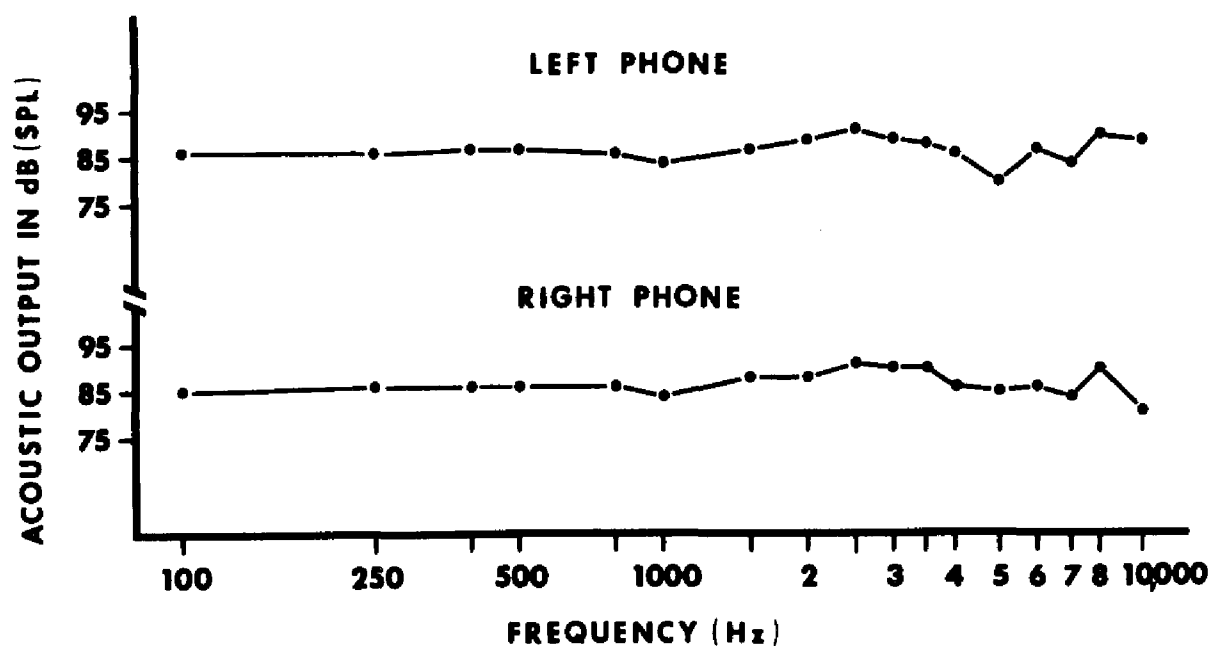


Figure 3. Frequency response of the Sharpe MK-II-S circumaural earphones used to transduce clicks and tone bursts. Input voltage to the phones was 34 mv. rms.

4000 Hz, the mean difference in frequency response between the right and left phones was 0.003 dB (s.d. = .68) with the greatest absolute difference of 1.19 dB occurring at 3000 Hz. Furthermore, the frequency response of each phone was stable over this range of frequencies, within 1 dB at each frequency, throughout the period of this study.

Monitoring of the Shape of the Click and of its Peak Amplitude

Each earphone, in turn, was mounted in the manner described above onto the flat plat coupler and over the half inch B&K microphone which was connected to the B&K cathode follower and power supply. The voltage input of the right and left channel pulses were transduced as clicks by the earphones and converted into a voltage output by the B&K instrumentation. With an attenuator setting of 10 dB on each channel, the voltage output was displayed on an oscilloscope and monitored during the course of the study.

Photographs of the click, taken with a Tektronix Oscilloscope Camera (Type C-27 with a Type C-27 camera bezel), represent changes in sound pressure as a function of time. Figure 4 shows the actual acoustic response of each earphone to the right and left channel pulses. The oscilloscope amplitude was 10 mv./cm. and the time sweep was 0.2 msec./cm. The acoustic response is seen as a rarefaction click with two main peaks and with "ringing." The rise times measured for each phone, from the onset of the acoustic response to the first peak, were both 0.1 msec. The peak amplitudes of each phone, also measured from the onset of the acoustic response to the first peak, were

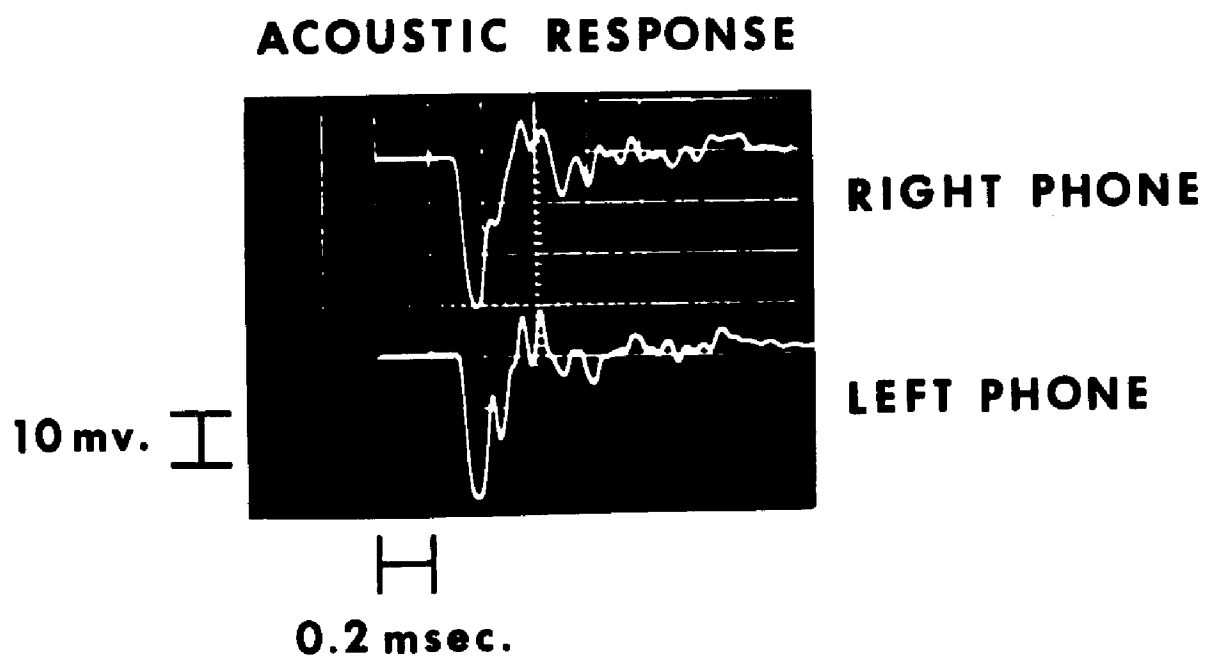


Figure 4. An oscilloscope photograph of rarefaction clicks transduced by each earphone to the right and the left channel pulses.

both 30 mv. Changes in level of attenuation did not affect either the shape of the acoustic response or the amount of "ringing." Comparison of photographs taken throughout the course of the study revealed that the acoustic response remained stable in shape, in rise time and in peak amplitude.

Calibration of the Spectral Composition of the Click for Each Phone

The voltage output of the B&K instrumentation for the acoustic (i.e., click) response of the right and left phones was fed through a Krohn-Hite Band Pass Filter (model 3700R) set at a gain of 20 dB. The Krohn-Hite filter was progressively set to pass discrete $1/3$ octave wide frequency bands having center frequencies ranging from 100 to 12,800 Hz. The voltage output of the Krohn-Hite filter was read on the True RMS meter and was simultaneously monitored on the oscilloscope. In order to obtain stable meter readings on the True RMS meter, a train of pulses was generated for each channel.⁵ Measurements were

⁵The difference between the spectral characteristics of a single pulse and that of a train of pulses is the appearance of energy at the repetition rate (i.e., the fundamental frequency) and at the harmonics of the pulse train which is not present in the spectral characteristics of a single pulse. The main reason for performing the spectral analysis was to compare the spectral composition of the clicks transduced by the right phone to that of the left phone. For that purpose, the additional energy of the pulse train was inconsequential, adding equally to the right and the left phones. However, because of the characteristics of the pulse and of the measuring instruments which necessitated that pulse trains be used, the readings at center frequencies of 100 Hz and 200 Hz (i.e., the fundamental frequency and the second harmonic of the repetition rate) may have been slightly elevated.

obtained separately for the acoustic response of the right and the left phone with an attenuator setting of 10 dB on each channel and a click repetition rate of 100/sec.

Figure 5 shows the results of this calibration plotted for rms voltage in dB (re 1 mv.) as a function of the center frequency for each 1/3 octave wide band. The curves for the right and left phones appear very similar in contour across the full range of center frequencies. The mean difference in acoustic (i.e., click) response between the right and left phones over this range of center frequencies from 200 to 12,800 Hz was only 0.03 dB (s.d. = 1.14). Moreover, as the distribution of these differences in click output closely parallels those differences obtained in frequency response across the phones, it appears that the spectral output of the clicks across the phones was largely determined by the frequency response of the phones. That is, it appears that pulses generated independently by the right and left channels were nearly identical.

Specification of the Click in dB SPL

The procedure used to specify the intensity of the click in dB SPL was modeled after the method used by Raab and Osman (1962) and corresponded to the peak equivalent voltage measure used by Deatherage and Hirsh (1959). Measurement of the peak click amplitude for each phone, from the onset of the acoustic response to the first peak, as reported earlier, was 30 mv. This first negative-going peak of the rarefaction click is the critical acoustic response, triggering the firing of auditory neurons. Therefore, as suggested by Deatherage and Hirsh, the

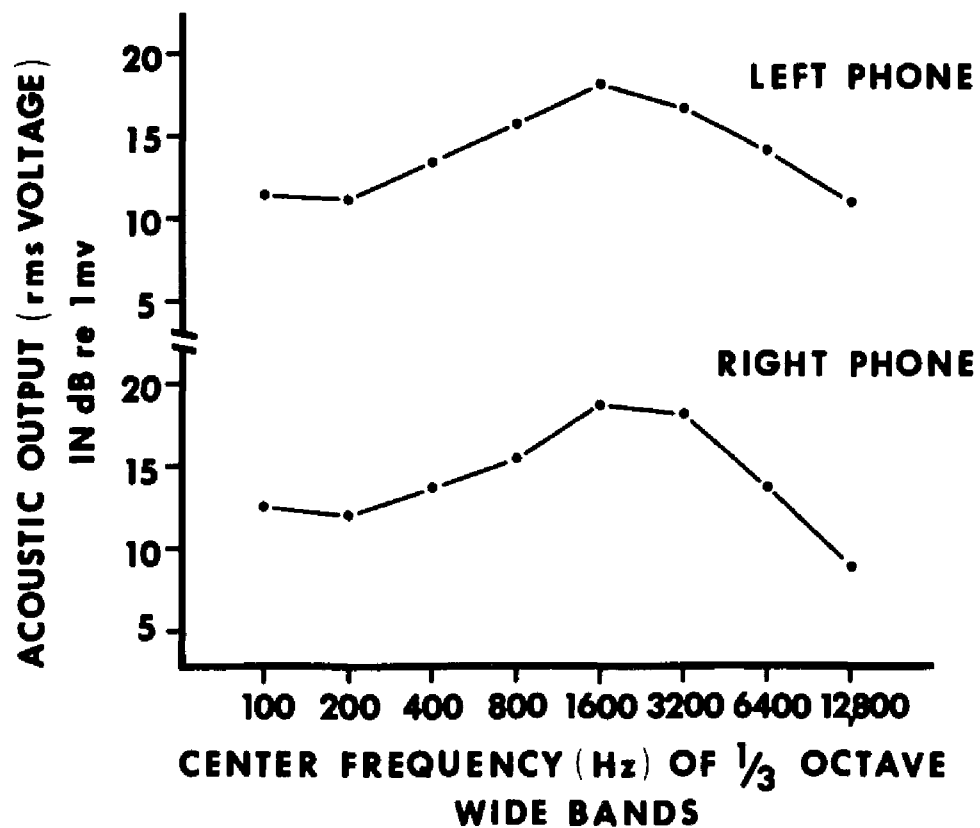


Figure 5. The spectral composition of clicks transduced by the right and the left earphones.

peak response amplitude for each earphone to a 1000 Hz tone, which is easily specifiable in dB SPL, was adjusted to equal the peak response amplitude for the click.

The sinusoidal output of the Hewlett-Packard Function Generator was set at 1000 Hz with the aid of the Hewlett-Packard Electronic Counter. The output was attenuated (Hewlett-Packard 350D attenuator) and amplified either in G_1 (see Figure 1) to be passed to the left phone or in G_2 to be passed to the right phone. The voltage output of the B&K instrumentation, arranged in the same manner as described elsewhere, was displayed on the oscilloscope. Separately, the peak to peak sinusoidal output of each phone for the 1000 Hz tone was adjusted to equal 60 mv. (i.e., 30 mv. peak voltage). This voltage output was then read in rms voltage on the True RMS meter and converted into dB SPL. The SPL measure in dB for the click was then taken as 3 dB less than the dB SPL response of each earphone to the 1000 Hz tone. With an attenuator setting of 10 dB for each channel, the intensity of the click output for the right phone was 115.30 dB and for the left phone was 115.43 dB.

Tone Burst Production

The apparatus employed in this study to generate tone bursts was designed to permit independent forced-choice measurements of the audiogram for each ear. The functional block diagram, Figure 6, illustrates how this was achieved. Although much of the apparatus depicted in Figure 6 has been described in the previous section, there were some new additions.

(D) Pure Tone Generator. The pure tone generator con-

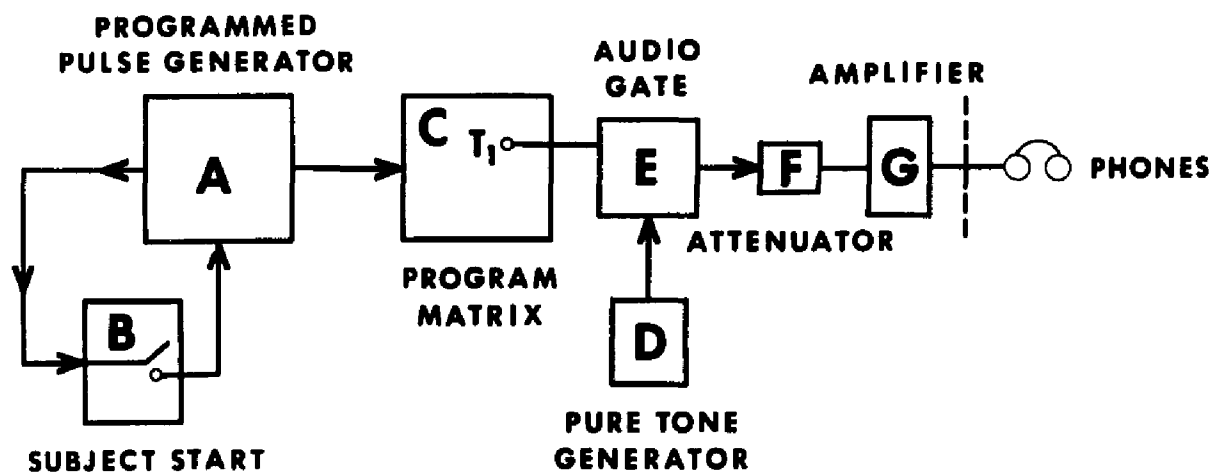


Figure 6. A schematic diagram of the experimental apparatus used to generate tone bursts for the determination of the forced-choice audiograms.

sisted of an audio oscillator (Hewlett-Packard, model 200CD) which was constantly monitored for the accuracy of its frequency output with a Hewlett-Packard Electronic Counter (model 522B).

(E) Audio Gate (local design). The audio gate shaped the sinusoidal output of the pure tone generator into discrete trapezoidal pulses with a rise time of 1 msec. and a duration of 500 msec. These pulses were then attenuated at F, amplified at G and transduced as tone bursts by a set of Sharpe MK-II-S circumaural earphones. Pulses were directed to either the right or left phone through a single phono-jack connection which could be easily switched.

Calibration of Pure Tone Apparatus

Five types of calibrations were required to permit control over the tone bursts. These were performed:

- 1) to measure the peak to peak amplitude of the pulses and monitor their shape.
- 2) to monitor the 500 msec. pulse duration.
- 3) to monitor the frequency response for each channel of the circumaural phones.
- 4) to monitor the shape of the tone burst transduced by the right and the left phone and the peak to peak amplitude of each acoustic response.
- 5) to specify the intensity of the audiogram obtained for each ear in dB SPL.

The measurement of the peak to peak amplitude of the pulses and the monitoring of their shape was performed once prior to

the initiation of testing for each subject. The other calibrations were performed once prior to the initiation of the study, once during the study and once at the completion of the study.

Monitoring of Peak to Peak Amplitude and Shape of Pulses

The peak to peak voltage of the 1000 Hz pulse (i.e., 500 msec. duration; 1 msec. rise time) was monitored with the oscilloscope and the True RMS meter at the input to the phones. Readings were made with the phones connected and the circuit loaded. It was found that with an attenuator setting of 0 dB and a pulse repetition rate of 7.75/sec., the peak to peak voltage displayed on the oscilloscope was 10 mv. and the rms voltage was 3.1 mv. For the purpose of illustrating the typical trapezoidal shape and sinusoidal character of the pulse, Figure 7 is a photograph of an oscilloscope tracing for a 2000 Hz pulse of abbreviated duration (10 msec.) with a 1 msec. rise time. The time sweep of the oscilloscope was 2 msec./cm. and the amplitude of the trace was 10 mv./cm.

Monitoring of the Pulse Duration

The duration of the 1000 Hz pulse was monitored simultaneously on the oscilloscope as a voltage input to either phone and from the B&K instrumentation as a voltage output of an acoustic response. A photograph of the oscilloscope tracing for the 1000 Hz pulse, monitored at the input to the phones, is shown as Figure 8. The time sweep of the oscilloscope was 100 msec./cm. and the amplitude of the trace was 10 mv./cm.

Calibration of the Frequency Response of the Phones

The same pair of Sharpe MK-II-S circumaural phones as was

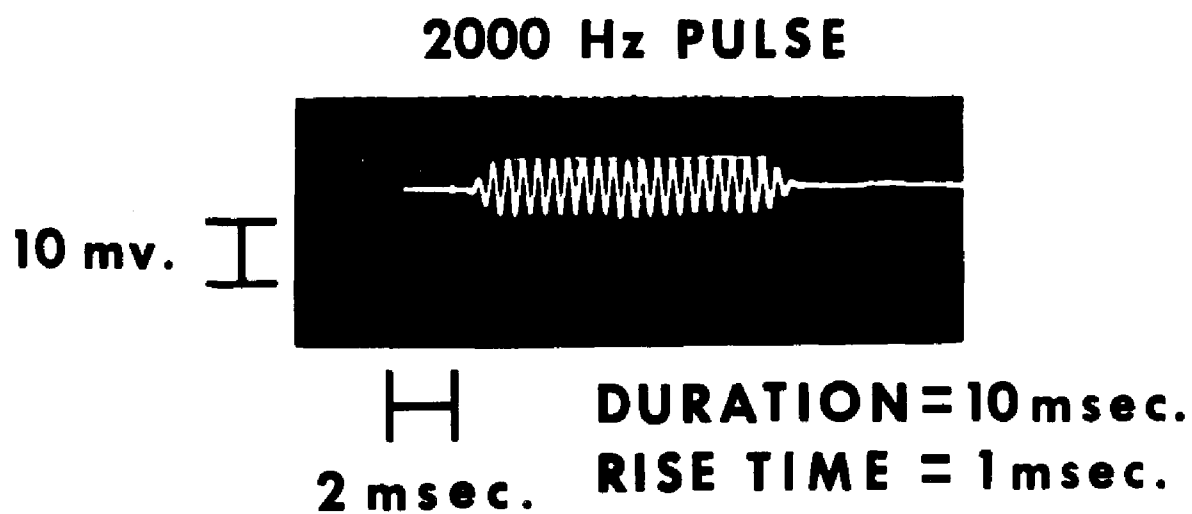


Figure 7. An oscilloscope photograph of a 2000 Hz pulse of abbreviated duration. Duration = 10 msec.; rise time = 1 msec.

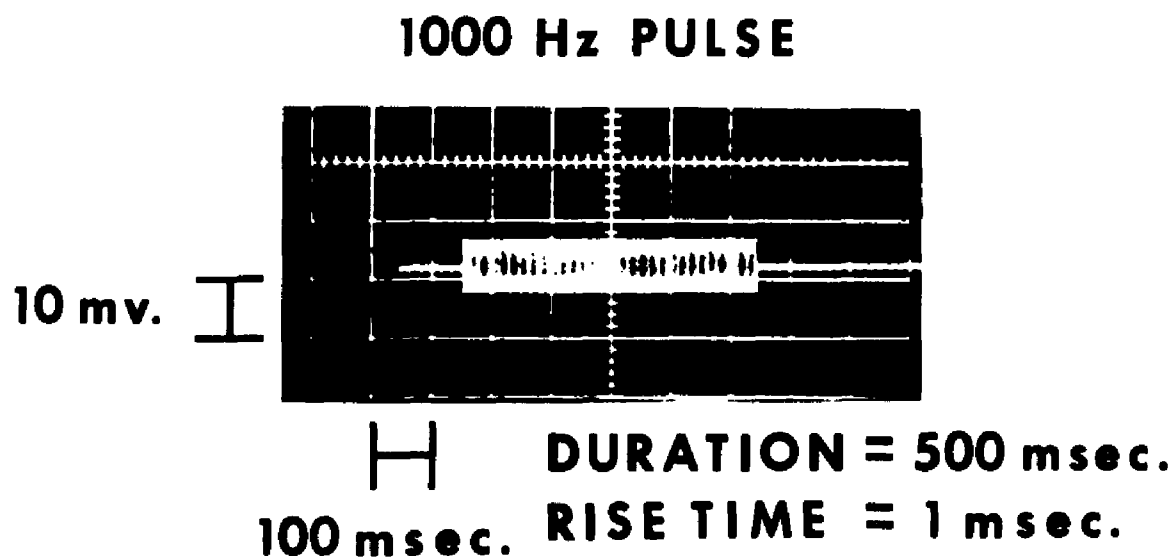


Figure 8. An oscilloscope photograph of a 1000 Hz pulse.
Duration = 500 msec.; rise time = 1 msec.

used to transduce clicks was also used to obtain audiograms. Refer to the prior section for a procedural description of this calibration as well as to Figure 3 for the frequency response of these phones.

Monitoring of the Shape of the Tone Burst and of its Peak to Peak Amplitude

The voltage output of the B&K instrumentation for the acoustic response of the right and the left phones to the 1000 Hz pulse was monitored with the oscilloscope. The trapezoidal shape and the sinusoidal characteristics of the tone burst were identical to those properties of the pulse observed at the input to the phones (see Figure 8). With an attenuator setting of 0 dB and an additional 15 dB of amplification, the peak to peak amplitude of the acoustic response for each phone to the tone burst was 2 mv. Repeated observations made throughout the course of the study revealed that the acoustic response remained stable in trapezoidal shape, in sinusoidal character, in rise time and in peak to peak amplitude.

Specification of the Audiogram in dB SPL

It was reported that with an attenuator setting of 0 dB, the peak to peak voltage of the 1000 Hz pulse measured at the input to the phones was 10 mv. peak to peak and 3.1 mv. rms. This voltage input to the phones was matched by a continuous 1000 Hz sinusoidal voltage output from a Hewlett-Packard Function Generator (model 3310A) which was attenuated 43 dB (Hewlett-Packard 350D attenuator), amplified at G (see Figure 6) and passed to the phones.

Each earphone, in turn, was mounted onto the flat plate coupler in the manner previously described for the calibration of the frequency response of the phones. In order to read the output of the B&K instrumentation with the True RMS meter, the input to the phones was increased by 21 dB. The voltage input to the phones was then read as 100 mv. peak to peak and 34 mv. rms. The frequency response of each earphone was then obtained for discrete frequencies over the audiometric range from 250-4000 Hz for this continuous and constant voltage input. The voltage output of the B&K instrumentation, which was read in rms voltage for each frequency, was converted into dB SPL in the manner previously described. The dB SPL equivalent to the setting of 0 dB attenuation for a tone burst of any given frequency was taken as 21 dB less than that particular frequency response in dB SPL.

Speech Reproduction

The apparatus employed in this study to generate pre-recorded speech material was designed to:

- 1) permit independent measurements of speech discrimination for each ear.

- 2) permit independent measurements of speech discrimination for each ear in dichotic paradigms with respect to interaural differences either in onset time, frequency or intensity.

Specifically, the design of the apparatus allowed for the physical independence and the separate attenuation of the electrical energy to be transduced as speech. The apparatus is described with reference to a functional block diagram (Fig. 9).

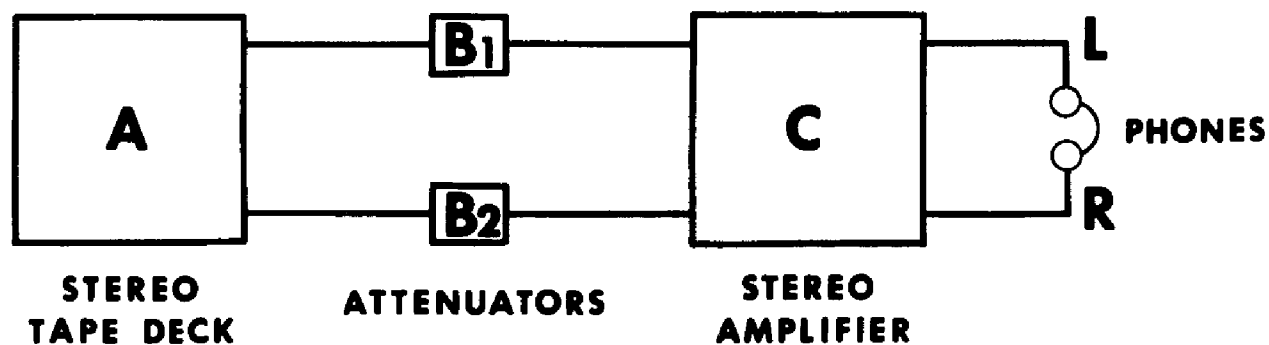


Figure 9. A schematic diagram of the experimental apparatus used to generate pre-recorded speech material.

(A) Stereo Tape Deck A stereo tape deck (Tandberg, model 3500X) played any one of four pre-recorded stereo tapes at a speed of 7.5 rpm.

(B_{1&2}) Attenuators. The voltage outputs of the stereo tape deck for the right and the left channel were independently attenuated by two Hewlett-Packard 350D attenuators. Each attenuator was adjustable in 1 dB steps over a range of 110 dB. A 600 ohm termination resistor was placed across the output terminal of each attenuator.

(C) Amplification. The right and left channel outputs were independently amplified by a stereo integrated amplifier (Kenwood, model KA-4006) and transduced as speech by a set of Sharpe MK-II-S circumaural earphones. This was a different set of phones from that used to transduce both clicks and pure tones. However, this set of phones was similarly calibrated at the factory and was selected on the basis of possessing a flat and uniform frequency response across the right and the left phones. The selection of the other components of the speech reproduction apparatus was based upon the same criteria, which was to achieve a flat and uniform frequency output across the two channels.

Calibration of Speech Reproduction Apparatus

Three types of calibrations were required to permit control over the speech stimuli. These were performed:

- 1) to equate the voltage output of each speech test, in dB, to the speech reception threshold of each ear (i.e., SL in dB) for the corresponding channels of the speech repro-

duction apparatus. This was performed once prior to the initiation of each speech test for each subject.

2) to determine the frequency response for each channel of the stereo amplifier.

3) to obtain the frequency response for each channel of the circumaural phones.

The last two calibrations were performed once prior to the initiation of the study.

Specification of SL in dB for Each Speech Test

The voltage output of the apparatus employed to generate tone bursts has been reported to be 3.1 mv. rms for a 1000 Hz pulse at an attenuator setting of 0 dB. For each speech test, the pre-recorded 1000 Hz calibrating tone was attenuated in each channel to equal 3.1 mv. rms and thus match the 0 dB setting of the tone burst apparatus. The speech reception thresholds for the right ear and for the left ear of every subject (i.e., the average threshold for 500 Hz, 1000 Hz and 2000 Hz tone bursts, specified in dB attenuation) were then each added to the existing settings of the corresponding right and left channel attenuators to achieve SL in dB.

Calibration of the Frequency Response of the Amplifier

The sinusoidal frequency output of the Hewlett-Packard function generator was set at 1000 Hz with the aid of a Hewlett-Packard Timer/Counter (model 5304A). This voltage output was fed through each input of the stereo tape deck (input and output potentiometers set at mid-range), through each of the two attenuators (set at 5 dB) and through each input of the stereo

amplifier (outputs balanced and potentiometer set at mid-range). With the earphones connected and the circuit loaded, the voltage output of each channel of the stereo amplifier was 34 mv. rms. The sinusoidal frequency output of the function generator was then set at discrete frequencies ranging from 250 to 4000 Hz. The voltage output of each channel of the stereo amplifier was read in rms voltage for each frequency setting.

Figure 10 shows the results of this calibration. The curves for the right and the left channels verify that the frequency output of each channel was indeed flat and that the frequency output was uniform across the two channels of the stereo amplifier. Over this range of frequencies, the mean difference in frequency response between the right and left channels (excluding 1000 Hz because the outputs were equated for this calibration) was 0.09 dB (s.d. = .12) with the greatest difference of 0.27 dB occurring at 250 Hz.

Calibration of the Frequency Response of the Phones

The apparatus was arranged in the manner described to calibrate the frequency response of the stereo amplifier. However, as the frequency output of the function generator was discretely set over the range from 100-10,000 Hz, the voltage output of the function generator was adjusted to yield a constant input to the phones of 100 mv. peak to peak and 34 mv. rms.

Each earphone, in turn, was mounted onto the flat plate coupler in the manner previously described. Refer to page 38 for the remaining details of this calibration procedure. Figure 11 shows the obtained frequency response for the right and left

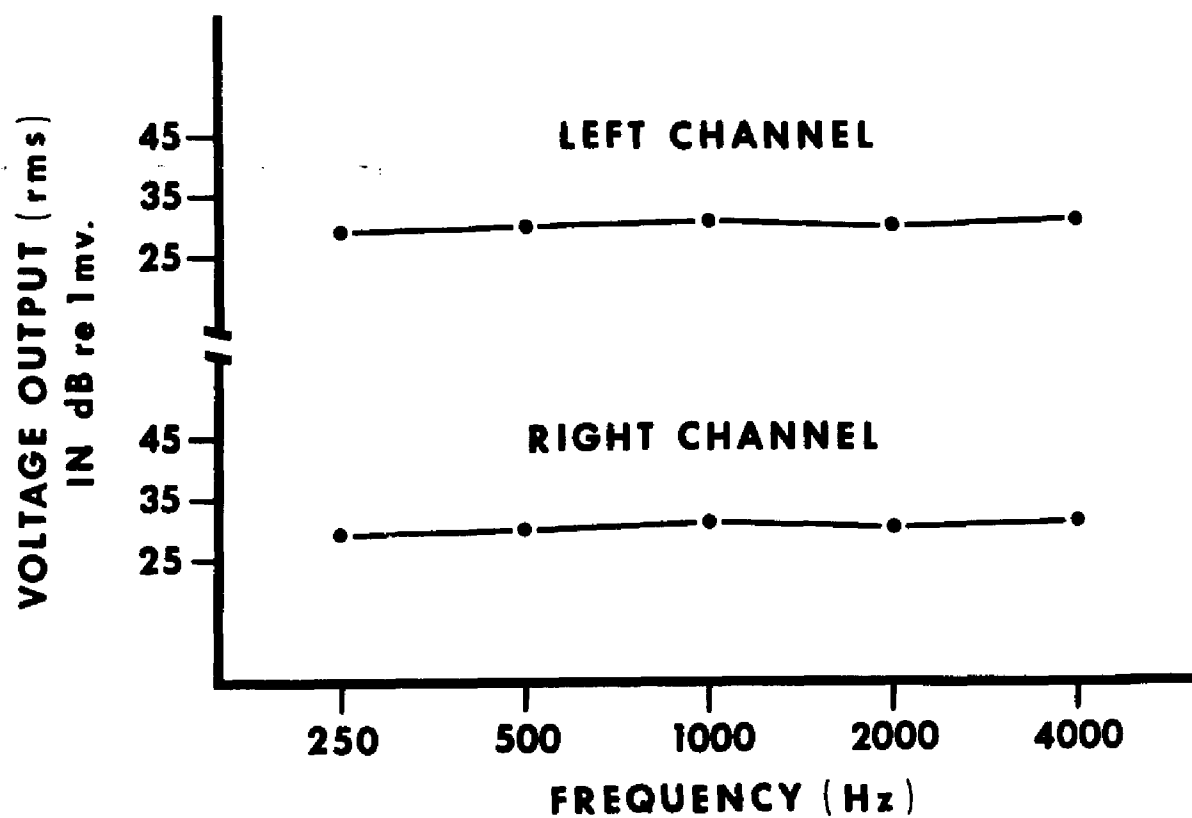


Figure 10. Frequency response of the Kenwood KA-4006 stereo amplifier.

phones in dB SPL. The curves reflect that this set of phones, like the set used to transduce clicks and tone bursts, also produced a flat frequency response which was well matched across the right and the left phones. Over the range of frequencies from 250-4000 Hz, the mean difference in frequency response between the right and left phones was 0.11 dB (s.d. = 1.5) with the greatest absolute difference of 3.45 dB occurring at 1500 Hz.

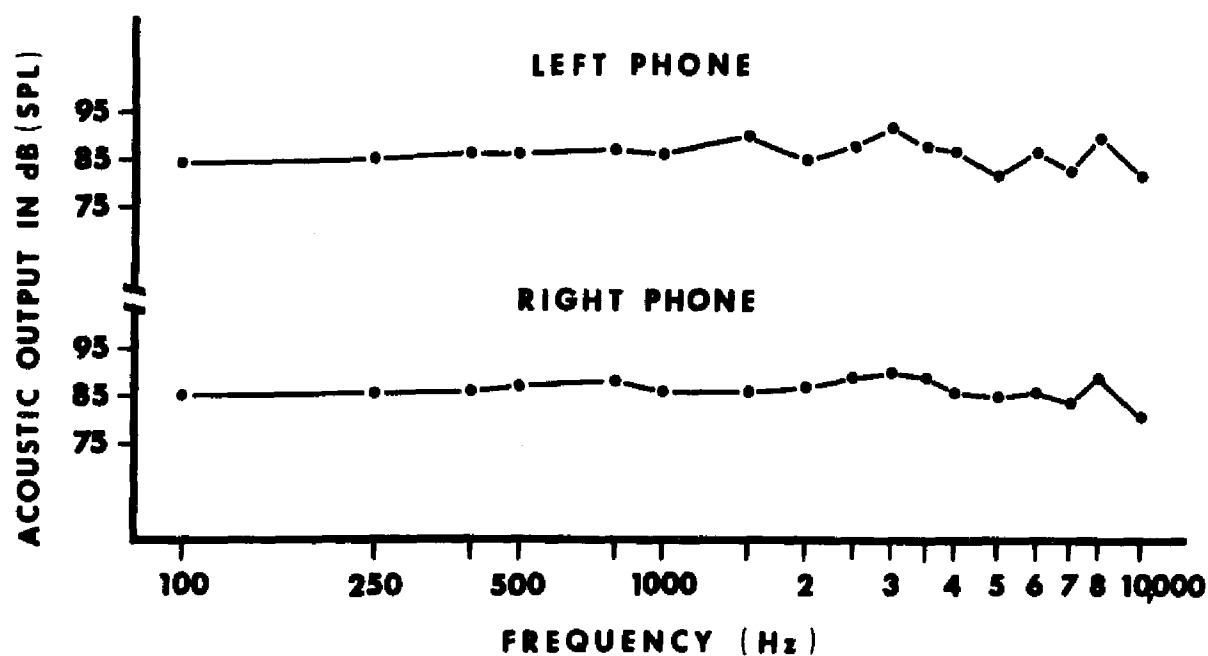


Figure 11. Frequency response of the Sharpe MK-II-S circumaural earphones used to transduce pre-recorded speech material. Input voltage to the phones was 34 mv. rms.

Chapter III

SUBJECTS AND PROCEDURE

Subjects

Psychiatric Patients

Screening. All male admissions to Kingsboro Psychiatric Center between 18 and 35 years of age were screened for the study upon admission. The screening consisted of three parts. First, their charts were reviewed together with ward personnel to exclude those patients who had histories of any of the following: drug or alcohol addiction, epileptic seizures, penal incarceration or evidence of mental retardation. Second, patients who passed the first screening stage were administered a ten minute screening interview consisting of key questions excerpted from the Multiple Diagnostic Strategy Schedule (MDSS). The purposes of the screening interview were to determine handedness and assess the patient's willingness and ability to sufficiently communicate his symptomatology so that a subsequent semi-structured interview (MDSS) administration could result in a definitive diagnosis. Patients who were either left-handed or judged to lack fluency in English, or who denied key symptomatology were excluded from further consideration.

All patients who passed the second stage of screening were asked to participate in the study. It was explained that their participation would in no way affect their treatment or length of hospitalization, that testing was not physically or psychologically harmful, that confidentiality concerning their performance would be maintained, that they could stop participation

at any time without penalty and that they would be paid for their participation. Patients who were willing to extend their informed consent to participate signed forms to that effect which had been approved by review committees at both the New York State Psychiatric Institute and Kingsboro Psychiatric Center.

Patients were escorted from the ward for the third stage of screening which was the determination of their click thresholds for each ear. Patients were excluded from further testing if they could not learn to perform the threshold task flawlessly at suprathreshold levels, or if they showed a threshold decrement of 20 dB or more in comparison to our non-patient standards or if they were found to have differential sensitivity across their ears of greater than 10 dB.

Identifying Data. Twenty male psychiatric inpatients who fulfilled the above criteria were tested on multiple measures of their central auditory system functioning. Patients ranged in age from 18-33 years ($\bar{X} = 25.85$; s.d. = 4.57). Racial composition was 75% Black, 20% Hispanic, 5% Caucasian. Length of hospitalization for this episode at Kingsboro Psychiatric Center ranged from 12-147 days ($\bar{X} = 52.21$; s.d. = 35.05).⁶ For 13 patients, this was either their 1st or 2nd psychiatric hospitalization. One patient was hospitalized for the 10th time and the remaining 6 patients were experiencing their 3rd to 5th hospitalization. The number of days from admission to the initiation of testing ranged from 1-18 days ($\bar{X} = 6.8$; s.d. = 5.52). Since it was not possible to withhold patients' medication at any period during their hospitalization, all patients received anti-

⁶Based upon a sample size of 19. Length of hospitalization data for one patient who has yet to be discharged at the time of this writing was not included.

psychotic medication throughout their period of testing and none received mood active medication. Eighty percent of patients received only phenothiazines during testing ranging from 2.92-25.56 mg/kg estimated equivalent daily dosage of chlorpromazine ($\bar{X}$ = 11.13; s.d. = 5.34) (see Prien and Caffey, 1975; Davis, 1976). Fifteen percent of patients received only the butyrophenone, haloperidol, ranging from 16.21-41.86 mg/kg estimated equivalent daily dosage of chlorpromazine ($\bar{X}$ = 28.06; s.d. = 12.93). One patient received only the thioxanthene, thiothixene at 8.18 mg/kg estimated equivalent daily dosage of chlorpromazine.

Non-Patient Controls

Non-patient controls were selected to match as closely as possible the age and racial composition of the patient population. All non-patients were referrals from the New York State Employment Service. They were paid on an hourly basis in addition to the task dependent rate at which we were permitted to pay patients.

Non-patient controls were screened in two stages. First they were administered the complete MDSS interview in an attempt to exclude individuals who appeared to have any suggestion of psychopathology.⁷ Non-patients were additionally excluded at

⁷Discrete item ratings were not made for the control MDSS because experience from a prior study had suggested that such an instrument which was sensitive to the assessment of psychosis did not effectively quantify a hierarchy of neurotic individuals.

this stage for any of the following: histories of psychiatric hospitalization or criminal incarceration, drug or alcohol addiction, epileptic seizures, mental retardation or left handedness. Non-patients were required to sign the same forms as patients, giving their informed consent to participate in the study. The second screening stage consisted of the measurement of their click thresholds for each ear. As for patients, non-patients were excluded from further testing if they showed a threshold decrement of 20 dB or more in comparison to our non-patient standards or if they were found to have differential sensitivity across their ears of greater than 10 dB or if they failed to learn to perform the threshold task flawlessly at suprathreshold levels.

Identifying Data. Ten male non-patient controls who fulfilled the above criteria were tested on multiple measures of their central auditory system functioning. Non-patients ranged in age from 18-33 years ($\bar{x} = 25.3$; s.d. = 4.47). Racial composition was 80% Black, 10% Hispanic and 10% Caucasian.

Right Temporal Lobe Lesioned Controls

Two right temporal lobe lesioned controls were tested on the same multiple measures of their central auditory system functioning as were psychiatric patients and non-patient controls.

One individual was a 56-year-old Caucasian male who was referred for testing by Dr. Sidney Diamond of Mt. Sinai Medical Center. This individual complained of difficulty comprehending speech in the presence of either background noise or cross con-

versation, dating back to a heart attack suffered nine months earlier. Additionally, complaints of word finding difficulty and problems with recent memory were noted. The confirming evidence for the lesion was determined by a computerized trans-axial tomography scan which revealed an infarct in the right temporal-parietal region.

The other individual was a 32-year-old black male who was seen one month post-surgically as an outpatient of Kings County Hospital. This individual had undergone a right temporal craniectomy for the removal of a right subdural hematoma of 30 c.c. and a right intracerebral hematoma of 20 c.c.

Procedure

Sensory Measures

Response criterion control. A major objective of this study was to obtain measurements of differences in sensory functioning between groups of psychiatric patients, organic patients and non-patients which were not confounded by response criterion. This was accomplished by using a forced-choice signal detection technique (see Green & Swets, 1966). The advantages of this technique for patient research, compared to the classical yes-no procedure for assessing signal detectability, have been demonstrated by Clark, Brown and Rutschmann (1967).

Forced-choice technique. A three-interval temporal forced-choice technique was employed to assess auditory signal detectability for clicks and for tone bursts. The auditory signal was presented in one of three observation intervals and the S had to indicate which of the intervals contained the signal by pressing one of three response buttons. Ss were seated in a

sound attenuating booth wearing a set of circumaural earphones. Two small fans within the booth (Rotron, MK⁴ Whisper Fans) produced a continuous low level of ambient noise.

The following sequence of events occurred for each trial.

A 0.5 sec. duration red light signalled the S that E was ready. The S would then initiate each trial by pressing a telegraph key, which produced another red light, signaling the beginning of the trial. After 3.6 sec., three red lights were presented in temporal sequence, 0.5 sec. on and 0.7 sec. off. Each auditory signal was presented 0.1 sec. after the onset of one of the three lights which all served as observation intervals. The S indicated his choice of which one of the observation intervals contained the signal by pressing one of three response buttons. When a S made a correct choice, a blue feedback light was presented. Ss were instructed that they would earn a one cent reward in addition to their hourly rate of pay for each correct response. Since there was no penalty for an incorrect response, Ss were encouraged to respond on each trial even if they believed that they did not hear the signal in any of the three observation intervals.

A Block-Up-and-Down-Two Interval Forced-Choice stepping procedure (BUDTIF) (Campbell and Lasky, 1968) was adapted for use in this study. The utilization of this procedure permits an accurate estimation of the signal intensity needed for 67% correct responses (50% adjusted for chance) in the three-interval forced-choice task. Campbell (1963) suggested that such a procedure might quickly provide information comparable in precision

and magnitude to that obtained through the implementation of more exhaustive experimental procedures.

A constant signal intensity was used during each block of three trials. The signal level used in a block was determined by the S's performance in the prior block according to the following stepping rules.

0 or 1 correct - increase the signal intensity level for the next block of trials;

2 correct - maintain the same signal intensity level for the next block of trials;

3 correct - decrease the signal intensity level for the next block of trials.

Two different procedural applications of this method were developed for use in this study. A) The first procedure was used to obtain the initial single click threshold estimates for each ear as well as the pure tone audiograms for each ear. This method is a quick procedure that is capable of yielding a precise and reliable threshold estimate in as short a time as ten minutes.

At the initiation of each threshold measurement, the signal intensity level was set at approximately 60 dB above sensation level. This high level of signal intensity was maintained until the E was convinced that the S was accurately performing the task by achieving a level of 100% correct detections. The signal intensity was then reduced in 5 dB steps per trial until the first incorrect response was recorded. From that point, the conventional blocking rules, which were previously described,

were invoked. Signal intensity was adjusted according to these blocking rules in 5 dB steps to achieve a bracketing of the S's threshold. After the S was presented with a fourth block at the same level of signal intensity, the stepping size was reduced to 1 dB. The same blocking rules governing this procedure continued until the S was again presented with a fourth block at the same level of signal intensity. That level of signal intensity, in dB attenuation, was recorded as the threshold estimate.

B) The second procedure was used to obtain independent measures of binaural click summation for each ear leading in a dichotic paradigm with respect to interaural onset times. This method is a procedure that is capable of concurrently yielding four independent threshold estimates, each of which is both precise and reliable. Ss were instructed to listen carefully for the faint click that they heard at the conclusion of procedure (A). They were told to listen carefully to both ears because now the click could occur with equal probability in either ear or in both ears.

The procedure was initiated, with blocking and a stepping size of 1 dB, from the most recently determined threshold level of signal intensity for each ear. The four threshold measurements, consisting of the single click determinations for each ear and the binaural click determinations for each ear leading in interaural onset time, were independently charted as four separate staircases. Each of the four staircases was randomized across blocks of trials with the constraint that each staircase

be presented twice within every sequence of eight blocks. This prevented any one staircase from inordinately suffering the effects of any momentary shift in sensitivity or attention. All staircases were continued, utilizing the blocking rules which were described earlier, until the last of the four staircases reached the point where a block was presented for the fifth time at the same intensity level. The threshold estimate for each staircase, in dB attenuation, was taken as the median of all signal levels revisited during the measurement of that staircase.

To facilitate the stepping in 1 dB steps from block to block for the binaural staircases, the sensitivity of both ears were equated on attenuators F_3 and F_4 by setting the dB difference in sensitivity between the ears on either attenuator F_1 or F_2 (see Figure 1).

To insure that the starting levels of signal intensity for each ear were truly equated for procedure (B), another estimate of the threshold for each ear was obtained for a binaural procedure. This procedure was similar to procedure (B) in that two concurrent staircases were independently determined for the right and the left ear single clicks. This procedure was initiated, with blocking and a stepping size of 1 dB, from the threshold level of signal intensity that was previously determined through the monaural paradigm of procedure (A). Each of the two staircases were randomized across blocks of trials with the constraint that each staircase be presented three times within every sequence of six blocks. Both staircases were con-

tinued for a minimum of eighteen blocks to assess the stability of each single click threshold estimate. The median of all signal levels revisited during the measurement of a staircase was taken as the threshold estimate for that staircase. These new estimates of the single click threshold for each ear were taken as the starting levels for the first session utilizing procedure (B). Thereafter, subsequent sessions of procedure (B) utilized the single click estimates for each ear that were determined in the previous session (see Shaw, Newman and Hirsh, 1947 for the advantages of equating SL to each ear for binaural threshold determination).

Since procedure (B) was begun at threshold levels for each ear, the stability of each of the four staircases was carefully monitored to assure that the S was accurately performing the task. Each staircase was continued from a minimum of 10 blocks to a maximum of 24 blocks. If the criterion of reaching five repeated intensity levels for any staircase was not met by 24 blocks, that staircase as well as the other three concurrently derived staircases was discarded. Similarly, all four staircases were discarded if the single click thresholds, which had been equated prior to each session, were divergent by 4 dB or more at the conclusion of a session. Several patients who were unable to perform this task adequately were discontinued from the study. Figure 12 shows the stability of the staircase data for one patient.

Motivational control. Another objective of this study was to obtain measurements of differences in sensory functioning

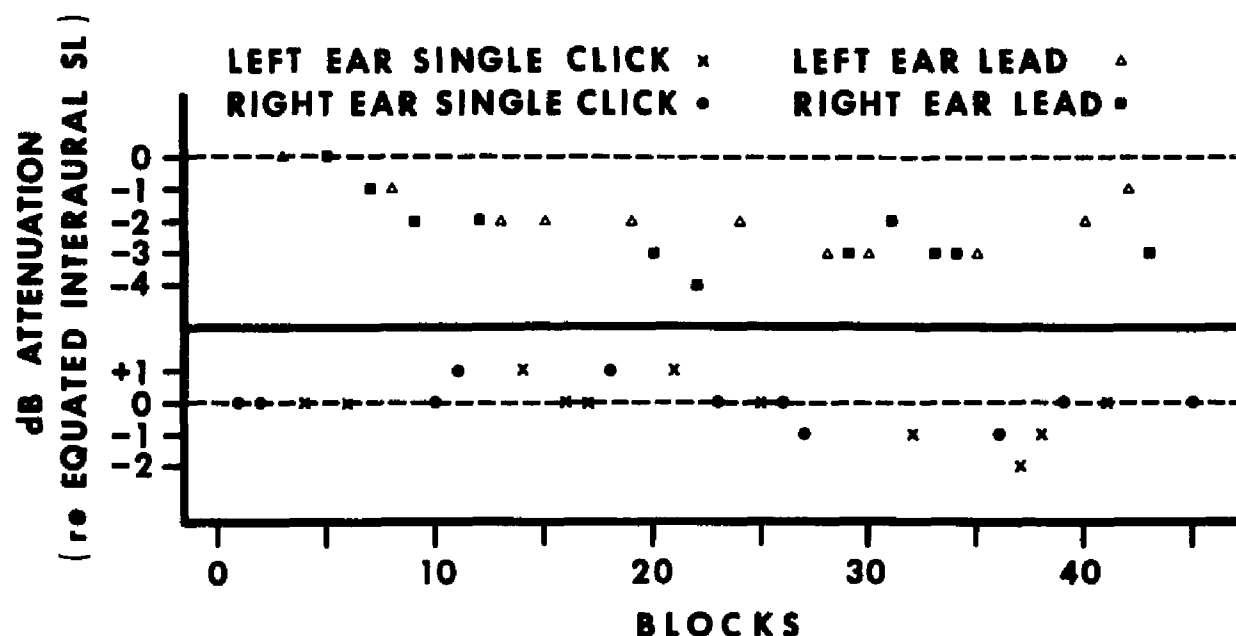


Figure 12. Block-Up-and-Down-Three Interval Forced-Choice staircase data for one patient. All four staircases were concurrently determined during the same session and were initiated at threshold with reference to equated interaural sensation level. The median of both the right and the left ear single click revisitations (single click thresholds) remained unchanged from their staircase starting levels. The left ear leading binaural click staircase displayed a threshold reduction of 2.12 dB, while the right ear leading binaural click staircase displayed a threshold reduction of 2.75 dB. Since the average single click threshold for this session was 0 dB attenuation, the magnitude of binaural energy summation for this session was 2.12 dB when the left ear was leading and 2.75 dB when the right ear was leading.

between groups of psychiatric patients, organic patients and non-patients which were not confounded by motivational differences. This was accomplished by designing the measurement of binaural click summation such that differences between patients and non-patients may be attributable to better performance on the part of the patients.

For each session, the magnitude of binaural click summation was simply the difference between the absolute detection threshold for a click pair, separated by a given interaural onset time, and the average of the absolute detection threshold for a single click presented to each ear. The subjective experience of detecting the presence of energy when the signal was a binaural click pair was identical to the subjective experience of detecting the presence of energy when the signal was a single click presented to either ear. Thus for each session, each S served as his own control for determining the magnitude of binaural click summation. Attempts to increase the magnitude of binaural click summation for non-patients, which were made prior to the initiation of the study, were unsuccessful. These attempts were made for binaurally presented diotic click pairs by filtering either the high or low frequency components from each of the clicks in the pair. Therefore, any evidence of greater binaural click summation for patients as compared to non-patients must be interpreted as better signal detection performance for the patients.

Piloting

Measures of binaural click summation were determined for

five non-patients prior to the initiation of the study for a parametric range of dichotic interaural onset times (Δt 's). The results of this pilot investigation, shown in Figure 13, influenced the selection of the three Δt 's for this study. The Δt of 0.01 msec. was selected because of the homogeneity of variance for this condition among subjects (s.d. = .32 for the right ear leading; s.d. = .31 for the left ear leading). In addition, the 0.01 msec. Δt condition produced the greatest magnitude of summation averaged across both the right and the left ear leading determinations ($|X| = 1.64$ dB). Both the Δt 's of 30 and 60 msec. were selected because these conditions produced the greatest absolute difference between the right and the left ear leading determinations (i.e., 0.9 dB at a Δt of 30 msec.; 0.67 dB at a Δt of 60 msec.). Moreover, there were opposite slopes for the functions between the Δt conditions of 30 and 60 msec. for the right and the left ear leading determinations.

Speech Measures

Another objective of this study was to determine the locus within the auditory system that is responsible for differences in central auditory perception between groups of psychiatric patients, organic patients and non-patients. A carefully selected battery of speech tests of central auditory system functioning were administered for this purpose (see Berlin, 1976). These included a monaurally presented W22 speech discrimination test and three different types of binaurally presented dichotic speech tests.

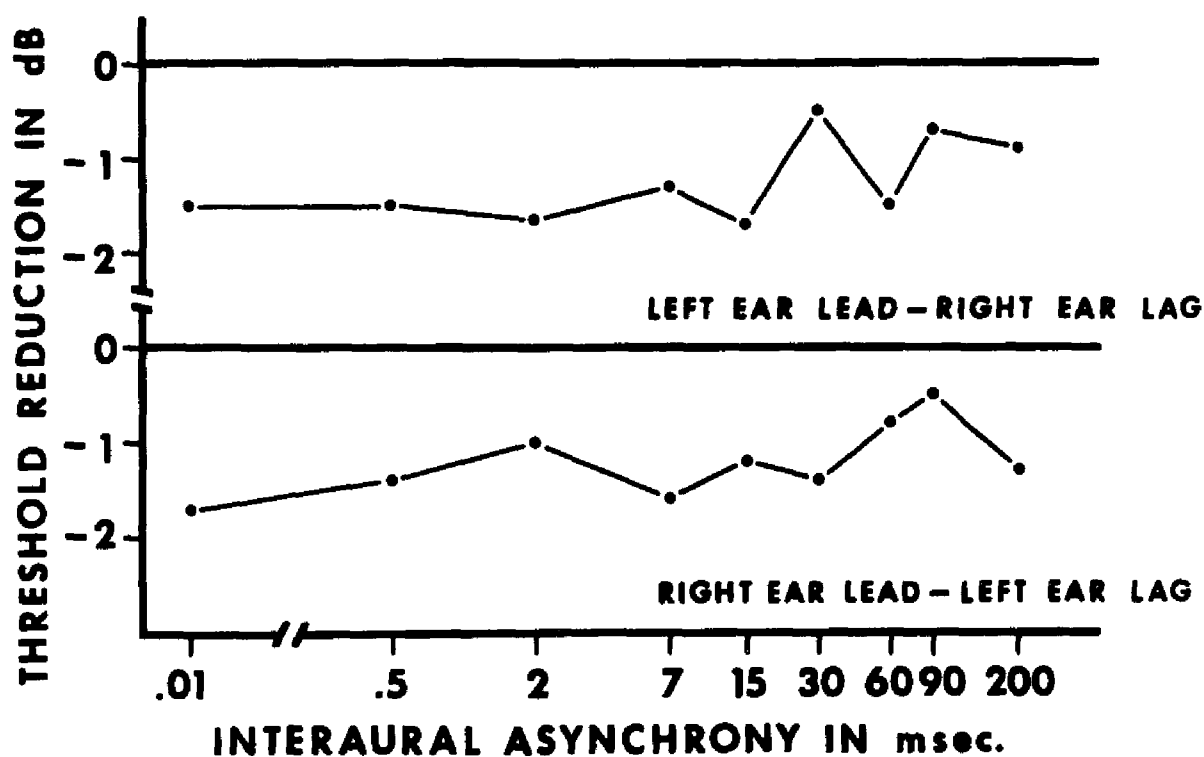


Figure 13. Pilot data for 5 non-patients reflecting binaural energy summation for threshold level clicks over a wide range of interaural onset asynchronies. Threshold reductions in dB for the binaural click pairs are plotted as difference scores with reference to the average single click threshold which was independently determined within each session.

All speech tests were administered in a quiet room which was acoustically tiled and carpeted. S's responses were recorded with an Electrovoice lavalier microphone which was fed into a Uher 4000 tape recorder. The final scoring of all speech test responses for each S was deferred until each response could be heard for the second time, so that its scoring might be verified from the audiotape. The speech reception threshold for each ear was taken as the pure tone averaged threshold for that ear, in dB attenuation, for the frequencies of 500, 1000 and 2000 Hz. The procedure for equating the voltage input to the phones for SL in dB across the apparatus which was used to obtain audiograms and the apparatus used to reproduce speech has been described in the previous section. However, there was a difference of 1 dB between the averaged 500, 1000 and 2000 Hz frequency response for the left phone that was used to transduce tone bursts and the averaged frequency response over this same range for the left phone that was used to transduce speech. Therefore, as the speech reception threshold for the phone that transduced tone bursts produced the greater output, the speech reception threshold for each S was appropriately corrected by subtracting 1 dB from the SL setting, in dB, on the left channel attenuator. No correction was necessary for the frequency responses of the right phones.

Speech Discrimination Test

A phonetically balanced (CNC) monosyllabic word discrimination test (CID W22) was administered monaurally to each ear at an intensity level of 50 dB re SL (i.e., re speech reception

threshold). The desired datum for each listener was the maximum percentage of total words that could be correctly repeated. The results of a pilot investigation for three non-patients influenced the selection of 50 dB re SL for this test, by determining that this was the intensity that produced the greatest level of percent correct performance (i.e., PB max.).

Four blocks, each consisting of a different fifty word CNC list, were presented in counterbalanced order (ABBA) to the right and to the left ear of each subject. The ear of initial presentation was also alternated for each subject. Subjects were instructed to listen carefully to each word in the appropriate ear, to repeat each word exactly as they heard it immediately after its occurrence, and to carefully articulate each repeated word. Percent correct performance was determined separately for each ear.

The W22 audiotape that was used in this study was copied from an original recording acquired from Technisonic Studios.

Staggered Spondaic Word Test (SSW)

The SSW test is a dichotic competing bisyllabic word test that was administered binaurally at an intensity level of 50 dB re SL for each ear (see Brunt, 1972). Each listener was instructed to listen carefully to a group of words which would be presented to both ears, to repeat all of the words exactly as they were heard immediately after the presentation of each group of words, and to carefully articulate each repeated word. Details concerning the scoring of the SSW test are described elsewhere (see Katz, 1973; Lynn and Gilroy, 1972).

The SSW test yields four independent and concurrent indices of speech perception; a measure of each ear for a monotic non-competing condition and a measure of each ear for a dichotic competing condition. Each trial consisted of the presentation of two bisyllabic words (spondees), one to each ear. The onset time of the two spondees were staggered so that the occurrence of the second syllable of the first spondee corresponded with the occurrence, in the other ear, of the first syllable of the second spondee. Figure 14 illustrates this mode of trial presentation. It can be seen that a semantic relationship exists across both ears for the non-competing syllables as well as within each ear for the non-competing and competing syllables that comprise each spondee (e.g., uptown, upstairs, downtown).

Four practice trials and forty test trials were presented to each subject. The test construction provided for the ear of first spondee presentation to be counterbalanced across trials. Consequently, half of the trials began with the first spondee presented to the right ear and the other half began with the first spondee presented to the left ear. It was therefore possible to analyze these data separately for trials with respect to the ear of first spondee presentation.

The determination, for each subject, of both non-competing and competing indices of speech perception for each ear, permitted each subject to serve as his own control for an assessment of lateralized central auditory functioning. Additionally, the raw level of SSW test performance was corrected for each subject with respect to speech discrimination accuracy. The speech discrim-

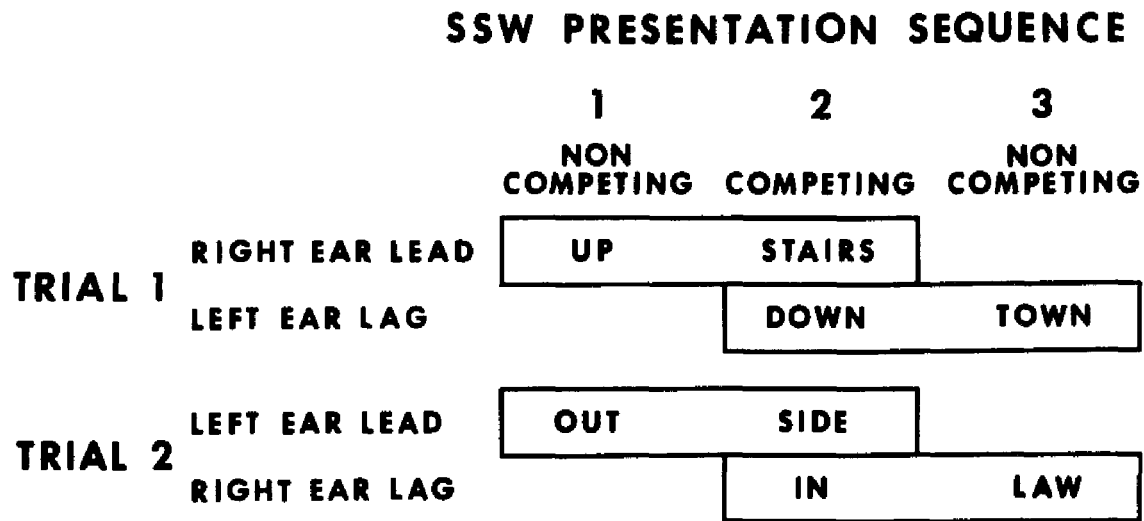


Figure 14. Example of two SSW test trials illustrating the temporal sequence of word presentation and reversal of the ear of first spondee presentation.

ination loss for each ear, represented by the W22 speech discrimination error score for that ear, was added to the appropriate percent correct performance scores for the right ear and for the left ear conditions of the SSW test.

The SSW audiotape that was used in this study was commercially acquired (Auditec of St. Louis) and was a third generation copy of the original recording.

Dichotic Binaural Fusion Test (DBF)

The DBF test is a measure of the binaural fusion of frequency filtered speech for phonetically balanced (CNC) monosyllabic words that were dichotically presented with respect to interaural frequency filtration (see Smith and Resnick, 1972). Each word was binaurally presented as two complementary segments (i.e., a low frequency component and a high frequency component) by means of band pass filtration, so that each monosyllable was, in effect, phonetically bifurcated into vowels and consonants.

The test consisted of three binaural conditions. In the first condition, dichotic "A," the high band was presented to the left ear simultaneously with the presentation of the low band to the right ear. The second condition was a diotic condition for which both the high and the low bands were concurrently presented to each ear. The third condition, dichotic "B," was the reverse of the first condition in that the high band was presented to the right ear as the low band was presented to the left ear.

The determination for each subject of both dichotic (central) and diotic (peripheral) indices of binaural fusion per-

mitted each subject to serve as his own control for an assessment of central auditory fusion. The inclusion of two opposite dichotic conditions further provided the opportunity to analyze these data to determine whether binaural fusion is differentially influenced by which ear receives which phonetic segment of the message.

Each listener was instructed to listen carefully to each word which would be presented to both ears, to repeat each word exactly as it was heard immediately after its presentation and to carefully articulate each repeated word.

The DBF test employed in this study was constructed (Joseph Danto Associates, Inc.) to parallel the test described by Smith and Resnick (1972). The materials were dubbed from an original recording of the Lehiste and Peterson (1959) CNC word lists acquired from Technisonic Studios. The lists were recorded on low-noise tape through a set of cascaded Allison Band Pass Filters to create two bands of filtered speech stimuli. After the materials were filtered, mixing of the high-pass and the low-pass signals was performed with an audiometer to create each of the three conditions in alternating sequence. Three different 50 word CNC lists were recorded in this manner to create three blocks, each of 50 trials. The sequence for alternating trial conditions was dichotic "A," diotic and dichotic "B," across 150 total trials.

Two segments of filtered white noise were recorded during the production of the DBF audiotape to provide a record of the spectral characteristics of both the low-pass and the high-pass

band components. One-third octave analysis of these segments of the completed DBF audiotape was performed with a B&K spectrum analyzer and is presented in Figure 15. It can be seen that the low-pass band was approximately one and one-third octave in width from 390-950 Hz and the high-pass band was approximately one-third octave in width from 1800-2150 Hz with its center frequency gain raised 10 dB re that of the low-pass band.

A parametric pilot investigation was conducted with three non-patients over a range of intensities to specify the intensity level for the DBF test presentation. There were three criteria that the selected intensity level needed to satisfy.

1. It was necessary that the two halves of the split signal be as mutually exclusive as possible to observe binaural fusion.
 2. It was necessary that the dichotic conditions reflect an equal phonetic contribution by each of the single bands.
 3. It was necessary that the dichotic conditions yield a percent correct score exceeding the arithmetic sum of the scores obtained from each single band alone.
- Thus, there needed to be minimal overlap between the high and low band spectra to satisfy criteria 1 and 2. Moreover, to satisfy criteria 3, the high and the low bands needed to be minimally intelligible when presented alone, monaurally to either ear, while being maximally intelligible when presented binaurally in dichotic combination.

The results of monaural and binaural pilot investigations of the DBF test, presented at an intensity level of 40 dB re SL

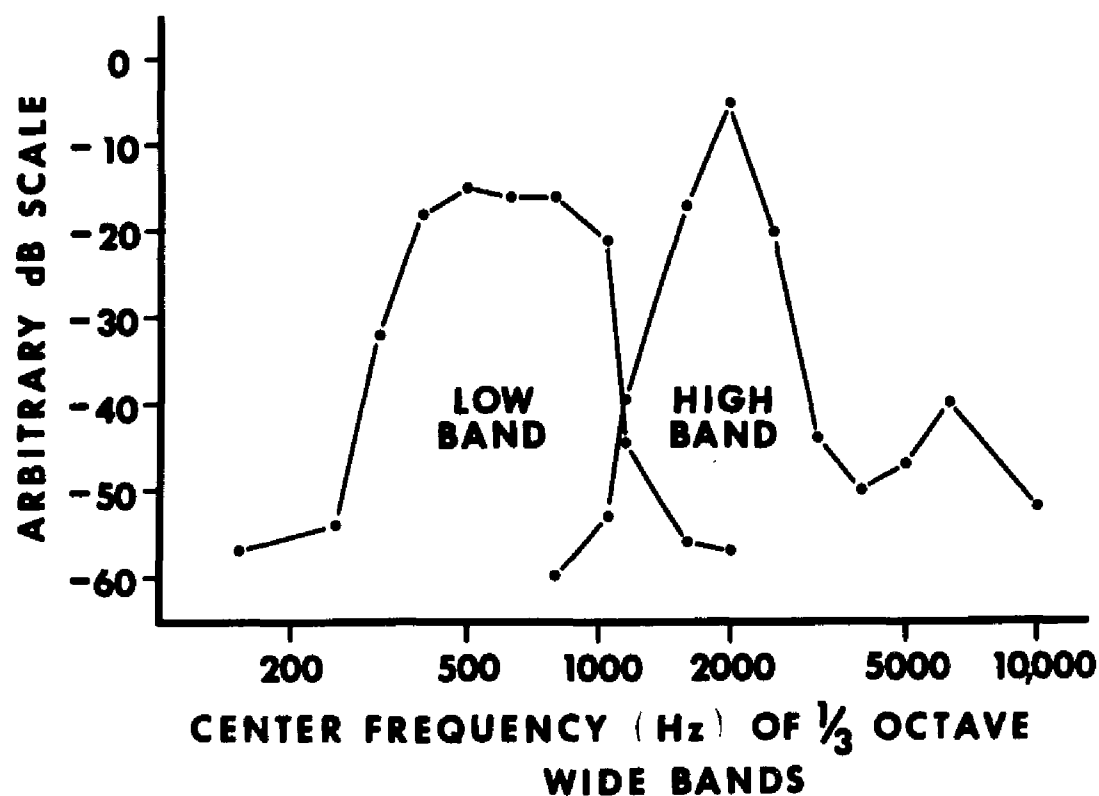


Figure 15. The spectral composition of the low-pass band and of the high-pass band components of the DBF audiotape. One-third octave analysis of filtered white noise segments was performed with a B&K spectrum analyzer.

to each ear of three non-patients, paralleled both the monaural and the binaural data reported by Smith and Resnick (1972) for 119 normal hearing pilot subjects. The DBF test was presented monaurally to the right ear of these non-patients from trial to trial by setting the left channel attenuator at its maximum setting for the duration of the test. The average monaural scores for this pilot investigation of three non-patients was 22% for the low band, 37% for the high band and 75% for both the low and the high bands presented concurrently to the right ear. The average binaural scores for this pilot investigation were 64% for the dichotic "A" condition, 76% for the dichotic "B" condition and 77% for the diotic condition. Thus, the mean binaural fusion score, averaged across the two dichotic conditions for these non-patients, was 7% below the mean diotic fusion score.

The DBF test was, therefore, administered binaurally to each subject at an intensity level of 40 dB re SL for each ear. It was found during piloting that the discriminability of the first block of trials differed from that of the remaining two blocks of trials. The first block of trials needed to be presented at an intensity level of 45 dB re SL in order to match the discriminability data generated by the remaining two blocks that were presented at an intensity level of 40 dB re SL. Therefore, the first block of fifty trials was presented at 45 dB re SL and was analyzed separately as practice data for all subjects.

Binaural Separation Test

The Binaural Separation Test is a dichotic competing sentence test that was administered binaurally at two different intensity levels. Each listener was instructed to listen care-

fully to each sentence that was presented to a designated test ear while ignoring the competing sentence concurrently presented to the non-test ear. Subjects were further instructed to repeat all of the words exactly as they were heard immediately after the presentation of each sentence and to carefully articulate each repeated sentence.

Five practice trials and ten test trials were presented to each subject twice. The first presentation to all subjects designated the right ear as the test ear and the second presentation to all subjects designated the left ear as the test ear. This order was fixed, rather than counterbalanced, because it was found, during the the pilot investigation, that all non-patients had greater difficulty with the condition in which the left ear was designated as the test ear when that condition occurred first. Contrastingly, no differences were observed as a function of presentation position when the condition in which the right ear was designated as the test ear occurred first.

The Binaural Separation Test was presented to the test ear of all subjects at an intensity level of 35 dB re SL for that ear. The intensity level of the sentences presented to the non-test ear of all subjects was 50 dB re SL for that ear. Thus, the sentences to which each subject was instructed to attend were 15 dB softer than were the competing sentences presented to the other ear that each subject was instructed to ignore. Percent correct performance was determined separately for the designation of each ear as the test ear.

The Binaural Separation Test that was used in this study was copied from an original recording by Willeford (1968).

Semi-structured Interview

A major objective of this study was to obtain measurements of differences in sensory functioning between affective and schizophrenic groups of psychiatric patients. It was therefore essential that the discrimination of psychopathology leading to the establishment of these orthogonal diagnostic groups of patients be based upon both rigorous and reliable behavioral criteria for class membership (see Shakow, 1962). Moreover, a prospective goal of this study is to evaluate which of these central measures of auditory perceptual functioning might be valuable adjuncts to an objective diagnostic assessment of psychopathology that is not based upon patient self-disclosure. A completely objective determination of psychopathological subgroupings may be more meaningful than contemporary methods of diagnostic classification with respect to predicting both vulnerability and prognosis, in addition to offering the potential of leading to a more successful treatment outcome for these individuals. Therefore, all psychiatric patients who participated in this study were interviewed with a comprehensive semi-structured protocol that was specially derived for this study to permit the eventual testing of concurrent validity between several measures of central auditory perception and several contemporary methods of diagnostic classification.

The Multiple Diagnostic Strategy Schedule (MDSS) is a hybrid protocol that was constructed of selected items from three source schedules: 1) the US-UK Interview Schedule that was used by the Cross National Study Diagnostic Project (Cooper, Kendell,

Gurland, Sartorius and Farkas, 1969); 2) the Present State Examination (PSE, 9th Edition) (Wing, Cooper, and Sartorius, 1974); and 3) the Schedule for Affective Disorders and Schizophrenia (SADS) (Spitzer and Endicott, 1975).

The combination of these schedules into a hybrid protocol was accomplished to satisfy both the immediate and the prospective goals of this study. A comprehensive and thorough interview was produced that could be effectively used during the study as a working instrument for the attainment of orthogonal diagnostic groups of patients. Additionally, this interview could also permit the subsequent testing of concurrent validity, using the measures of central auditory perception that were obtained in this study as a criterion, for the evaluation of each of the following approaches toward objective diagnostic assessment: 1) Items from the US-UK Interview Schedule may generate symptom profiles for twenty factors of psychopathology that are based upon standard scores which were derived from a prior factor analysis of the ratings for 500 patients in New York and London hospitals (Fleiss, Gurland and Cooper, 1971). The reliability of these ratings and their validity as a prognostic indicator of short-term outcome of hospitalization have been assessed and reported elsewhere (Kendell, Everitt, Cooper, Sartorius and David, 1968; Gurland, Fleiss, Barrett, Sharpe, Simon, Copeland, Cooper and Kendell, 1972); 2) Items from the PSE may be used to generate a CATEGO computer diagnosis (see Wing et al., 1974); 3) A combination of US-UK items, PSE items and SADS items may be used to produce a diagnosis based upon the Research Diag-

nostic Criteria (RDC) developed by Spitzer, Endicott and Robins (1975).

Analyses of acoustosensory patient performance with respect to other diagnostic strategies, including the three outlined above, shall be dealt with in subsequent reports. This initial report, for the purposes of both clarity and expediency, will only present the central auditory perceptual data of psychiatric patients with reference to a single diagnostic strategy that was derived according to the following procedure.

Every patient was interviewed with the complete MDSS protocol at the same period during their course of auditory testing. Each interview was audio recorded using individual lavalier microphones (Electrovoice) for both the patient and the interviewer which were mixed (Shure Audio Mixer) prior to their input to a Uher 4000 tape recorder. Concurrently, video recording of each interview was achieved with an Ampex 7500 video recorder in combination with a closed circuit TV camera (General Electric).

Diagnoses were provided by a psychiatrist, Dr. Lawrence Sharpe, who was kept blind with respect to all aspects of this study. Dr. Sharpe was simply furnished with both the audiotape and the videotape of every patient and instructed to provide a diagnosis for each patient. Dr. Sharpe is a member of the project team of the Cross-National Study of Diagnosis of the Mental Disorders, whose ratings of psychopathology and diagnoses have shown satisfactory reliability among members of the team (Cooper, Kendell, Gurland, Sharpe, Copeland and Simon, 1972; Gurland, Fleiss, Cooper, Sharpe, Kendell and Roberts, 1970). Diagnoses

were based on the International Classification of Diseases (I.C.D.), 8th edition, and the relevant glossary of terms provided by the British Registrar General's office (General Register Office, 1968). The diagnoses of a second psychiatrist, Dr. Barry Gurland, are currently being determined for purposes of assessing reliability and providing diagnostic confirmation. As these diagnoses are not yet available, this report will be based solely on Dr. Sharpe's diagnoses.

Order of Testing

The testing for each subject was performed in the following sequence.

1. Initial single click threshold. The single click threshold of each ear was determined monaurally according to the forced-choice procedure (A). The order of ear measurement was alternated across subjects. Each subject was given a three minute rest period, inside of the acoustic chamber, between the two sessions.

2. Binaural single click threshold. The single click threshold of each ear was independently determined according to the binaural forced-choice procedure (B).

3. Binaural click summation. Estimates of binaural click summation were obtained separately for right ear leading click pairs and for left ear leading click pairs according to the binaural forced-choice procedure (B). The three settings of interaural onset time (Δt), each of which was held constant for the duration of a session, were randomized across sessions and counterbalanced across subjects. Each subject was given a

three minute rest period inside of the acoustic chamber after every 16 blocks of trials and a twenty minute rest period outside of the acoustic chamber after each session.

4. Semi-structured interview. Subjects were interviewed with the MDSS protocol.

5. Pure tone audiograms. The threshold of each ear for tone bursts of 500 msec. duration was determined monaurally according to the forced-choice procedure (A). Frequency settings of 500, 1000 and 2000 Hz were each held constant over a duration of two sessions to sequentially obtain both the right ear and the left ear threshold estimates for each frequency. The order of ear measurement and the setting of frequency were randomized over every two sessions and counterbalanced across subjects. Each subject was given a three minute rest period inside of the acoustic chamber after each session and a twenty minute rest period outside of the acoustic chamber after the fourth session.

6. Speech measures. Four speech tests consisting of the W22 Speech Discrimination test, the SSW test, the DBF test and the Binaural Separation test were administered in the manner previously described.

The total duration of each subject's testing lasted from 15 to 20 hours including rest periods.

CHAPTER IV

RESULTS

Diagnosis

The group of twenty psychiatric inpatients, all of whom had been given hospital diagnoses of schizophrenia, were separated into two diagnostic groups according to study diagnoses which were based upon semi-structured interviews. One group of eight patients retained the diagnosis of schizophrenia, while the other group of nine patients were reclassified under the diagnostic rubric of affective psychosis. The remaining three patients were reclassified as belonging to other diagnostic categories, and their data will not be considered for this report.

The diagnostic sub-classification for each member of the affective and of the schizophrenic groups, as independently provided by hospital and study diagnoses, are contrasted in Table 1. It is not surprising (e.g., see Ollerenshaw, 1973; Abrams et al., 1974) that of the ten patients who were given a hospital diagnosis of paranoid schizophrenia, only three patients retained that diagnosis for the study. The remaining seven patients were reclassified as manic-depressive manic (3), manic-depressive depressed (2), manic-depressive mixed (1) and schizoaffective (manic) (1).

Group Characteristics

Identifying data for the three principal subject groups of affective patients, schizophrenic patients and non-patients are presented in Table 2. All three groups were nearly identical

Table 1

Diagnostic Sub-Classification Provided by Hospital and Study Diagnoses

Patient Groups

Affectives (N=9)

Patient No.	Hospital Diagnosis	Study Diagnosis
1	Acute Schizophrenic Episode (295.40)*	Manic-Depressive-Depressed (296.2)
2	Schizophrenia, Catatonic Type, Withdrawn (295.24)	Manic-Depressive-Depressed (296.2)
3	Paranoid Schizophrenia (295.3)	Manic-Depressive-Mixed (296.9)
4	Paranoid Schizophrenia (295.3)	Manic-Depressive-Depressed (296.2)
5	Paranoid Schizophrenia (295.3)	Manic-Depressive-Manic (296.1)
6	Paranoid Schizophrenia (295.3)	Manic-Depressive-Manic (296.1)
7	Schizophrenia, Chronic Undifferentiated Type (295.9)	Manic-Depressive-Manic (296.1)
8	Paranoid Schizophrenia (295.3)	Manic-Depressive-Depressed (296.2)
9	Paranoid Schizophrenia (295.3)	Manic-Depressive-Manic (296.1)

Schizophrenics (N=8)

Patient No.	Hospital Diagnosis	Study Diagnosis
10	Paranoid Schizophrenia (295.3)	Paranoid Schizophrenia (295.3)
11	Paranoid Schizophrenia (295.3)	Paranoid Schizophrenia (295.3)
12	Schizophrenia, Chronic Undifferentiated Type (295.9)	Paranoid Schizophrenia (295.3)
13	Schizophrenia, Chronic Undifferentiated Type (295.9)	Paranoid Schizophrenia (295.3)
14	Paranoid Schizophrenia (295.3)	Schizo-Affective-(Manic) (295.7)
15	Schizophrenia, Catatonic Type, Withdrawn (295.24)	Schizo-Affective-(Manic) (295.7)
16	Schizophrenia, Chronic Undifferentiated Type (295.9)	Paranoid Schizophrenia (295.3)
17	Paranoid Schizophrenia (295.3)	Paranoid Schizophrenia (295.3)

* I.C.D. Number

Table 2
Identifying Data for Principal Subject Groups

	Subject Groups		
	(N=9) Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Mean Age	25.22 (5.09)*	25.38 (4.00)	25.30 (4.47)
Racial Composition			
%Black	78	75	80
%Hispanic	22	25	10
%Caucasian	0	0	10
Mean Length of Current Hospitalization/Days	49.50** (33.15)	46.38 (25.97)	—
Mean Total Number of Hospitalizations Including Present	1.44 (0.53)	3.62 (2.67)	—
Mean Number of Days From Admission to Initiation of Testing	6.89 (4.99)	8.50 (6.35)	—
% Receiving only Phenothiazines	89	88	—
Mean Dosage Level (re estimated Equivalent Daily Dosage of Chlorpromazine)	10.80 (4.02)	12.01 (7.02)	—
% Receiving only Haloperidol	11	12	—
Dosage Level (re estimated Equivalent Daily Dosage of Chlorpromazine)	16.21 (0)	41.86 (0)	—

* Standard Deviation

** based on a sample size of 8

with respect to age and racial composition. The two patient groups were also well matched for both type and level of medication. Differences between patient groups with respect to total number of hospitalizations and length of current hospitalization were not significant.

Binaural Click Summation

Single Click Thresholds

The group means and standard deviations of the average single click thresholds which were determined concurrently with dichotic click thresholds according to the binaural forced-choice procedure (B), are presented in Table 3 for the three principal subject groups.⁸ A two-way ANOVAR with repeated measures revealed that although the affective patients had the least sensitive click thresholds in each ear, group differences were not significant ($F[2,24] = 1.68$; $p = .208$). Nor were there significant ear differences for click sensitivity either between groups or summed across groups. Additionally, the single click threshold data for each group was reasonably stable across sessions. The mean group standard deviations of single click threshold determinations are presented in Table 4.⁹

The group means of the initial single click threshold estimates which were determined according to the quick monaural

⁸ The average single click thresholds for the two right temporal lesioned controls ranged from 33.08 dB SPL to 36.00 dB SPL ($\bar{x} = 34.54$; s.d. = 2.06) for their right ear and from 37.89 dB SPL to 49.14 dB SPL ($\bar{x} = 43.52$; s.d. = 7.95) for their left ear.

⁹ The standard deviations of the single click thresholds for the two right temporal lesioned controls ranged from 1 dB to 1.68 dB ($\bar{x} = 1.34$; s.d. = 0.48) for their right ear and from 0.82 dB to 1.47 dB ($\bar{x} = 1.14$; s.d. = 0.46) for their left ear.

Table 3

Mean Average Single Click Thresholds for Affective
Patients, Schizophrenic Patients and Non-Patients

Ear	Subject Groups		
	(N=9) Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Left	42.66* (5.53)**	41.67 (4.89)	40.03 (3.73)
Right	42.92 (4.82)	40.51 (4.13)	38.42 (3.92)

*Thresholds in dB SPL
**Standard Deviation

Table 4

Mean Standard Deviations of Single Click Thresholds for
Affective Patients, Schizophrenic Patients and Non-Patients

Ear	Subject Groups		
	(N=9) Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Left	1.54 * (.49)**	1.61 (1.26)	1.00 (.39)
Right	1.15 (.73)	1.55 (.93)	.88 (.61)

*Standard Deviations in dB
**Standard Deviation

procedure (A) were little different from the group means which have been presented in Table 3. These differences ranged from .08 dB to 1.06 dB over the six cells within the table ($\bar{x}$ = .44 dB/cell; s.d. = .35).

Dichotic Click Thresholds

Right temporal lesioned controls. The mean threshold reduction for the two right temporal lesioned controls is plotted in Figure 16 with each patient's average single click threshold serving as a referent. Plotting the data in this form permits each individual to be evaluated as his own control. It is clear that the greatest degree of threshold reduction (i.e., binaural summation) occurred at interaural asynchronies (Δt_s) of 0.01 and 60 msec. Moreover, these subjects' performance was asymmetrical at interaural asynchronies of 30, 60 and 90 msec; the degree of binaural summation was greater when the lag click was presented to the ear that was contralateral to the lesioned hemisphere (i.e., the left ear).

Affective patients, schizophrenic patients and non-patients. The mean threshold reduction for affective patients, schizophrenic patients and non-patients is plotted in Figure 17 with each patient's average single click threshold serving as a referent. The affective patients displayed their greatest degree of threshold reduction (i.e., binaural summation) at interaural asynchronies (Δt_s) of 0.01 and 60 msec. The affective patients also showed evidence of asymmetrical performance, achieving a greater degree of binaural summation when the lag click was presented to their left ear. The direction of this interaural asymmetry

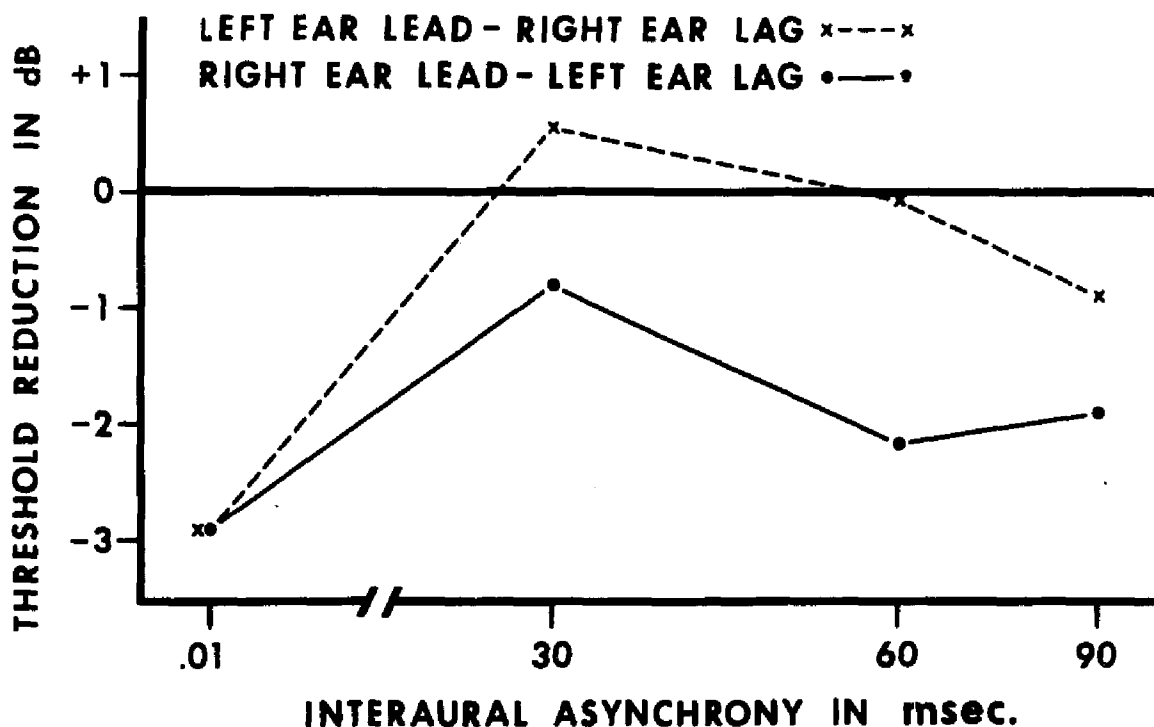


Figure 16. Data for two right temporal lesioned controls reflecting binaural energy summation for threshold level clicks over a range of four different interaural onset asynchronies. Threshold reductions in dB for the binaural click pairs are plotted as difference scores with reference to the average single click threshold which was independently determined within each session.

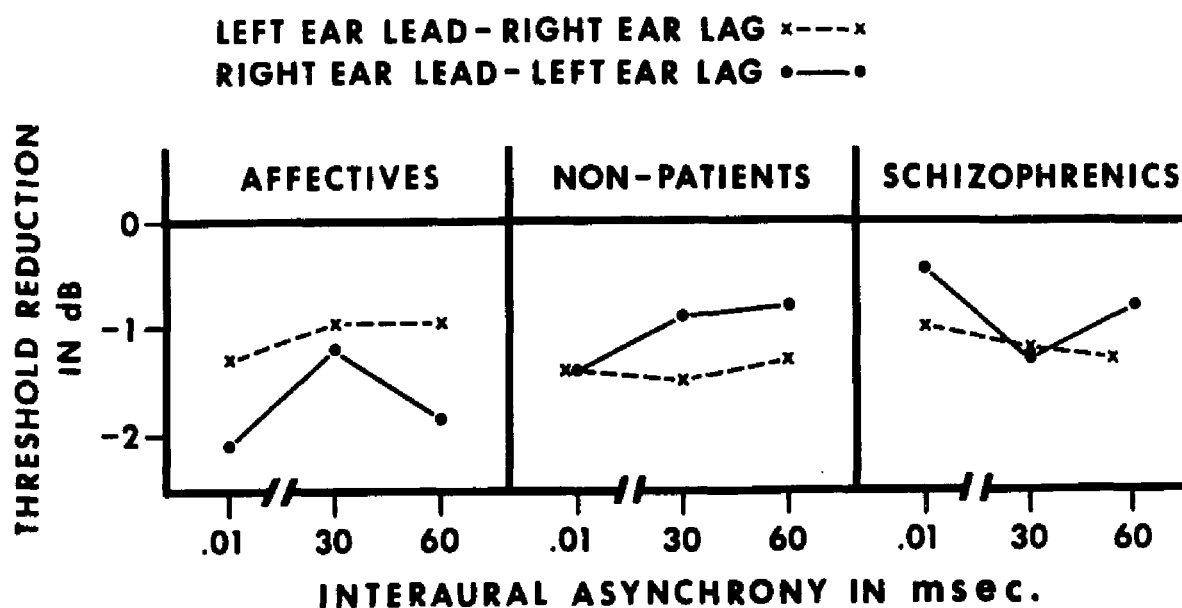


Figure 17. Data for 9 affective psychotic patients, 8 schizophrenic patients and 10 non-patient controls reflecting binaural energy summation for threshold level clicks over a range of three different interaural onset asynchronies. Threshold reductions in dB for the binaural click pairs are plotted as difference scores with reference to the average single click threshold which was independently determined within each session.

is consonant with what could be expected given right temporal lobe dysfunction (e.g., see Figure 16). Moreover, it concurs with predicted performance, based upon Flor-Henry's hypothesis, which would anticipate lateralized right hemispheric dysfunction in affective psychotic patients. In contrast, schizophrenic patients and non-patients showed their greatest degree of binaural summation when the lag click was presented to their right ear.

The results of a three-way ANOVAR with repeated measures on two factors for these data (see Table 5) revealed that the interaural asymmetry between affective patients, schizophrenic patients and non-patients bordered on significance at the .05 level summed over all three interaural asynchronies ($F[2,24] = 3.12$; $p = .062$). Specifically, a separate one-way ANOVAR of the difference scores between the right ear leading and the left ear leading conditions, performed between groups for an interaural asynchrony of 60 msec., achieved significance ($F[2,24] = 3.47$; $p < .05$). Scheffé multiple comparisons (see Scheffé, 1959) revealed that the mean interaural asymmetry (i.e., the mean difference score between the right ear leading and left ear leading conditions) for affective patients was significantly greater than the mean interaural asymmetry for schizophrenics and non-patients taken together ($t = 2.63$; $p < .05$).

It should be recalled that interaural sensitivity differences were minimized by equating right and left ear single click thresholds prior to each session. The practice of "adjusting" single click thresholds prior to each session proved successful

Table 5

Three-way ANOVAR for the Binaural Summation
of Dichotic Click Pairs for Affective Patients,
Schizophrenic Patients and Non-Patients

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Prob. F Exceeded</u>
Group	3.44	2	1.72	0.87	0.428
Error	47.04	24	1.96		
Ear	0.00	1	0.00	0.00	0.981
Ear x Group	8.65	2	4.32	3.12	0.062
Error	33.27	24	1.38		
Δt^*	0.27	2	0.13	0.06	0.937
Δt x Group	6.52	4	1.63	0.78	0.543
Error	100.13	48	2.08		
Ear x Δt	0.23	2	0.11	0.24	0.785
Ear x Δt x Group	2.78	4	0.69	1.44	0.232
Error	23.06	48	0.48		

*Interaural Asynchrony

in achieving near equal levels of detection for each ear. The mean "adjusted" interaural single click threshold differences, obtained concurrently with the dichotic click thresholds for an interaural asynchrony of 60 msec., were 0.01 dB for affective patients (s.d. = 1.68), 0.4 dB for schizophrenic patients (s.d. = 2.00), and 0.4 dB for non-patients (s.d. = 1.40) in the direction of greater sensitivity for the right ear in all three groups.¹⁰ Therefore, the greater interaural asymmetry of binaural summation, achieved by the affective patients for a dichotic asynchrony of 60 msec., cannot be explained by interaural sensitivity differences to single clicks.

Furthermore, the distinctive interaural asymmetry displayed by the affective patients cannot be explained as the consequence of a difference between patient groups with respect to either type or level of medication (see Table 2). An index of the relationship between the magnitude of interaural asymmetry for each patient and the phenothiazine dosage level for that patient (in mg/kg estimated equivalent daily dosage of chlorpromazine) was obtained separately for each patient group for an interaural asynchrony of 60 msec., employing Pearson product-moment correlations. No significant correlation was found for either patient group ($r = -0.08$ for schizophrenics; $r = 0.10$ for affectives¹¹).

¹⁰ The "adjusted" interaural single click threshold differences for the two right temporal lesioned controls at an interaural asynchrony of 60 msec. ranged from -1.75 dB to +2.00 dB ($\bar{X} = +0.12$; s.d. = 2.65) in the direction of greater sensitivity for the left ear.

¹¹ Positive correlations reflect a direct relationship between increasing dosage level and increasing asymmetry in the direction of greater summation for the right ear leading condition.

Speech Perception

Speech Reception Thresholds

The results of a three-way ANOVAR with repeated measures on two factors for the pure tone threshold data revealed that the average speech reception thresholds of the affective and the schizophrenic patient groups (see Table 6¹²) were approximately 5 dB less sensitive for both ears in comparison to non-patients ($F[2,23] = 3.46$; $p = .048$). There were no other significant differences in pure tone sensitivity between groups either for ear and/or for frequency.

Speech Discrimination

The groups of affective patients, schizophrenic patients and non-patients performed equally well on the CID W22 word discrimination test (see Table 7¹³). A two-way ANOVAR with repeated measures was performed on these data and revealed no significant differences between groups for level of performance summed across both ears or separately for either ear.

SSW Test

Right temporal lesioned controls. The raw percent correct

¹²The pure tone thresholds in dB SPL for the two right temporal lesioned controls at 500, 1000 and 2000 Hz ranged from 29.60 dB to 31.60 dB ($\bar{X} = 30.60$; s.d. = 1.41), from -1dB to 24 dB ($\bar{X} = 11.50$; s.d. = 17.68), and from -2.60 dB to 3.40 dB ($\bar{X} = 0.40$; s.d. = 4.24) for their right ear; from 26.50 dB to 31.50 dB ($\bar{X} = 29$; s.d. = 3.54), from 4.70 dB to 14.70 dB ($\bar{X} = 9.70$; s.d. = 7.07), and from 10.50 dB to 13.50 dB ($\bar{X} = 12.00$; s.d. = 2.12) for their left ear. The speech reception thresholds ranged from 9.33 dB to 19 dB ($\bar{X} = 14.16$; s.d. = 6.84) for their right ear and from 15.57 dB to 18.23 dB ($\bar{X} = 16.90$; s.d. = 1.88) for their left ear.

¹³The percent correct word discrimination scores for the two right temporal lesioned controls ranged from 84 to 91% ($\bar{X} = 87.50$; s.d. = 4.95) for their right ear and from 75 to 90% ($\bar{X} = 82.50$; s.d. = 10.6) for their left ear.

Table 6

Mean Pure Tone Thresholds for Affective Patients,
Schizophrenic Patients and Non-Patients

Ear	Frequency (Hz)	Subject Groups		
		(N=9) [†] Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Left	500	37.88* (8.33)**	38.12 (4.14)	33.60 (6.19)
	1000	12.82 (7.49)	14.01 (8.06)	9.50 (6.91)
	2000	14.39 (10.73)	13.25 (11.21)	6.50 (3.53)
	Speech Reception Threshold	21.86 (5.49)	21.80 (6.57)	16.54 (4.47)
Right	500	38.35 (5.57)	38.22 (5.07)	33.70 (5.51)
	1000	14.75 (7.09)	12.38 (7.69)	8.30 (5.66)
	2000	11.51 (4.11)	10.65 (7.68)	6.80 (2.91)
	Speech Reception Threshold	21.46 (4.37)	20.42 (5.99)	16.27 (3.19)

*Thresholds in dB SPL

**Standard Deviation

† For one patient, right and left ear thresholds could be obtained only for the 2000 Hz tone. Mean right and left ear thresholds for the 500 Hz and 1000 Hz tones as well as the mean speech reception thresholds reflect a sample size of 8.

Table 7

Mean Percent Correct Word Discrimination for Affective
Patients, Schizophrenic Patients and Non-Patients

Ear	Subject Groups		
	(N=9) Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Left	90.89 (6.9)*	91.25 (2.71)	94.60 (3.78)
Right	91.56 (4.80)	90.25 (3.69)	94.30 (3.68)

*Standard Deviation

SSW test performance of the two right temporal lesioned controls is presented in Figure 18. The asymmetrically poor performance by these subjects for the ear contralateral to their lesioned hemisphere, especially marked for the competing condition, is typical of the SSW performance reported elsewhere (e.g., Brunt, 1972; Lynn and Gilroy, 1972; and Katz, 1968) for individuals with unilateral right temporal lesions.

Affective patients, schizophrenic patients and non-patients.

The raw percent correct SSW test performance of affective patients, schizophrenic patients and non-patients is presented in Figure 19. Performance differences between groups were particularly marked for competing syllables. While schizophrenic patients did more poorly than non-patient controls for competing syllables in both their ears, affective patients displayed an asymmetrical performance decrement for only their left ear. The direction of this interaural asymmetry is consonant with what could be expected given right temporal lobe dysfunction (e.g., see Figure 18). Moreover, it concurs with predicted performance, based upon Flor-Henry's hypothesis, which would anticipate lateralized right hemispheric dysfunction in affective psychotic patients.

The bilaterally poor performance of schizophrenics for competing syllables is consistent with the reports of others (e.g., Ludwig et al., 1962 and Maloney et al., 1976) that word discrimination in schizophrenic patients is particularly marred when the task difficulty is increased by presenting distracting words to the opposite ear. Furthermore, the bilaterally poor perform-

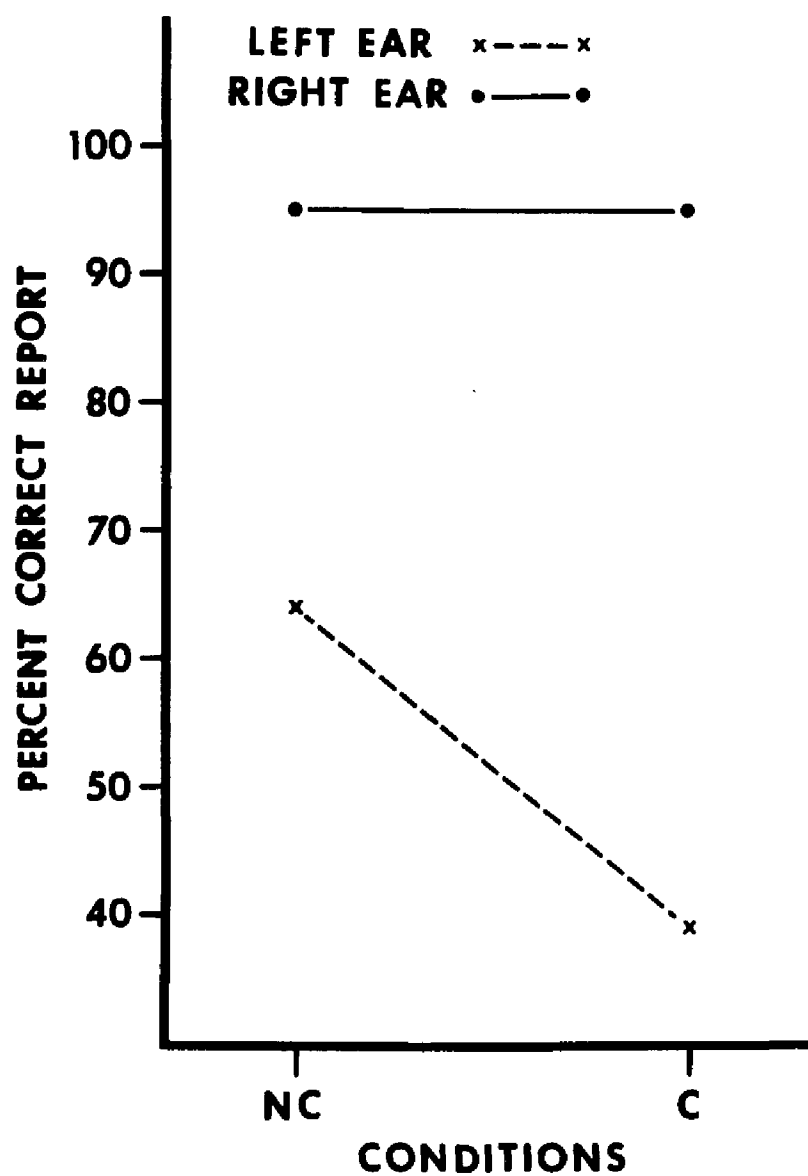


Figure 18. Raw percent correct SSW test performance for two right temporal lesioned controls. NC = non-competing condition; C = competing condition.

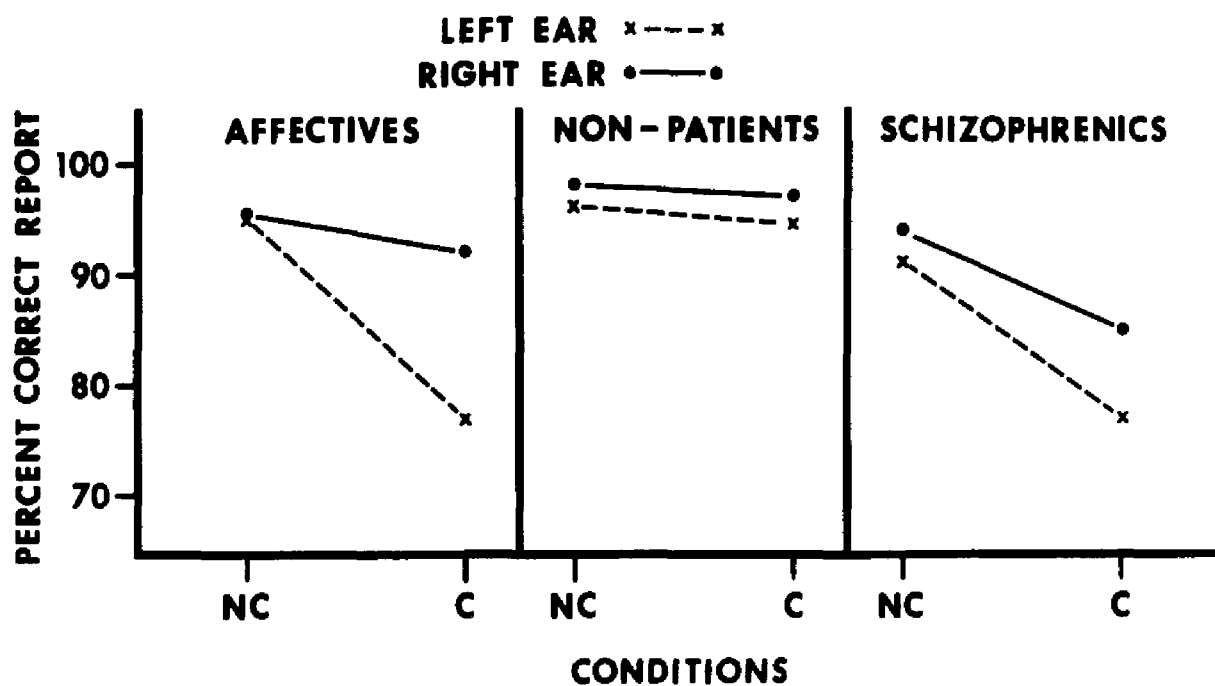


Figure 19. Raw percent correct SSW test performance for 9 affective psychotic patients, 8 schizophrenic patients and 10 non-patient controls. NC = non-competing condition; C = competing condition.

ance of schizophrenic patients for competing syllables mirrors the findings of Polidoro (1970) who reported that acute schizophrenics performed bilaterally poorer than non-patient controls for competing syllables yet performed as well as non-patients for non-competing syllables.

The results of a three-way ANOVAR with repeated measures on two factors for these data (see Table 8) were highly significant for the main effects of group, ear and condition (i.e., competing vs. non-competing). Of particular relevance were the significant two and three-way interactions among group, ear and condition. Scheffé multiple comparisons revealed that the significance of the three-way interaction among group, ear and condition was attributable to differences between the affective patients and non-patients ($t = 3.29$; $p < .025$) as well as between the affective patients and both the schizophrenic patients and non-patients taken together ($t = 3.04$; $p < .025$).

The distinctive performance of the affective patients on the SSW test cannot be explained as the consequence of a difference between patient groups with respect to either type or level of medication (see Table 2). An index of the relationship between the magnitude of the raw SSW difference score between ears and conditions for each patient (i.e., $(RC-LC)-(RNC-LNC)$) and the phenothiazine dosage level for that patient (in mg/kg estimated equivalent daily dosage of chlorpromazine) was obtained separately for each patient group employing Pearson product-moment correlations. No significant correlation was found for either patient

Table 8

Three-way ANOVAR for the SSW test Performance of
 Affective Patients, Schizophrenic
 Patients and Non-Patients

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Prob. F Exceeded</u>
Group	1857.41	2	928.70	7.46	0.003
Error	2984.01	24	124.33		
Ear	709.67	1	709.67	26.15	<.001
Ear x Group	170.01	2	85.00	3.13	0.062
Error	651.22	24	27.13		
Condition	1684.48	1	1684.48	46.24	<.001
Cond. x Group	567.22	2	283.61	7.78	0.002
Error	874.11	24	36.42		
Ear x Condition	290.45	1	290.45	14.14	0.001
Ear x Cond. x Group	226.43	2	113.21	5.51	0.011
Error	492.69	24	20.52		

group ($r = 0.11$ for schizophrenics; $r = -0.03$ for affectives¹⁴).

Corrected SSW test percentages, which compensated for each subject's right and left ear speech discrimination error score, were also investigated with a three-way ANOVAR having repeated measures on two factors. The outcome closely matched the results of the three-way ANOVAR for the SSW raw score data. The significance of the three-way interaction among group, ear and condition was unchanged ($F[2,24] = 5.51$; $p = .011$).

The most conservative analysis of SSW test performance is the adjusted percent correct score, which compensates for response bias by considering only the better half of each subject's performance for each condition. Adjusted SSW test scores were, therefore, also examined with a three-way ANOVAR having repeated measures on two factors. The three-way interaction among group, ear and condition remained significant ($F[2,24] = 3.55$; $p = .045$).

It should be recalled that half of the SSW trials began with the first spondee presented to the right ear and the other half began with the first spondee presented to the left ear. The mean number of errors for each syllable as a function of which ear received the first spondee is plotted in Figure 20 for the two right temporal lesioned controls and in Figure 21 for affective patients, schizophrenic patients and non-patients. An inspection of these curves for all four groups reveals that correspondence between the number of errors for "right ear first" versus "left ear first" trials is greatest for the two right temporal lesioned

¹⁴ Positive correlations reflect a direct relationship between increasing dosage level and increasing difference scores between both ears and conditions according to the procedure (RC-LC) - (RNC-LNC).

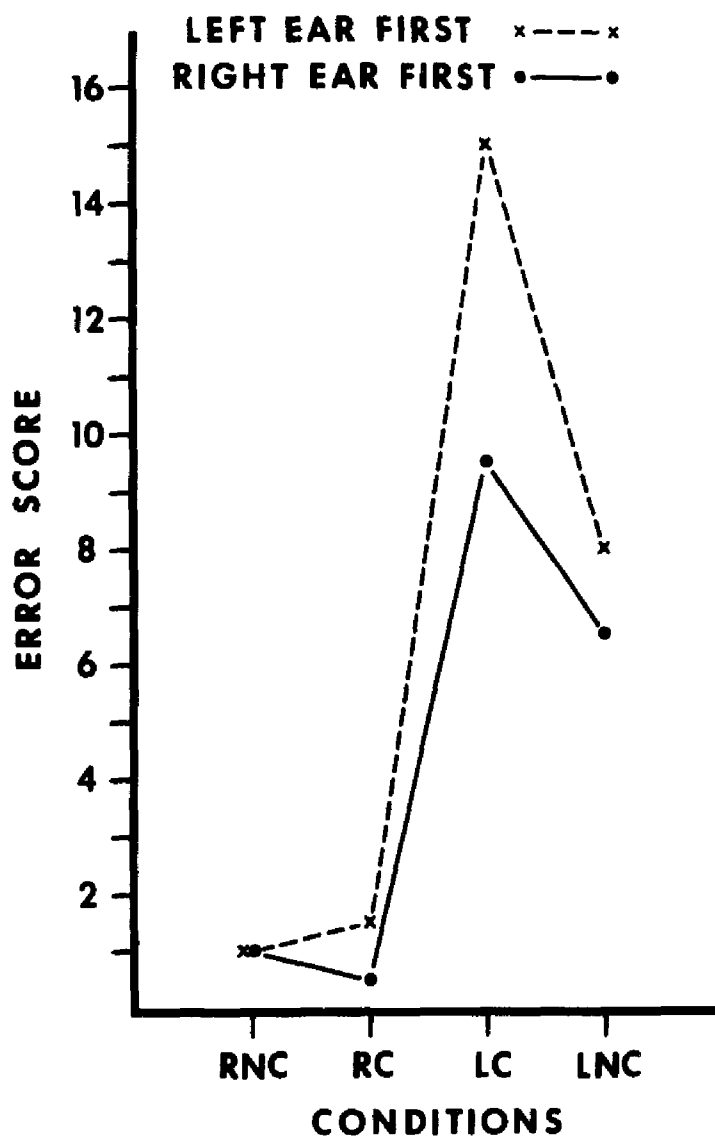


Figure 20. Raw SSW test performance for two right temporal lesioned controls contrasting error scores for "right ear first" trials with "left ear first" trials. RNC = non-competing condition for the right ear; RC = competing condition for the right ear; LC = competing condition for the left ear; LNC = non-competing condition for the left ear.

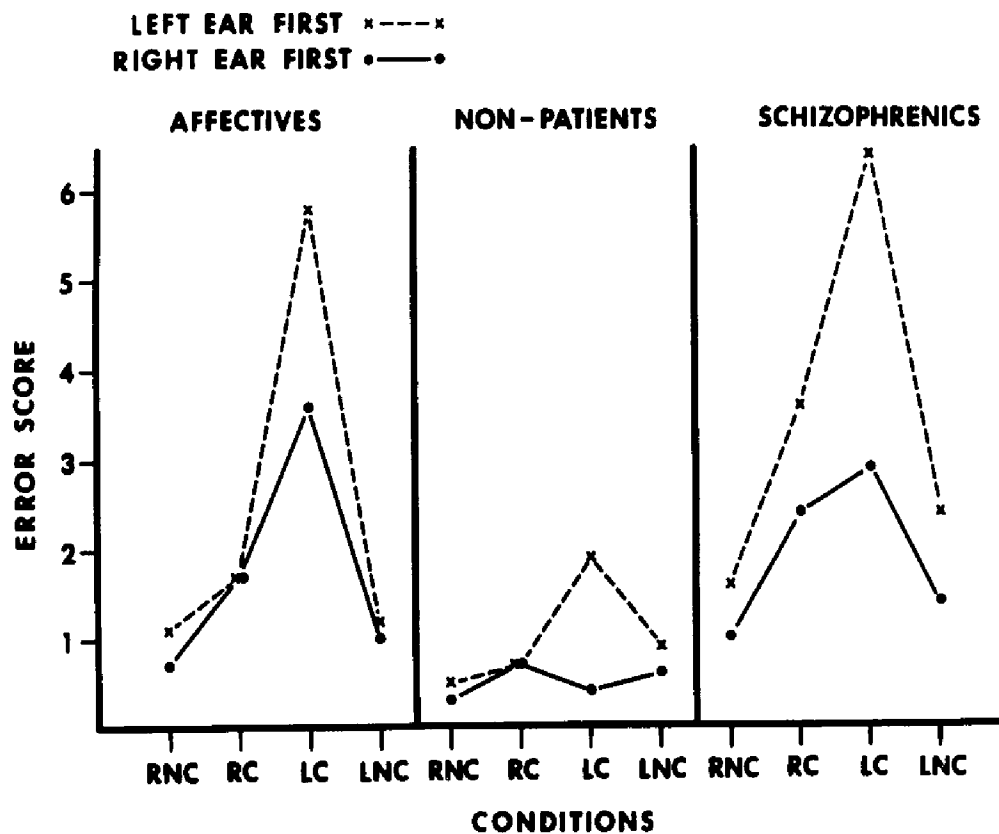


Figure 21. Raw SSW test performance for 9 affective psychotic patients, 8 schizophrenic patients and 10 non-patient controls contrasting error scores for "right ear first" trials with "left ear first" trials. RNC = non-competing condition for the right ear; RC = competing condition for the right ear; LC = competing condition for the left ear; LNC = non-competing condition for the left ear.

controls and for the affective patients. Katz (1973) reasoned that a patient with a unilateral temporal lobe lesion would make errors for competing syllables presented to their contralateral ear irrespective of whether these syllables were in the first spondee or the second spondee and irrespective of whether they were in "right ear first" or "left ear first" trials. Thus, the observed correspondence for affective patients between their number of errors for "right ear first" versus "left ear first" trials could be expected given right temporal lobe dysfunction.

These data for affective patients, schizophrenic patients and non-patients were further examined with a four-way ANOVA having repeated measures on three factors (see Table 9¹⁵). While the individual main effects of group, ear, condition and position were all highly significant, their four-way interaction was not significant. Of particular interest for this analysis was the two-way interaction between group and position which bordered on significance at the .05 level. Inspection of Figure 21 suggests that this interaction is chiefly attributable to lesser correspondence for the performance of schizophrenic patients between "right ear first" and "left ear first" trials compared with either affective patients or non-patients. Therefore, the greater interaural asymmetry of SSW test performance, displayed by affective patients for competing syllables, cannot be explained by a positional response bias for "right ear first" versus "left

¹⁵ The small differences between the statistics pertaining to group, ear and condition in this table and those presented in Table 8 were the result of rounding errors attributable to the differential use of error scores (i.e., Table 9) and percentages (i.e., Table 8).

Table 9

Four-way ANOVAR for the SSW Test Performance of
Affective Patients, Schizophrenic Patients and Non-Patients

<u>Source</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>	<u>Prob. F Exceeded</u>
Group	146.02	2	73.01	7.35	0.003
Error	238.48	24	9.94		
Ear	57.36	1	57.36	28.35	<0.001
Ear x Group	14.06	2	7.03	3.47	0.047
Error	48.56	24	2.02		
Condition	133.43	1	133.43	46.81	<0.001
Cond. x Group	42.71	2	21.36	7.49	0.003
Error	68.41	24	2.85		
Ear x Cond.	23.10	1	23.10	13.91	0.001
Ear x Cond. x Group	17.25	2	8.62	5.19	0.013
Error	39.84	24	1.66		
Position	47.18	1	47.18	25.98	<0.001
Pos. x Group	11.47	2	5.73	3.16	0.061
Error	43.60	24	1.82		
Ear x Pos.	14.41	1	14.41	3.97	0.058
Ear x Pos. x Group	0.58	2	0.29	0.08	0.923
Error	87.03	24	3.63		
Cond. x Pos.	12.00	1	12.00	7.31	0.012
Cond. x Pos. x Group	2.62	2	1.31	0.80	0.461
Error	39.39	24	1.64		
Ear x Cond. x Pos.	12.16	1	12.16	4.14	0.053
Ear x Cond. x Pos. x Group	0.65	2	0.32	0.11	0.896
Error	70.44	24	2.93		

ear first" trials.

DBF test

The groups of affective patients, schizophrenic patients and non-patients performed equally well on the Dichotic Binaural Fusion test (see Table 10¹⁶). All three groups displayed approximately 10% diotic gain over each of the dichotic conditions. These data lie within the range of the "negative" DBF test score interpretation that was utilized by Smith and Resnick (1972) for the assessment of brain stem dysfunction.

A two-way ANOVAR with repeated measures was performed on these data and revealed no significant differences between groups for level of performance summed across both dichotic conditions or separately for either dichotic condition (i.e., dichotic "A" or dichotic "B"). The correspondence between the percent correct DBF test performance of affective patients, schizophrenic patients and non-patients may be seen in Figure 22.

The finding that affective patients and schizophrenic patients do as well as non-patients on a speech discrimination test that is sensitive to brain stem level dysfunction suggests that there is no deficit in the functional integrity of brain

¹⁶ The percent correct difference scores between the diotic and dichotic conditions for the two right temporal lesioned controls ranged from 26 to 61% ($\bar{x}$ = 43.50; s.d. = 24.75) for dichotic "A" and from 7 to 21% ($\bar{x}$ = 14; s.d. = 9.90) for dichotic "B." The levels of percent correct performance ranged from 12 to 35% ($\bar{x}$ = 23.50; s.d. = 16.26) for dichotic "A," from 52 to 54% ($\bar{x}$ = 53; s.d. = 1.41) for dichotic "B" and from 61 to 73% ($\bar{x}$ = 67; s.d. = 8.48) for the diotic condition. The diotic-dichotic difference score for dichotic "B" is within the "negative" range of DBF score interpretation. The interpretation of the dichotic "A" score is uncertain, however, because of the great variability between these two subjects and because the results of audiometric evaluation for each of these individuals revealed a substantial sensitivity loss at 4000 Hz for their left ears.

Table 10

Diotic Gain for Affective Patients, Schizophrenic
Patients and Non-Patients on the DBF Test

Condition	Subject Groups		
	(N=9) Affectives	(N=8) Schizophrenics	(N=10) Non-Patients
Dichotic "A"	11.78* (10.47)**	10.62 (6.67)	9.50 (8.03)
Dichotic "B"	10.44 (13.53)	5.62 (11.32)	10.70 (8.91)

*Diotic percent correct -
dichotic percent correct

**Standard Deviation

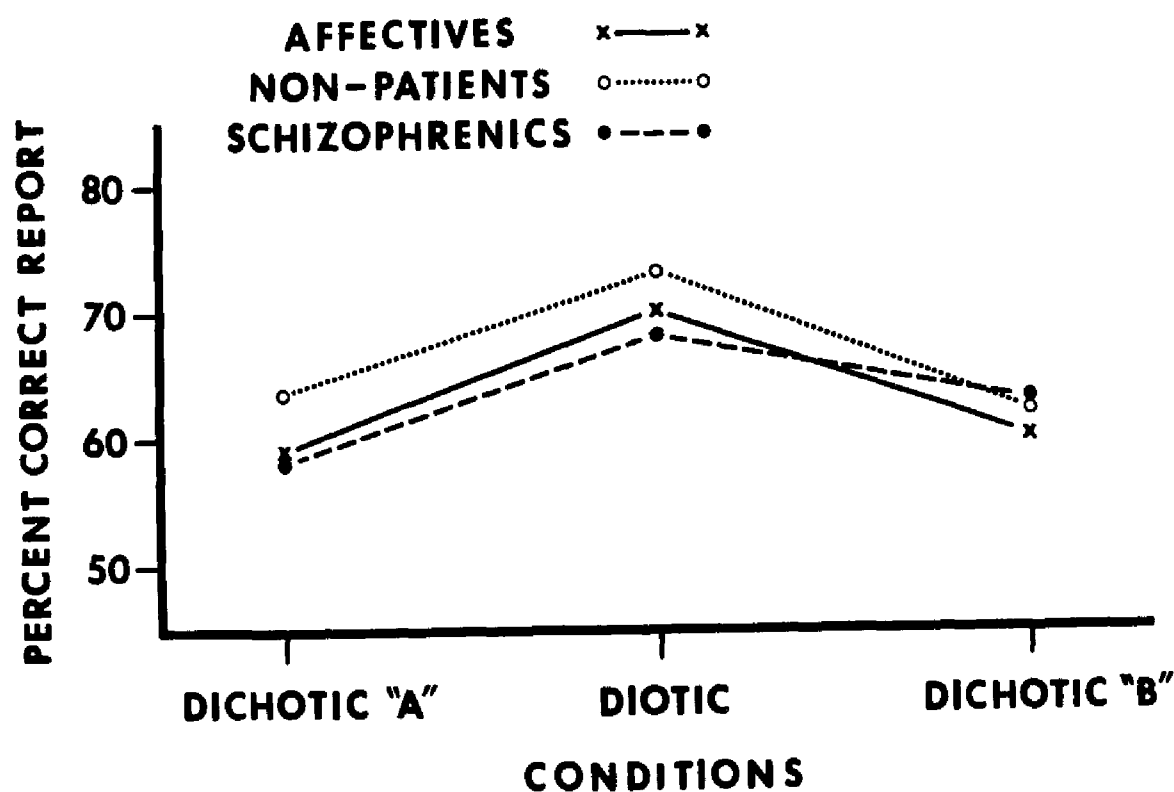


Figure 22. Raw percent correct DBF test performance for 9 affective psychotic patients, 8 schizophrenic patients and 10 non-patient controls. Dichotic "A" = the high-pass band is presented to the left ear as the low-pass band is presented to the right ear. Diotic = the high-pass band and the low-pass band are simultaneously presented to each ear. Dichotic "B" = the high-pass band is presented to the right ear as the low-pass band is presented to the left ear.

stem level structures for these groups. Moreover, the demonstration that the performance of affective patients parallels that of schizophrenic patients and non-patients on an auditory perceptual task that is specifically sensitive to brain stem level dysfunction, underscores the notion that it was the specificity of the other auditory perceptual tasks to unilateral temporal lobe dysfunction which led to the distinctive performance by affective patients rather than to any characteristic difference in their central auditory perceptual functioning (e.g., such that may be attributable to level of arousal) under difficult task conditions.

Binaural Separation Test

Right temporal lesioned controls. The percent correct test performance of the two right temporal lesioned controls was 100% (s.d. = 0) when the right ear was the test ear and ranged from 0 to 30% ($\bar{X}$ = 15; s.d. = 21.2) when the left ear was the test ear. The asymmetrically poor performance by these subjects for the ear contralateral to their lesioned hemisphere is typical of the Binaural Separation Test performance reported elsewhere (e.g., Lynn and Gilroy, 1972; Willeford, 1968) for individuals with unilateral right temporal lesions.

Affective patients, schizophrenic patients and non-patients. The percent correct test performance of affective patients, schizophrenic patients and non-patients is presented in Figure 23. An analysis of these data with a two-way ANOVA having repeated measures revealed that although there was a significant difference between ears summed across groups ($F[1,22] = 7.61$; $p = .011$),

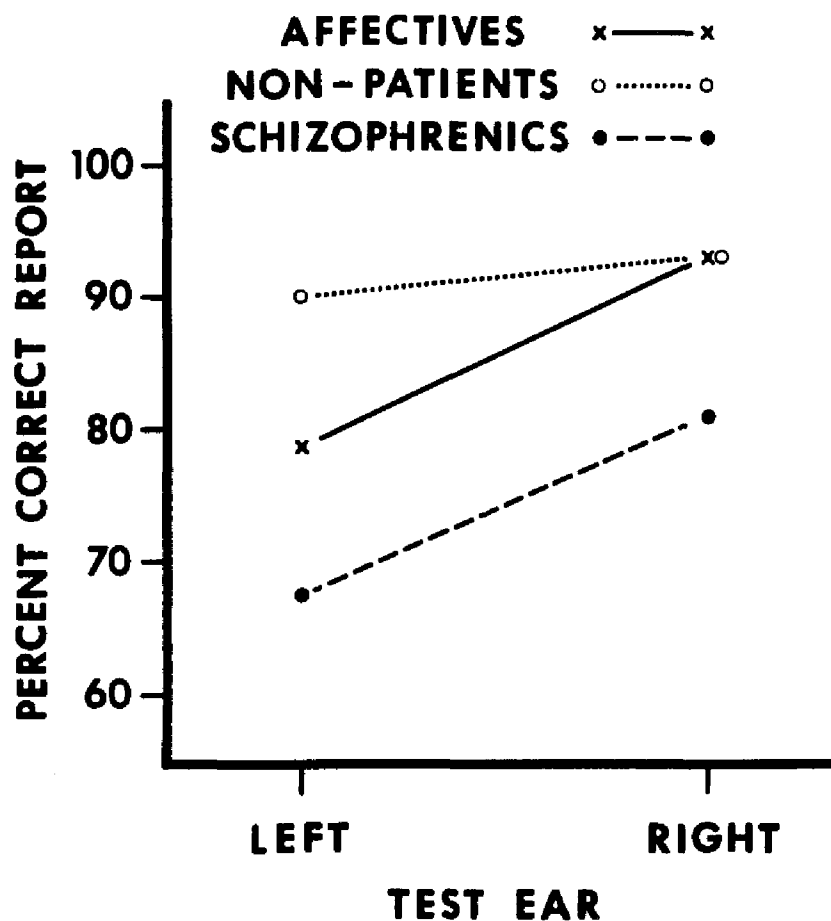


Figure 23. Raw percent correct Binaural Separation Test performance for 7* affective psychotic patients, 8 schizophrenic patients and 10 non-patient controls. The intensity of sentence presentation to the test ear was 15 dB less than the intensity of sentence presentation to the non-test ear. *Note that data was not obtained for two patients from the affective psychotic group which reduced that sample size to seven.

there was not a significant difference between groups in overall level of performance for both ears ($F[2,22] = 2.94$; $p = .074$) nor was there a significant interaction between group and ear ($F[2,22] = 1.06$; $p = .36$). It is interesting, however, to note that although both patient groups displayed parallel performance decrements between their ears, affective patients only differed from non-patients for their left ear performance. In contrast, schizophrenic patients performed more poorly than non-patients for both their right and left ears.

CHAPTER V

DISCUSSION

Characteristic Central Auditory Perception

The acoustosensory data generated by this investigation, together with an independent assessment of behavior pathology, have successfully demonstrated that clinical dissimilarities between affective psychotic patients and schizophrenic patients underlie predicted differences in their central auditory perceptual functioning. Specifically, affective psychotic patients displayed evidence of lateralized right temporal lobe dysfunction for dichotic measures employing both speech and non-speech stimuli. The direction of their interaural performance asymmetries was consonant not only with the performance of the two right temporal lesioned controls who were tested on these same measures in this study, but with the reported acoustosensory asymmetries of other unilateral right temporal lesioned or lobectomized individuals who were tested on similar measures by other investigators. Moreover, obtained performance for affective psychotic patients concurred with predicted performance based upon Flor-Henry's hypothesis of right temporal lobe dysfunction in affective psychotic patients. In contrast, the hypothesis of an association between affective psychosis and generic brain stem dysfunction at or below the level of the superior olive received no support.

The schizophrenic patients, in contrast to the affective patients, did not display evidence of lateralized cortical dysfunction for dichotic measures composed of either speech or

non-speech stimuli. However, the absence of asymmetrical acoustosensory performance for schizophrenic patients is not necessarily inconsistent with the part of Flor-Henry's hypothesis which associates left temporal lobe dysfunction with schizophrenia. Compared with the dichotic performance of right temporal lesioned individuals for both speech and non-speech stimuli, left temporal lesioned individuals have been shown to display smaller interaural performance asymmetries (e.g., see Milner et al., 1968; Berlin, Lowe-Bell, Janetta and Kline, 1972; Bender and Diamond, 1975). This is attributable to the general finding of bilaterally depressed performance arising from the degradation of both hemispheric inputs when the dominant hemisphere for language processing is impaired. It was therefore not predicted, apriori, that schizophrenic patients would display interaural performance asymmetries for any of the dichotic measures employed in this study.

An alternative hypothesis for the absence of performance asymmetries for schizophrenic patients is that their performance may have normalized under phenothiazine medication.¹⁷ Recent evidence suggests that clinical improvement for schizophrenics with phenothiazines may be paralleled by a reduction of hemispheric asymmetries (Serafetinides, 1972, 1973; Gruzelier and Hammond, 1976b; Hammond and Gruzelier, 1977; Goldstein and

¹⁷ There is general support in the literature for the hypothesis that phenothiazines produce essentially no effect upon the hearing sensitivity of schizophrenics (Emmerich and Levine, 1970; Ludwig et al., 1962; Gruzelier and Hammond, 1976). However, the report of differential effects for phenothiazine medication upon paranoid and non-paranoid schizophrenics by Rappaport, Silverman, Hopkins and Hall (1971) (also see Rappaport et al., 1972) renders this literature equivocal (see Emmerich and Levine, 1973; Rappaport, 1973).

Stoltzfus, 1973). Moreover, since none of the patients received mood-active medication and all of the patients received anti-psychotic medication,¹⁸ the differential appropriateness of medication type for the two patient groups must be noted.

While the hypothesis cannot be ruled out that differential drug exposure for the two patient groups may have enhanced their differential acoustosensory performance, it appears improbable. Correlations between individual dosage level and the magnitude of interaural performance asymmetries were very low for both patient groups. Additionally, these results parallel the report of Rochford, Swartzburg, Chowdhrey and Goldstein (1976) for EEG amplitude asymmetries for both affective and schizophrenic patients. According to these investigators "...It should be emphasized that although the difference between left and right (EEG) variances has been found in all patients with depression, it is not present in all schizophrenics, and even in those where it exists, a correlation with diagnosis is not so readily obtained [p. 222]."

It also appears improbable that the results of this study could have been influenced by non-sensory differences between patient groups. The experimental design of the binaural summation paradigm that was employed in this study controlled for the effects of motivational, attentional and response criterion variables. Similarly, the speech measures that were obtained in

¹⁸ 88% of the patients receiving study diagnoses of either affective psychotic or schizophrenic received only phenothiazine medication.

this study incorporated experimental designs that permitted each subject to serve as his own control. Additionally, all of the speech and non-speech measures were administered with reference to the sensation level of each ear for every subject. It therefore also seems unlikely that the results of this study could have been influenced by peripheral auditory sensitivity differences between patient groups.

The extensiveness of the battery of speech and non-speech measures requiring from 15-20 hours of testing for each patient, limited the sample sizes that were tested. Additionally, the removal from consideration of the data for three patients who were given study diagnoses other than affective psychosis or schizophrenia further reduced sample sizes. It should therefore be recognized that differences between groups on some measures, which were not statistically significant, might nevertheless be meaningfully interpreted. Conversely, the finding of statistically significant differences for speech and non-speech measures of acoustosensory performance between patient groups, despite the smallness of sample sizes, underscores the saliency of patient differences in their CANS functioning as well as the sensitivity of the measures employed to detect these differences.

Locus of CANS Dysfunction

A major objective of this study, in addition to the determination of differences in acoustosensory functioning between groups of psychiatric patients and non-patients, was to resolve the locus within the auditory system that is responsible for these differences in CANS perception. Thus, an interpretation

of the speech and non-speech data generated by this study, as it bears upon the locus of CANS dysfunction, may provide greater insight into the neuropathology of affective psychosis and schizophrenia.

Temporal Lobe vs. Brain Stem

The finding that affective patients, schizophrenic patients and non-patients performed equally well on the Dichotic Binaural Fusion Test suggests that there was no impairment in the functional integrity of brain stem level structures at or below the level of the superior olive for either patient group. However, it would be imprudent to generalize from these data that the functional integrity of upper brain stem structures (i.e., at or above the level of the inferior colliculus) was similarly unimpaired.

It should be recalled that the averaged pure tone threshold data for both the affective and the schizophrenic patient groups were approximately 5 dB less sensitive for both ears in comparison to non-patients. This is notable because cortical lesions alone are not characterized by an abnormality of the pure tone audiogram. Furthermore, the dichotic data reported by Berlin, Cullen, Berlin, Tobey and Mouney (1975) for a patient with a presumed lesion in the region of the medial geniculate bodies stresses the similarity of that patient's performance to both temporal lobectomees and hemispherectomees. The hypothesis of upper brain stem dysfunction therefore, while compatible with the bilateral pure tone sensitivity data displayed by both patient groups (e.g., see Calcareo and Antonelli, 1968) is not

necessarily incompatible with these patients' dichotic performance. Clearly, a distinction of upper brain stem from temporal lobe perceptual dysfunction must await the development of new technology. At present, with conventional techniques, the function of upper brain stem structures is neuro-otologically indistinct from the function associated with secondary cortical zones.

Anterior vs. Posterior Temporal Lobe

Lynn and Gilroy (1972) compared the performance of 5 patients with anterior temporal lobe lesions and 5 patients with posterior temporal lobe lesions for both the SSW test and the Binaural Separation Test. For both tests, the performance of the posterior temporal lesioned patients was more impaired than the performance of the anterior temporal lesioned patients. Specifically, posterior temporal lesioned patients displayed markedly abnormal scores on the SSW test for the ear contralateral to their lesioned hemisphere under both competing and non-competing conditions. In contrast, anterior temporal lesioned patients displayed abnormal SSW test scores for the ear contralateral to their lesioned hemisphere under only competing conditions. Similarly, on the Binaural Separation Test, all patients with posterior temporal lesions achieved perfect scores when the test ear was ipsilateral to their lesioned hemisphere and 0% correct when the test ear was contralateral to their lesioned hemisphere. Anterior temporal lesioned patients had less difficulty with competing sentence discrimination.

The data generated in this study for the two right temporal

lesioned controls on both the SSW test and the Binaural Separation Test appear to parallel the pattern of perceptual impairment reported by Lynn and Gilroy for their posterior temporal lesioned patients. Similarly, the data for the affective patients in this study on both the SSW test and the Binaural Separation Test appear to parallel the pattern of perceptual impairment reported by Lynn and Gilroy for their anterior temporal lesioned patients. Thus, the slight performance differences in this study between the two right temporal lesioned controls and the affective psychotic patients may be a consequence of slightly different foci of dysfunction within the right temporal lobe between these two groups.

The hypothesis of an anterior focus of impairment within the temporal lobe of psychotic patients has been postulated by Flor-Henry (1976). He contends that "...the endogenous psychoses reflect lateralized, asymmetrical dysfunction of the anterior limbic structures, more particularly of the orbital frontal-anterior temporal regions, anatomically and functionally linked through the uncinate fasciculus [p. 785, 786]." Employing neuropsychological test data to independently validate psychiatric research diagnoses, Flor-Henry further concluded that "...the significance of disturbance in the anterior rather than the posterior aspects of the limbic system is further suggested by the fact that the strongest associations between diagnosis and lateralized disturbance hold in the frontal regions and are still evident in the temporal but disappear in the parietal areas [p. 786]."

Therefore, it is not surprising that monaural word discrimination, as evaluated by the CID W22 test and by the non-competing conditions of the SSW test, was unimpaired for both patient groups. Disturbances in phonemic perception are widely accepted as characteristic of posterosuperior lesions within the temporal lobe. Presumably, only when the task of phonemic perception is made increasingly complex such as under conditions of dichotic stimulation, do both psychiatric patients and anterior temporal lesioned patients begin to experience perceptual difficulty. Similarly, the absence of significant single click threshold differences between patient and non-patient groups may have been reflective of relatively intact posterosuperior temporal lobe functioning (i.e., sparing adjacent primary auditory cortex).

Clearly, the hypothesis of an anterior temporal lobe focus of dysfunction for the functional psychoses would predict more subtle perceptual dysfunction than would the alternate hypothesis of posterior involvement. The value of employing both stringent methodology and measures which are sensitive to small perceptual effects should therefore be emphasized for future psychophysiological research with psychiatric populations.

A Theoretical Interpretation

The interaural perceptual asymmetry displayed in this investigation by the affective psychotic patients for the binaural energy summation of dichotic click pairs is consistent with the pattern of lateral bias for the resolution of click pairs that was reported by Bender and Diamond (1975) for right temporal lesioned patients. According to Bender and Diamond, when there

exists a sensory information overload with reference to processing capacity, such as may occur under conditions of dichotic stimulation, the re-organization of perceptual space becomes manifest in neurologically impaired individuals. A dominant perceptual half-space becomes evident in an attempt to improve the efficiency of sensory information processing either through a reduction in the total stimulus input (e.g., constriction of perceptual space) or through greater unilateral processing by the more intact cerebral hemisphere. If the latter adaptation occurs, the dominant perceptual half-space will emerge on the side contralateral to the more efficient hemisphere. Thus, unilateral right hemispheric dysfunction might be thought of as resulting not solely in impaired left sided attention, but in enhanced right sided attention at the same time. This is evident not only in the auditory modality but has been shown to be true for visual and tactile stimuli as well (see Bender and Diamond, 1975; Gruzelier and Hammond, 1976; Milner, 1975).

An analogous model for a dominant perceptual half-space has been suggested in terms of excitatory and inhibitory neurophysiological interactions by Benson and Teas (1976) to explain the perceptual dysfunctions which follow unilateral cortical lesions. The model, incorporating an earlier model by van Bergeijk (1962), assumes that symmetrical groups of neural cells within each hemisphere respond in a predominantly excitatory manner to stimulation of the contralateral ear and in a predominantly inhibitory manner to stimulation of the ipsilateral ear. Lateralized auditory perceptual processing is postulated

by the model to be mediated by a comparison of the quantity of residual neural excitation between cortical hemispheres. A listener with unilateral hemispheric dysfunction should experience a greater than normal margin of residual neural excitation between cortical hemispheres because of a generalized reduction in the level of neural responsiveness for the impaired hemisphere. Thus, a dominant perceptual half-space would emerge contralateral to the greater residual neural excitation of the functionally intact hemisphere.

The binaural summation data of the affective patients (particularly for an interaural asynchrony of 60 msec.) was characterized by a greater magnitude of summation when the right ear led and the left ear lagged than for the opposite stimulus configuration. It should be recalled that binaural click summation may be conceptualized as the antithesis of binaural click resolution. Therefore, the greater summation by the affective patients for the right ear leading condition in comparison to the left ear leading condition may alternatively be considered to reflect poorer two click resolution for that condition in which the right ear led. As suggested above, this could be attributable either to the degraded perception of the lag click in the left ear or to the enhanced perception of the lead click in the right ear such that it masked the sharp resolution of the lagging click (see Babkoff and Sutton, 1966). Bender and Diamond (1975) offered the following explanation:

"...the quality of an extinction type of interaction effect, as has been frequently reported, appears to be a graded phenomenon, e.g., a stimulus on the affected side may be recognized

and reported but it may appear to the patient as smaller, less distinct or distorted...the patient may fail completely to acknowledge the stimulus verbally, but by making an appropriate behavioral response, indicate that he was aware of the unreported stimulation; or finally, he may conjoin the sensations. By conjunction we mean the joining together of attributes of both stimuli in a double simultaneous stimulation pair into the verbal report of a single combined perception... [p. 401]."

It was predicted prior to this study that if a temporal lobe locus was implicated in the neuropathology of affective psychosis, these patients could be expected to display interaural performance asymmetries for the binaural energy summation of dichotic click pairs which would be particularly evident at an interaural asynchrony of 60 msec. The confirmation by these data of this prediction, especially regarding the interaural asynchrony of 60 msec. (see introduction, page 20), supports the notion that binaural energy summation is regulated by neural interactions at the cortical level.¹⁹ The hypothesis of a cortical locus of dysfunction for affective psychotic patients is therefore strengthened.

Implications for Effective Psychiatric Treatment

The finding of differences in central auditory perceptual functioning between affective psychotic patients and schizophrenic patients adds validity to the nosological differentiation of these two patient groups. It would therefore seem imperative, in light of the effectiveness of psychopharmacological therapeutic agents for the treatment of affective psychosis, that a

¹⁹ von Békésy (1960) originally proposed that the encoding of interaural time and intensity may depend upon inter-hemispheric comparisons of the activity of neural populations (also see Rosenzweig and Rosenblith, 1950; Babkoff and Sutton, 1966; Sternberg and Knoll, 1973; Babkoff, 1975).

major initiative within the mental health professions be undertaken to improve the clinical detection of affective psychotic individuals from the totality of psychiatric individuals.

Additionally, the finding that distinctive modes of central auditory perception have been observed for each patient group may offer insight into the characteristic nature of diathesis-stress interactions for these patient groups (see Rosenthal, 1970). For example, the asymmetrical limitations of perception displayed by affective psychotic patients under conditions of double simultaneous stimulation for speech and non-speech stimuli may be envisioned as generalizing to environmental stimuli. The theorized formation of a dominant perceptual half-space could be conceptualized as a coping strategy to improve the efficiency of sensory information processing. Sensory information overloads which presumably elicit the re-organization of perceptual space are most likely experienced out of the laboratory as a component of environmental stress. It is not inconceivable, therefore, that a profile of an individual's performance under conditions of double simultaneous stimulation (e.g., dichotic stimulation) may provide an objective assessment of that individual's characteristic adaptiveness under stress, which could then serve as an indicator of vulnerability to specific psychiatric dysfunction. Preventative therapeutic measures could then be initiated for selected individuals before the occurrence of severe symptomatology. Furthermore, an objective indicator of this type could be invariant with respect to the variables of culture, educational level, psychiatric history and degree of

self-disclosure.

Suggestions for Future Research

This study was designed to uncover characteristic differences in central auditory processing between psychiatric subgroups to establish their independence as diagnostic entities. Subsequent reports based upon continued analysis of these data will evaluate the relative effectiveness of several contemporary diagnostic strategies of classification for their ability to discriminate these patients solely on the basis of behavioral indices without knowledge of their perceptual performance. Gurland (1972) has suggested that "...confidence in the validity and potential usefulness of psychopathological classification would be increased were there more certainty about the relationship between psychopathology and physiology [p. 417]."

The prospect of improvement in the provision of mental health care rests upon progress in the investigation of psychopathology. The finding of distinctive CANS functioning between sub-groups of psychiatric patients is a small but important advance toward an eventual understanding of the etiological mechanisms which are operative in the neurogenesis and/or sociogenesis of specific psychiatric disorder. To this end, promising revelations in the field of experimental psychopathology must be pursued. More data on larger samples of subjects are needed not only to confirm these findings but to test new hypotheses which may bear more directly upon the etiology of the functional psychoses.

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