COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF HEALTH

COMMONWEALTH ACOUSTIC LABORATORIES

SYDNEY

SUMMARY - REPORT ON PRESENT AUDIOLOGIC METHODS FOR TESTING DISORDERS OF THE AUDITORY NERVOUS SYSTEM

by

P. WOODROFFE

C.A.L. INTERNAL REPORT No. 1

DATE: July, 1963.

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Address: 5 Hickson Road,
Miller's Point.
Sydney.

Director: N.E. Murray.

C.A.L. Informal Report No.26

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Preliminary remarks and references.

This report is intended to review present knowledge of central processes in hearing, with particular reference to differential diagnostic methods for peripheral[1] and central deafness. The main body of evidence in this field has been contributed by neurophysiologists since Lorente de No. More recent advances in methodology, including electrophysiology and its related techniques, have permitted investigators like Rasmussen and Galambos in America and Jungert in Sweden to assess the significance of various areas of the auditory nervous system, but although evidence from these studies is stimulating it is inconclusive in the majority of cases, the more so as most of these have been carried out at an infrahuman level. The few comprehensive enquiries into human auditory perceptive mechanisms, e.g. by Penfield and Roberts (1959), have presented a good deal of data without serving to clarify the confused state of present thinking in this area.

Contributions of audiology to the study of processes in central hearing have, until the last 10 years or so, been limited to clinical procedures of tonal and verbal audiometry, which are generally recognized to be inadequate for all but the most superficial observations. These shortcomings have recently forced the introduction of more exacting test situations those where physiological and psychologicalprocesses of the highest order are involved. The literature to date has been pathologically orientated, being concerned with the diagnostic significance of various tests for disordered central functioning as in cases of cerebral tumour,cranial trauma, etc. and in the less specific disorders of which presbycusis has claimed the most attention.

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[1]We adhere to the distinction made by Groen and Hellema (1960) between peripheral and central deafness:

" 'Peripheral' in contract to 'central' lies before the first junction of the auditory tracts of the left and right ears. This first meeting point is located in the superior olivary nucleus. So a peripheral perceptive deafness may be due to a deficiency in the cochlea, in the n. octavus (1st neuron), in the acoustic nuclei and in the connection (the 2nd neuron) between these and the superior olivary nuclei. Any disturbance higher up is considered here as central."

Pioneering work has been carried on independently in several different countries. Bocca in Italy, Matzker in Germany and Chocholle and others in France have each made somewhat different approaches to the problems. In America, Jerger has synthesized a good deal of this previous material and has also proposed a number of additional procedures. The primary aim of modern investigators seems to be the development of a diversified battery of auditory tests which not only make possible a diagnosis of cerebral auditory disorder but allow more specific conclusions to be made regarding nature and site of lesion.

Ablation experiments with animals have defined fairly clearly the extent of auditory function which may be performed at a mainly peripheral or mesencephalic level; classic pure tone audiometry, for example, has little diagnostic significance for central deafness as in many instances threshold values may well be within normal limits. Accordingly, research has been concentrated on introducing stimulus material which must be synthesized or integrated at higher levels[1]. Due to the redundancy of phonetic units in speech however, and to the complexity of the interconnections of test and contralateral ear in the auditory neural pathways, conventional speech tests fail to differentiate between the normal and brain-damaged individual with anything like adequate precision.

Bocca and his associates appreciated the necessity for making perception of the speech stimulus more difficult as early as 1953. They found that by varying such factors as physical quality of the verbal pattern (acoustically filtered speech, interrupted speech: Bocca and Finzi, 1953; Bocca et.al. 1954, 1955; Bocca and Calearo, 1956), duration of the signal (accelerated voice: Bocca 1956, 1958), length of the message (long sentences or lists of words: Bocca 1956, 1958); meaning (meaningless sentences: Bocca 1958), and rhythm (prosodic alteration or accent shift, aperiodic variations of speed, reversed sentences: Bocca 1958), it was possible to demonstrate

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[1]c.f. Bocca (1958): "Until the physiological experiments are able to bridge the gap between form and experience (which is highly improbable) we shall be obliged, when studying sensation at a psychological level, to set apart all the traditional experimental and clinical methods, and to avail ourselves of testing material of a purely psychological value. Pure tones and simple sounds must be abandoned, and words and sentences must be resorted to; because they alone own the symbolic, emotive, mnemonic, and evocative qualities which acquire their significance at a cortical level."

that cortical recognition of the verbal image was significantly impaired in relation to normal performance in cases of tumour involving the auditory area of the temporal cortex and in presbycusis. The authors observed that "in the vast majority of the cases (of temporal lobe tumour) so far examined, discrimination was much poorer in the ear lying opposite to the side of the intracranial lesion" (Bocca et. al. 1954).

These observations of patients who exhibited unilateral deafness prompted Bocca to experiment with a new approach to binaural hearing, following the report of Hirsh in 1948. The test material used was speech (lists of 10 mixed logotomes or nonsense bisyllables, and of 10 meaningful bisyllabic PB words). The examiner delivered the words through 2 independent channels to the two ears of the subject. Channel 1 provided attenuation, Channel II attenuation plus low-pass filtering cut off at 500 cps. Output intensity at Channel I is adjusted each time at a level which permits a discrimination score of no more than 40% in repeated tests. With Channel II the acoustic filter allows no more than 50% discrimination at a sensation level of 45 db. Bocca (1955) notes that: "if the two stimuli are presented simultaneously, one to each ear of the subject, discrimination score becomes much higher and reaches a per cent value which is approximately equal to the addition of the two monaural discrimination scores. The experiment provides evidence of binaural summation and binaural integration". Subsequent studies by the author have examined the diagnostic relevance of these binaural and monaural methods in establishing a semeiology of the cortical disturbances of hearing and their implications for neurological theory as in the importance of the crossed and uncrossed fibres in the auditory pathway and in hemispherical dominance.

In 1957, Matzker and Ruckes in Germany published the first report of their test of binaural integration for examining disorders of the central auditory system. Matzker's book (1958[a]) which gives details of methodology and describes the application of the test to a large number of subjects, has been reviewed by R. Thalmann who gives the following summary: "In principle the test material, in this case speech, is divided into 2 frequency bands, 500-800 cps and 1500-2400 cps. Speech restricted to either band alone is practically unintelligible but both bands together presented to one or both ears simultaneously give good intelligibility. If the two bands are presented to each ear separately, the low band to one side and the high band to the other, people with normal brain function are able to synthesize these two bands; they then make only a few errors in repeating speech material. In people with dysfunction of the CNS this ability to synthesize is often impaired, and in this case significantly more errors are made. This is a positive binaural test result.

Practical application of this test was studied on 1000 subjects both normal and pathologic. Under conventional physiologic conditions, BT positive results were found in 34% of children below 14 years and approaching 100% of people over 75 years of age. In the age group 20 to 60 years, the BT was negative in 97 to 98.5% of the cases. In the pathologic group the tumour cases showed the highest rate of positive test results 84% of a total of 38 cases. Lower percentages of positive test results were found in other groups, such as those with atrophic and vascular diseases, multiple sclerosis, epilepsy and trauma. In many of these cases hearing as determined by the classical methods was normal." In subsequent reports (Matzker and Ruckes 1958[b],1958[c], 1959[a], 1959[b], 1960) further implications of the BT and a test of sound localization are considered in relation to the anatomy and neurophysiology of the auditory nervous system.

The main content of these papers may be reviewed briefly as follows; Matzker and Ruckes (1958): The authors report on the application of the BT to diagnosing disorders of central hearing. The importance of the medial geniculate body as a relay for the crossed and uncrossed fibres in the brain stem is stressed. Two cases are described where synaptic connections in the brain stem away from the focus of the lesion (a cerebellar tumour) were disordered, giving a positive test result. A reflex vascular disturbance is postulated to account for this spread of effect. From the summary: "The binaural test is particularly designed to test the auditory connections in the brain stem. A high proportion of positive results was obtained in cases of cerebral tumour and in head injuries. Two cases of tumour with positive BT's were examined post-mortem. Although the main lesion did not involve the brain stem, histological examination confirmed the theory that in these cases there is a circulatory disturbance in the region of the mid-brain resulting in degeneration of the nuclei and consequent loss of function of the auditory connections."

Matzker (1958[b]); from the summary: "An attempt is made to explain the existence of a directional perception in binaural hearing of slight time differences as resulting from centrifugally coursing inhibitory impulses in the auditory pathways of the brain stem. These centrifugal pathways have already been demonstrated anatomically as well as electrophysiologically. A switching model developed by us allows a detailed analysis of the psychoacoustic phenomenon of directional hearing using very small, artifically produced time differences. From this example, the great importance of the central inhibitory pathways in the organized completion of the hearing act becomes obvious. Finally, we refer to the inhibitory pathways which are present in very similar form in the eye". Matzker found that the effect held for pure tones of all frequencies up to 12,000 cps as well as for a click; he claims that this negates the phase difference explanation for directional hearing of pure tones. The inhibition is therefore considered to be dependent, not upon the specific frequencies of the acoustic stimulus but solely upon the anatomical fibre sequence, i.e. the "circuitry" of the brain stem.

Experimental procedure followed this design: An electrically produced noise - a series of 15 clicks per second - was presented to each ear of the subject at an equal intensity level. An electrical delaying network with 36 settings allows the production of optimal variable time differences between the sound stimulus in each ear without changing the intensity; these differences vary from 0.018 m.sec. to 0.648 m.sec. and may be set to arrive earlier in either ear. Adjustment of the dial position allows the subject to perceive the sound source in a 0^o-90^o progression left or right. The inhibitory effect is conceived as resulting from this sequence of events in the brain stem: a click is received at ear A and the stimulus transmitted along the centripetal tracts predominantly to the contralateral cortical area. At the same time impulses are sent across the inhibitory pathways, the crossing taking place at 3 main levels, the trapezoid body, the lateral lemniscus and between the posterior colliculi. They arrive at the cochlear nucleus, and olive and the lateral lemniscus at the contralateral side and block the synapse before the facilitating impulse of the corresponding stimulus frequency at the secondarily stimulated ear B can arrive. Thus inhibition of the stimulus conducted from B results in diminished contralateral cortical excitation, i.e. there is now a loudness difference between the acoustic stimuli. This accounts for the directional perception.

Matzker (1958[c]): In this paper and subsequent articles (1959[a]), 1959[b]), 1960) the author presents further considerations of the BT[1] and the test of directional hearing with artificially produced time differences as indicators of central auditory pathology. He states that positive BT results were demonstrated with presbycusis and brain tumours in all sites, and more rarely, in brain atrophies, cranial trauma, hypertension and various kinds of epilepsy. Representative test results are discussed; anatomy and neurophysiology of the auditory nervous system are considered in detail in relation to two categories of central hearing disturbance:

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1 Matzker altered the frequency bands for speech in the BT vis:

Low pass : 500-800 cps (unchanged)
High pass: 1815-2500 cps.

1. Unspecific, diffuse cerebral decrease in auditory capacity.

This is manifested by a general interference in every aspect of cerebral hearing, e.g. in presbycusis where pitch differentiation, directional hearing, memory for words and speech discrimination may all be affected. These diffuse effects may also be present with hypertonia, cerebral atrophy and head injuries. As far as can be ascertained their anatomical basis is "a general degeneration of the ganglion cells throughout the whole brain. It may be caused by a senile degenerative process, by chronic circulatory disturbances or by a reflex spastic vascular mechanism. This would explain the diffuse degeneration of the ganglion cells of the auditory nuclei in the brain stem in tumours of the frontal lobe" (Matzker 1959[a]).

2. Specific, localized auditory disorders

These are caused by processes which involve some part of the auditory pathways or auditory cortex:

(a) bulbo-peduncular auditory disorders (predominantly lower auditory capacities concerned);

(b) thalamic auditory disorders (very rare);

(c) cortical auditory disorders (higher auditory capacities).

Matzker notes that group2 occurs almost only in combination with group 1. He lists 2 different kinds of approach to their detection:

1. General auditory tests (threshold audiogram, conventional recruitment, adaptation and speech discrimination tests). Their application to cerebral auditory diagnosis is very limited.

2. Cerebral auditory tests

   (a) monaural tests (cf. Bocca's work with distorted speech);

   (b) binaural tests - binaural summation and integration, alternating speech (Bocca); the BT, directional band recording with absolute time differences, binaural interval sense (Matzker).

Matzker (1959b) states that at that time that BT had been given to more than 1700 patients and the sound location test to more than 400 patients; results suggested that they could be used, within limits, to locate the site of the brain lesions. "While a high score of mistakes in the binaural test is indicative of a functional failure of the synaptic connections within the brain stem, the deviation of the localization band to one side points to a cerebral lesion on the contralateral or to a brain stem lesion on the homolateral side. It appears that the dividing level above which contralateral localization and below which homolateral localization occurs is the ventral brain stem. In each individual case one has to make sure of course that a deviation observed was not caused by a unilateral peripheral impairment".

A related approach, which uses language-free stimulus material, however, has been proposed by French investigators, notably R. Maspetiol and his associates who have based their ideas on preliminary work by the neurophysiologist R. Chocholle. Three methods are proposed (Maspetiol et.al. 1960, 1961) for testing disordered central hearing:

1. <u>A test of auditory reaction time</u>

Auditory reaction time is examined using different frequencies at a constant sensation level. A delay may be demonstrated by one ear in relation to the other or by both ears as against visual latency time. The assertion is made that a pathological delay in auditory perception can apparently be established only in relation to a cortical lesion, specifically of the temporal lobe. No abnormality of latency time was noted in cases of occipital or frontal lesions, tumours of the cerebellopontine angle, or in "various neurological dysfunctions". All presbycusics exhibited delayed auditory reactions.

2. <u>A non-verbal test of binaural integration (based on the DL test)</u>

Processes of facilitation and inhibition of the DL for intensity are examined in the presence of a constant contralateral tone or noise. Chocholle has demonstrated that the DL increases in amplitude with a constant contralateral tone of the same frequency (an inhibiting effect) and decreases in amplitude with a constant contralateral tone of a different frequency (facilitating effect). Absence of these phenomena suggests a failure of binaural integration. The authors assert that this occurs only in cases of cortical lesion involving the temporal lobe. They found that all cases of presbycusis but three exhibited <u>normal binaural integration</u> (this contradicts Matzker's results with verbal material).

In apaper presented to the Society of Laryngology of Paris Hospitals (Thibaut et.al 1961), it is claimed that the auditory reaction test is indicative of superficial lesions like simple endocranial hypertension while the Non-Verbal Integration Test suggests a more profound lesion since it involves the cortico-reticular connections.

3. <u>A test of post-stimulatory auditory fatigue with a simultaneous low-intensity contralateral sound</u>

Adaptation is observed to be less for degree of hearing loss and recovery time by this method than with the simple test - i.e. without contralateral stimulation. The authors propose this phenomenon as a means for testing central deafness. They reject the classical notion of a oochlear origin for auditory fatigue and locate it tentatively in the central auditory pathways, possibly at the reticular level. Absence of an inhibiting effect is taken to be suggestive of disordered binaural integration. Most of the evidence for this is based on neurological studies of the centrifugal nervous system.

Much of this material has been adapted by Jerger in America who has been investigating the possibility of constructing a battery of auditory tests. He demonstrated the validity of this principle for diagnosing cerebral lesions and in assessing their probable extent and location by administering various combinations of the following tests:

1. <u>Loudness balance</u>. Alternate and simultaneous loudness balancing: In a study by Jerger, Allen, et.al, (1961), the authors describe the following variation of the Fowler test. The tone was fixed at a sensation level of 20 db in the poorer ear and the patient varied the intensity at the better ear until the alternating tones were equally loud. The arithmetic average of three separate intensity judgments by the patient was taken as a "match". With simultaneous loudness balance the tones are presented to both ears at once at a level 20 db above threshold. The tone is again fixed in the poower ear and this time the patient adjusts the intensity at the better ear until he achieves localization of the sound image in the median plane. The procedure is repeated at various frequencies.

Successful application of these two techniques to patients with lesions in the higher auditory pathways is dependent, according to Jerger, on strict adherence to the procedural sequence. First, it should be noted that the intensity is fixed on the ear contralateral to the affected cerebral hemisphere and varied on the ipsilateral ear. Second, the patient ideally makes the intensity judgments himself, using a 2 db step attenuator and a "match" is defined as the average of three successive trials. Results of a separate investigation (Jerger 1960[b]) suggest that with involvement at relatively high cortical levels, abnormalities of loudness equation without concomitantly disordered median plane localization may be consistently observed. There is no evidence, on the other hand, for abnormalities of median-plane localization occurring without concomitant equal-loudness disorders. This suggests that equality of loudness depends on the entire afferent pathways, including the temporal cortex, whereas intracranial median-plane localization depends only upon the integrity of the pathways up to "some critical sub-cortical centre". (Cf. Maspetiol et. al. 1960, 1961 - see above). Further details of instrumentation, procedure and interpretation with these methods are given in Jerger and Harford (1960).

2. <u>SISI test</u>: Short Increment Sensitivity Index: Short (200 m.sec, 1-db intensity increments are superimposed[1] at 5 second intervals on a pure tone of constant amplitude at a sensation level of 20 db. The patient is instructed to respond to any perceived momentary change in loudness. Results are expressed in terms of the percentage of 20 increments to which a response is made. A "SISI-gram" may be constructed by graphing SISI-score in per cent (ordinate) against frequency (abscissa) using the conventional audiometric symbols for right and left ears. In the original study (Jerger, Shedd and Harford, 1959) with 75 subjects, conductive and retrocochlear losses showed very low SISI scores, never exceeding 15%. Meniere and noise-induced losses, however, yielded relatively high percentages, the minimum score of any of these patients being 70%.

3. <u>Bekesy Audiometry</u>: Jerger distinguishes four basic types of Bekesy response using the methods of conventional sweep frequency threshold tracings for both continuous and interrupted stimuli and also threshold for 3-minute fixed-frequency tracings (cf. Jerger, Allen et. al. 1961, p. 351):

<u>Type I</u> - "The Type I relationship is characterized by an interweaving or superposition of continuous and interrupted tracings, and by a tracing width which is constant over frequency and average about 10 db. There is however, considerable variation about this mean value. Tracing widths as small as 3 db and as large as 20 db are not uncommon.

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[1] Instrumentation for the SISI test is described in Jerger, Shedd and Harford (1959). Since August, 1957, however, Jerger has been using a "modified commercial audiometer" for all measurements.

In the case of fixed frequency tracings, the Type I relationship is reflected in two interweaving, horizontal tracings.

<u>Type II</u> - Type II tracings differ from Type I in two respects. First, the continuous tracing drops below the interrupted at high frequencies, but never to any substantial extent. The gap seldom exceeds 20 db and ordinarily does not appear at frequencies below 1000 cps. Second, the width or amplitude of the continuous tracings is often quite small (3-5 db) in these higher frequencies. This narrowing of the width or amplitude of the continuous tracing, is of course, the classical Bekesy sign, thought by many to indicate the presence of loudness recruitment.

In fixed-frequency tracing, the Type II result is quite clear-cut. The interrupted tracing is, again, horizontal and of normal width, but the continuous trace drops from 5-20 db below the interrupt within the first minute; thereafter, it remains at a fairly stable level. There is a reliable difference between interrupted and continuous tracings, but the difference is relatively small and remains quite constant after the first 60 seconds of tracing. Furthermore, the difference appears only at mid and high frequencies (i.e. above 500-1000 cps).

<u>Type III</u> - Type III tracings are quite dramatic. The continuous tracing drops below the interrupted to a remarkable degree. Furthermore, the two curves may diverge at relatively low frequencies (100-500 cps). It is not uncommon to observe the continuous tracing break away at a frequency as low as 150 cps and drop to a level as much as 40-50 db below the interrupted tracing. The width of the continuous tracing ordinarily remains, however, quite normal.

In Type III fixed-frequency tracings the interrupted tracing is horizontal, but the continuous drops very rapidly and ordinarily does not stabilize at all. Typically, the continuous tracing begins at the same level as the interrupted but describes a rapidly descending trace to the limit of the equipment. A 40-50 drop within as little as 60 seconds is not unusual.

<u>Type IV</u> - Type IV tracings more closely resemble Type II than Type III but differ in one important respect. The continuous tracing falls consistently below the interrupted at frequencies below 500 cps. At higher frequencies the continuous may fall a constant distance below the interrupted, resembling a Type II in this respect. The tracing width may or may not become abnormally small further adding to possible confusion with Type II. At mid and high frequencies there may be some overlap between C and I. The distinguishing feature, however, occurring in both conventional and fixed-frequency tracings, is the gap between C and I at relatively low frequencies (100-500 cps). Type IV tracings differ from Type III tracings in that C ordinarily does not show a precipitous drop over time." Details of design, procedure and

interpretation are given in the original paper (Jerger, 1960c); the author notes that Type I tracings appear predominantly in lesions of the middle ear (otosclerosis, otitis media), Type II tracings in cochlear lesions (Meniere's, noise induced) although some fall into the Type I category. No Meniere's case exhibited a Type III tracing. In VIIIth nerve lesion (acoustic neurinoma) Type III and Type IV tracings predominate. No acoustic neurinoma ever exhibited a Type II tracing.

4. Speech tests

1) Conventional PB-word discrimination scores[1]

a) Groen and Hellema (1960) demonstrated the effects of binaural interaction on speech intelligibility scores by comparing monaural and binaural speech perception functions. They state that if the binaural curve is steeper than the two monaural curves (roughly by a factor of 2) the auditory deficiency is located between the cochlea and the superior olinary nucleus. When the binaural curve is parallel to the monaural curve, the lesion is located centrally beyond the superior olinary nucleus.

b) In a group of 12 patients exhibiting hearing loss of sudden onset (examined by Jerger, Allen, et. al. 1961), four showed an overall pattern taken to be "clearly suggesting cochlear lesion". They demonstrated measurable PB discrimination. The remaining 8 patients whose overall pattern was suggestive of VIIIth nerve lesion failed to score at all on the PB tests.

2) SWAMI test: (Speech with Alternate Masking Index)

This tests the subject's ability to integrate complementary fragments of speech delivered to both ears at the same time. Jerger (Jerger, Mier et.al. 1960) recorded a single PB word list simultaneously on both tracks of a dual channel magnetic tape recorder. Alternating bursts of thermal noise were superimposed on the speech material during recording. The noise alternated between channels at the rate of one burst per second; i.e. on one channel for .5 sec. and then the other for .5 sec. and so on. The noise level was 20 db greater than the average speech peaks.

Played back through the earphones, the PB words are practically unintelligible when heard monaurally. With binaural listening, however, a discrimination score of 90-100% is possible for normal subjects as the stimulus material is perceived to be spatially "separated", the noise being hearind in each ear alternatively while the speech is localized in the centre of the head.

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[1] Procedure for administering this speech discrimination test is given in Jerger, Mier et.al (1960). Test lists of 50 monosyllabic PB words (developed by the Psycho-Acoustic Laboratory at Harvard University) were recorded on tape and played back to the subject's ear at 40 db sensation level.

3) Filtered speech tests

a) LPFS: Low-Pass Filtered Speech. A single PB word list was recorded through an acoustic filter set to a low-pass cut off frequency of 500 cps and a rejection rate of 17 db per octave. The list was presented at 45 db above threshold first to one ear then to the other (Jerger, Mier et.al. 1960).

b) Bocca's test of binaural summation and integration.

The following sequence of PB-50 word lists was presented (Jerger, 1960b):

1. Left ear: low-pass filtered.

2. Right ear: faint unfiltered.

3. Combined (Left ear: low pass filtered; right ear: faint unfiltered).

4. Right ear: low pass filtered

5. Left ear: faint unfiltered.

6. Combined (right ear: low pass filtered; left ear: faint unfiltered).

An identical list and recording was used for each set of equivalent conditions on the two ears; i.e. a recording of NDRC PB-50 17 for low-pass filtered speech on each ear, a recording of PB-50 18 for the faint unfiltered condition and PB-50 19 for the two combined conditions. Jerger asserts that this is a critical point as he doubts that interlist equivalence of PB-50 words holds under conditions of gross distortion. He considers the learning effect to be negligible in comparison. The low-pass filtered signal was set at 45 db above average threshold, the faint unfiltered signal at a level which permitted a PB discrimination score of 50%.

c) A variation of Matzker's test of binaural integration of narrow-band filtered speech.

This test, so far unpublished, is describedby Farrant (1958), who applied it to assessing speech synthesis ability in children. Low-pass (500 cps at 30 db per octave cut-off) and high-pass (4000 cps at 30 db per octave cut off) filtered PBK word lists were recorded on stereophonic tape and presented to the subject in the following sequence:

1. PBK list 3, unfiltered: left ear.
2. PBK 4, unfiltered: right ear.
3. NDRC PB 13, 500 cps, 4000 cps: binaural practice.
4. PBK 1A, 500 cps and 4000 cps: binaural (L And R).
5. PBK 3B, 500 cps (word order reversed): left ear.
6. PBK 4B, 4000 cps (word order reversed): right ear.
7. PBK 1B, 4000 cps and 500 cps (reversed order)L binaural (R & L
8. PBK 3C, 500 cps (word order 25,50,24,49,...1,26): right ear
9. PBK 4C, 4000 cps (word order 25,50,24,49...1,26): left ear.

It is suggested that this test is applicable to children as young as 8 years of age or younger.

The aim of the present study is to investigate the possibility of establishing a battery of auditory tests for central deafness drawn from the material presented above. It is apparent from the literature that no single test can be taken as a reliable predictor at this stage. It is also clear that a good deal of the evidence proposed conflicts with other findings. Nonetheless, the work of Jerger and others, while not conclusive, suggests that with a suitably diversified battery of tests it should be possible to make a tentative differentiation between lesions occurring at various levels in the auditory pathways, for example at the cochlea, VIIIth nerve, brain stem and temporal cortex. As more data becomes available it may be possible to specify which combination of tests is most applicable to these levels.

The following information is now available on the tests described above.

1. Matzker's binaural fusion test

We have been unable to duplicate Matzker's results using similar pass bands. Menzel (1962) has suggested however that information from research at the Veteran's Administration shows that other combinations of pass bands proved to be more sensitive to central synthetic functioning than the combination used by Matzker.

2. Jerger's SISI test, Bekesy audiometry and ABLB test

Jerger (1962) gives an excellent summary of the effectiveness of combining these 3 particular methods to determine the site of an auditory disorder.

3. Our own experience suggests that this battery can effectively be strenghtened by PB word list tests and possibly the Luscher test.

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