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Methods to evaluate central hearing deficiencies and to localize brain damage are reviewed beginning with Bocca who showed that patients with temporal lobe tumors made significantly lower discrimination scores in the ear opposite the tumor when speech signals were distorted. Tests were devised to attempt to pinpoint brain damage on the basis of auditory tests; Jerger found that both temporal lobe tumors and brain-stem damage could lead to the same results on the tests. Bocca suggested delivering different signals to the two ears to assess the integration or binaural summation of the central neural system. Matzker suggested two individually meaningless sounds presented simultaneously, one to each ear; a normal system would apparently integrate sounds better. Studies by Bocca, Jerger, Sanchez-Longo, Forster, Matzker, Harris, and Hayashi indicated that subjects with organic symptoms showed poorer integration than subjects without these symptoms; however, it was not clear where binaural integration took place. Conclusions were that Matzker's procedure is probably inadequate as a general test to localize brain damage. More research is indicated as the technique shows promise for studying an organism's binaural integration abilities. (RP)

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THE BRAIN AS A MIXER, I. PRELIMINARY LITERATURE REVIEW: AUDITORY INTEGRATION[1]

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In a review of earlier work on techniques for studying central auditory integration, Matzker's (1958) binaural fusion procedure emerges as the most promising method for measuring binaural integration abilities.

Progress has been slow in developing methods to evaluate central hearing deficiencies. Patients with central lesions are often judged by the otologist to have essentially normal hearing. The reason is the bilateral cerebral cortical representation of hearing for each ear: because each ear projects to both sides of the brain, a lesion within the brain must be enormous and probably lethal (covering auditory areas on both sides of the brain) before it results in deafness measurable by a conventional hearing test. More sensitive tests of auditory discrimination often involve the patient's intelligence, education, and memory, as well as his hearing, and so produce results that are difficult to interpret.

One of the first break-throughs on this problem came in the early 1950's when Bocca (1955) and his colleagues showed that the ability to understand distorted speech was modified substantially in the contralateral ear of patients with temporal lobe tumors. The patients had essentially normal hearing for pure tones and undistorted, ordinary speech, but when the speech signal was distorted by low-pass filtering, acceleration of rate, periodic interruption, or artificially scanning speech, the discrimination scores were significantly lower for the ear opposite the side of the pathological temporal lobe.

Bocca's finding suggested a new use for two standard tests of auditory discrimination which were in wide use at the time. The Rush-Hughes (RH) and W22 tests both involved delivering 50 phonetically balanced (PB) monosyllabic words and asking the subject to repeat each word. Individually, the tests were ineffective in diagnosing brain damage, but it turned out that in combination they could.

Investigators had noticed that the RH test consistently resulted in 20% more errors than the W22, apparently as a result of distortion in the RH recordings and of the clipped and speedier method of presenting the words. A difference in score greater than 20% between the two tests was found to indicate a disturbance in the auditory areas of the temporal lobes; and it was particularly in the ear contralateral to the damaged hemisphere that such a difference would appear (Goetzinger, Dirks, & Baer, 1960). Apparently the greater difficulty of the RH test functions in the same manner as the distortions of speech in Bocca's work.

Jerger (1954) provided further evidence from 24 patients with organic CNS disease. He used five monaural tests, three of them simple tests of the type developed by Bocca and his colleagues. The UL or "undistorted loud" test required subjects to repeat 50 PB words which were presented 50 db above threshold. The UF or "undistorted faint" test delivered 50 PB words at only 30 db above threshold. The LPFS, or "low-pass filtered speech" test, delivered 50 PB words with a 500 cps filter, so that the words were muffled and difficult to understand.

The two other tests differed from the others in that they involved a primary signal to which the listener had to attend in the presence of a secondary or competing signal on the non-test ear. Test #2 presented 50 PB words (50 db above threshold) to one ear, while a different speaker simultaneously read a complete sentence to the other ear at a level 10 db more intense than the PB words. The subject had to ignore the sentences in one ear and repeat aloud the PB words he heard in the other. Test #3 was similar to test #2 except that the test signal was a complete sentence requiring a multiple-choice answer, and the competing signal on the other ear was the continuous discourse of two different speakers.

Scores for all of these tests were determined separately for the two ears, the ear homolateral and the ear contralateral to the affected side of the brain.

Jerger presented results for four groups of subjects. Group A consisted of seven patients with low-brain-stem lesions (below the cochlear nucleus) presumably not involving the auditory system. These patients, as expected, showed normal test results, with no difference between the two ears on any of the five tests. Group B consisted of seven patients with unilateral brain-stem damage involving the auditory system. The tests showed a 20% decrease in number of correct responses for the ear contralateral to the damage. The only exception was in test #3, where performance was good on both ears.

Group C consisted of six patients with unilateral temporal lobe lesions involving Herschl's gyrus. The results were quite similar to those for Group B, except that in tests #2 and #3 the contralateral ear showed a much poorer response. In Group D, designed as a control for Group C, four subjects with parietal, frontal, or remote temporal cortical lesions were tested. A slight (5-10%) difference between the two ears was found. The authors suggested that the auditory system had sustained some secondary damage during the neurosurgical procedures to which all the patients of this group had been subjected.

In summary, the PB monaural tests apparently detected auditory brain-stem or cortical lesions. The only test differentiating between locations, however, was test #3. The authors concluded that it was too soon to comment on the diagnostic value of any of these tests. Many more subjects had to be tested and the location of the central lesions checked. To be sure, the tests supported Bocca's findings of decreased ability to understand some signals in the contralateral ear of patients with temporal lobe tumors; however, they also showed that brain-stem damage could lead to the same result. What was needed was a test that could localize the area of damage. Again it was Bocca (1961) who suggested the method to aid in solving this problem. It involved simultaneously delivering different signals to the two ears, and studying the synthesis or integration of these messages.

This phenomenon of bilateral fusion or integration has an interesting history. Throughout the nineteenth and early twentieth centuries most people thought that there was no real binaural summation of intensity or loudness, but simply a sensation of greater clarity and fullness of sound. However, later studies of summation at threshold gave substantial evidence that at the level of the CNS a nearly perfect summation of the stimuli heard by the two ears does occur. An experiment by Bocca (1955) gave clear evidence of this summation. He used both nonsensical and meaningful disyllabic words. First he presented to one ear a normal voice delivering these words and lowered the intensity until the subject was unable to identify and repeat more then 30% of the words. Then to the other ear he presented the same words at 45 db. above threshold, using a 500 cps low-frequency band-pass filter to distort the syllables. With this arrangement, subjects were unable to articulate more than 50% of the words. When both stimuli were delivered together to one or both ears by means of loudspeakers, the louder stimulus behaved as a masking stimulus of the weaker one, and discrimination remained equal to that observed for the suprathreshold distorted stimulus alone. However, when the two stimuli were delivered through earphones separately and simultaneously to the two ears, binaural discrimination was approximately equal to the arithmetic addition of the two monaural discriminations: articulation jumped to 80% or 90%. During this binaural stimulation, the subjects thought they were hearing only suprathreshold stimulation and were unaware of the contralateral subthreshold stimulus except that the voice became suddenly "much clearer" when it was introduced.

Bocca concluded that with one ear thus providing power and the other ear providing quality, he had produced clear evidence of binaural summation and of binaural integration. He did not immediately speculate on the exact site of this process, but it was clear that if the site could be determined, the method might be fruitful for diagnosis of specifically localized brain damage.

The Jerger study cited earlier marked an initial attempt to localize integration. In Jerger's binaural test, called the SWAMI, or "speech with alternating masking index," 50 words were presented to both ears simultaneously, but a much louder masking noise, 20 db more intense than the speech, was switched once a second from one ear to the other. Under this masking noise, intelligibility was quite poor on either ear separately, but the two monaural signals complemented each other in time and intelligibility was not appreciably impaired. The normal brain apparently fused the speech information from the two ears effectively.

The SWAMI results showed a 20% reduction for both the cortical and brain-stem auditory-damaged groups, which was no more than would be expected from the normal 20% reduction in basic PB scores on the contralateral ear. This negative finding was unexpected, since integration was expected to take place in the brain stem. The authors spoke of other evidence, without citing it, to support their suggestion that the mechanism of binaural fusion was situated at a relatively low level in the brain stem and was not appreciably affected by lesions at only slightly higher levels. Presumably they were identifying the trapezoid fibers as responsible for integration, but the evidence for such a locus is negative rather than positive. The problem of localization has certainly not been solved.

A different kind of test which seemed to involve some kind of binaural integration was suggested by Sanchez-Longo and Forster (Matzker, 1958), who studied the ability to localize sound in patients with brain tumors. Using "white noise" as their test signal, they demonstrated that in patients with tumors of the temporal lobe a sound source is lateralized to the contralateral side. In patients with lesions in other cerebral regions, they found no deficits in ability to localize sound.

Matzker (1958) used this same technique, varying interaural time differences for pure-tone signals of frequencies between 125 Hz and 8000 Hz, which were interrupted at regular intervals. The smallest time interval used was 0.018 msec., which was long enough to cause a definite lateralization of the imaginary sound source to the side where the signal arrived first. The greater the time difference, the more lateral the sound seemed to become. At an interval of 0.648 msec., in normal subjects, the source appeared to have moved to a position exactly 90° off the median plane.

The investigator started testing <u>Ss</u> with the maximal interaural time difference and decreased the interval in steps. The zone of mid-line impression, or "localization band" was established for each subject. With increasing age, the band was found to widen considerably.

Matzker tested more than 400 patients with this technique. He found that a deviation of the localization band occurred in cases of cerebral lesion on the contralateral side or brain-stem lesions on the homolateral side. He defined the dividing line above which contralateral localization and below which homolateral localization occurs in the ventral brain stem. "Ventral brain-stem" is an unclear term, though; presumably Matzker was suggesting that only lesions in the trapezoid fibers cause a deviation in localization toward the homolateral side. Since deviations are also found at all other levels of the auditory system, however, the trapezoid fibers cannot be identified as a specific site for integration involved in localization. Lesions in frontal, parietal, and occipital lobes, as well as in the temporal lobe, also contributed to abnormal localization. And with each individual, it was necessary to insure that deviations were not caused by unilateral peripheral impairment. In short, the sound localization test appears inadequate to localize brain-stem lesions.

Matzker therefore developed a "selective test of the central auditory connections in the brain stem," designed to explore the integration of signals travelling in the bilateral auditory pathways. He was particulary interested in damage involving the medial geniculate body, which he believed "collects all the fibers from the homo- and contralateral sides and relays them to the cortex on the same side." Matzker's picture of the auditory pathways differs from the traditional anatomical diagrams (see Crosby, Humphrey, & Lauer, 1962, p. 276); Figure 1 taken from Matzker (1958) in simplified form shows the auditory pathway from one ear:

Insert Figure 1 about here

In Matzker's test two simultaneous but individually meaningless sounds are presented, one to each ear. Words are split by narrow band-pass filters into a low-frequency band (500-800 Hz), which is presented to one ear, and a high-frequency band of the same word (1500-2500 Hz), which is presented to the other ear. The single band is virtually unintelligible: no more than 20% of the words in it can be recognized. However, there is excellent integration of the two components, since together they permit almost 100% recognition when the test is given to normal subjects. The integration presumably takes place in the brain stem, after which impulses are transmitted to the cerebral cortex, where the frequencies are translated into speech (Matzker, 1960).

On tests with more than 1700 subjects, Matzker obtained results that accorded with his theoretical predictions. In almost all cases of cerebral tumor in all brain regions, test results were positive (84%). A high proportion of recent head injuries gave a positive result, with the binaural test reverting to negative as other symptoms disappeared. The test was also negative with all psychotics, most epileptics, and patients with multiple sclerosis. In subjects over 70 years of age, the test was always positive, presumably because of the physiological loss of ganglionic cells with age.

In two cases in which the binaural test gave positive results, autopsy revealed tumors away from the brain stem, in the cerebellum or in the frontal lobes, but no macroscopic abnormalities in the brain-stem or auditory pathways. However, microscopic sections showed hemorrhaging, intravascular clotting, and other signs of circulatory disturbance in the brain stem. Moreover, nerve cell nuclei, Nissl granules, and cytoplasm clearly showed degenerative changes. Apparently a reflex circulatory disturbance through the brain stem had led to an insufficient supply of oxygen to its nuclei. As a result the functioning of the synaptic connections in the brain stem was impaired.

Harris (1963) used Matzker's binaural test on 25 brain-damaged and 25 normal subjects. He found a significant difference between the two groups. In two larger studies, using 175 subjects aged 7 through 20, Harris again found that subjects with organic symptoms showed poorer integration than subjects with only functional symptoms presumably arising from "psychological" causes. He found no significant relationship between auditory integration and age, sex, obstetrical history, birth conditions, or levels of reading ability.

A more recent study of Matzker's fusion test (Hayashi et al., 1966) adds some significant information. Hayashi widened the scope of Matzker's study by presenting the signals at several different intensity levels and by introducing the additional testing conditions here diagrammed:

Insert Figure 2 about here

Among 78 subjects he found five cases of poor binaural fusion: two head injuries, one temporal lobe epilepsy, one cerebellar ataxia, and one sensorineural deafness of unknown cause. All cases of inner ear impairment showed a normal pattern of binaural fusion and so lent support to Matzker's belief that the test indicates damage to central rather than peripheral auditory mechanisms. However, the most interesting result was the tendency of poor binaural function to occur when the high band was connected to the ear opposite the side of the affected cerebral area. For example, in one case of head injury poor binaural function was found only when the signals from the high-band filter were given to the left ear; the function was normal when the signals were given to the right ear.

Hayashi concluded that the site of binaural fusion could not be the brain stem, since "synapses of auditory pathways are closely gathered in a relatively narrow place in the brain stem and lesions in the area would cause poor binaural function regardless of the side of the ear receiving the signals passing through the high band or the low one." The laterality of the results suggest to him that the site of binaural fusion is "the cortical or subcortical area."

Preliminary Conclusions

It appears reasonable to extract the following implications from the above review: Matzker's procedure is probably inadequate as a general test to detect brain damage, since many areas of the brain may be damaged without affecting performance on the test--particularly in the case of small lesions outside the auditory pathways or even involving fibers that are within the auditory system but play no role in integration.

Furthermore, Matzker's test may have only limited promise as a test to localize brain damage. It is not all clear where binaural integration takes place, whether at the level of the trapezoid fibers, or of the cochlear nuclei, or of the nucleus of the lateral lemniscus, or of the inferior colliculus, or of the cortex, or of any combination of these. And even if the loci of auditory integration were determined, lesions in remote areas, by causing vascular damage to the relevant areas, might still make it extremely difficult to detect the loci of the major lesion.

Obviously, far more direct validation of Matzker's procedure is necessary by studying the binaural integration abilities of patients with a clear pathology and histology that gives the exact location and nature of the brain damage.

Although Matzker's procedure may be inadequate to diagnose specific brain injury, it has particular promise as a technique for studying an organism's binaural integration abilities. Little, if anything, is known about the relationship of this ability to other performance variables. Hence, further exploration and development of the procedure appear warranted.

Footnote

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References

Bocca, E. Binaural hearing: Another approach. Laryngoscope, 1955, 65, 1164-1171.

Bocca, E. Factors influencing binaural integration of periodically switched messages. Acta Otolaryngolica, 1961, 53, 142-144.

Bocca, E., & Calearo, C. Central hearing processes. In J. Jerger (Ed.), Modern developments in audiology. New York: Academic Press, 1963. Pp. 337-371.

Crosby, E. L., Humphrey, T., & Lauer, E. W. Correlative anatomy of the nervous system. New York: Macmillan, 1962.

Goetzinger, C., Dirks, D., & Baer, C. Auditory discrimination and visual perception in good and poor readers. Annals of Otology, Rhinology, and Laryngology, 1960, 69, 121-136.

Harris, R. Central auditory functions in children. Perceptual and Motor Skills, 1963, 16, 207-214.

Hayashi, R., Ohta, F., & Morimoto, M. Binaural fusion test: A diagnostic approach to the central auditory disorders. International Audiology, 1966, 5, 133-135.

Jerger, J. Auditory tests for disorders of the central auditory mechanism. In W. Fields and B. Alford (Eds.), Neurological aspects of auditory and vestibular disorders. Springfield, Ill.: Charles C. Thomas, 1954. Pp. 77-86.

Matzker, J. Two new methods for the assessment of central auditory functions in cases of brain disease. Annals of Otology, Rhinology, and Laryngology, 1960, 69, 121-136.

Matzker, J., & Ruckes, J. A new hearing test for the diagnosis of brain stem lesions. German Medical Monthly, 1958, 3, 258-260.

Thompson, R. F. Foundations of physiological psychology. New York: Harper and Row, 1967. Pp. 259-275; 332-346.

Wolman, B. B. (Ed.), Lesions of the temporal cortical area and disturbances of auditory gnosis: Sensory aphasia. In Handbook of clinical neurology. New York: McGraw-Hill, 1965. Pp. 715-720.

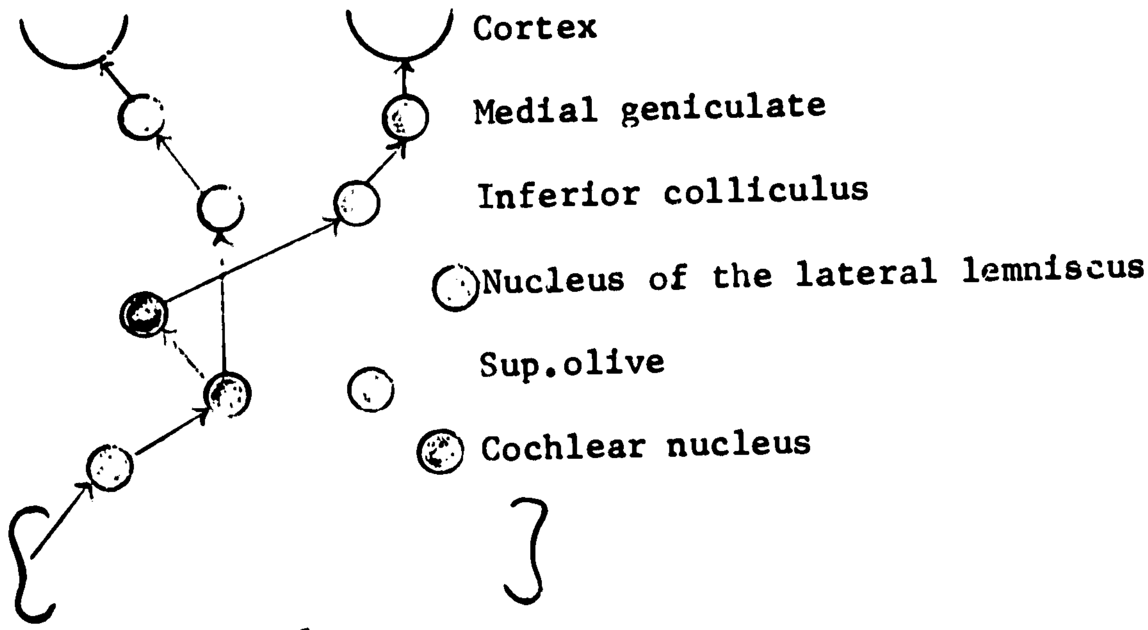

Figure 1

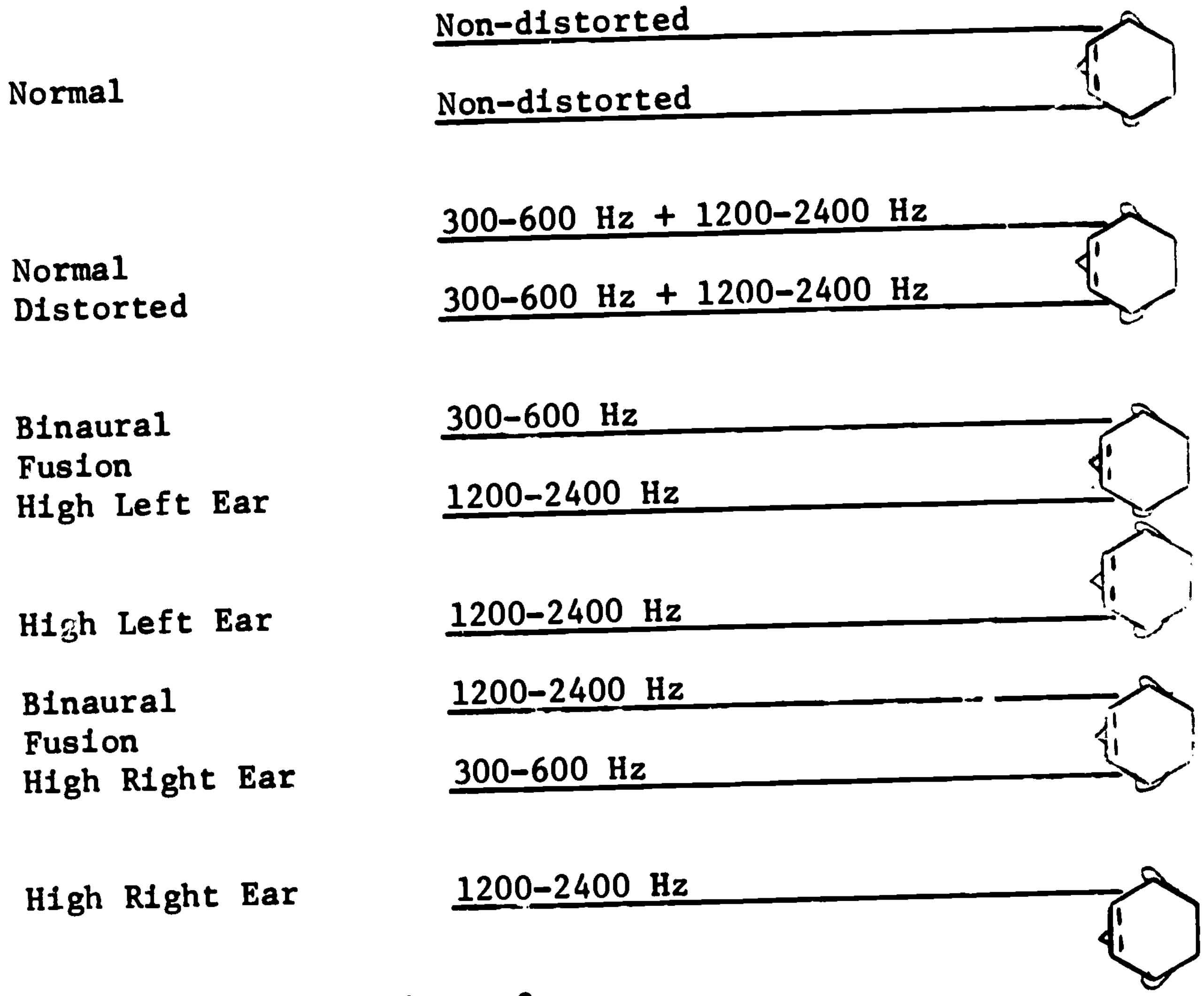

Figure 2