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# Central Auditory Speech Test Findings in Individuals with Subjective Idiopathic Tinnitus

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***Abstract:*** This study reports central auditory speech test performance of 25 consecutive patients with subjective idiopathic tinnitus of the severe disabling type. A preliminary study of 14 individuals who had subjective idiopathic tinnitus and complained of difficulty in hearing and understanding revealed a high incidence of abnormal central auditory speech test performance (71%), despite satisfactory peripheral hearing. The results (1) identify objectively for the first time that tinnitus affects specific components of the auditory pathway; (2) provide a basis for monitoring methods of tinnitus control; and (3) provide a basis for understanding "the interference effect" and problem of communication difficulties in patients with tinnitus of the severe disabling type.

Since 1977, more than 4,000 individuals with subjective idiopathic tinnitus (SIT), primarily of the severe disabling type, have been seen at the Tinnitus Center, Health Sciences Center at Brooklyn, State University of New York. Central auditory speech tests (CASTs) were performed in selected cases when further diagnostic information of the central hearing mechanism was deemed necessary.

In our center, many patients complaining of tinnitus report difficulty in hearing and understanding or the "interference" effect of tinnitus on their ability to communicate. They are convinced that the tinnitus is causing this problem and that absence of the tinnitus would restore their hearing and understanding.

The addition of CASTs to the Medical Audiologic Tinnitus Patient Protocol (MATPP) establishes a baseline with respect to central processing function for each tinnitus patient and enables continued correlation of test findings with both clinical type of tinnitus (using the MATPP) and the subjective complaint of decreased hearing or understanding (or both) not supported by conventional audiological test findings.

Results of standard audiometric tests (i.e., pure tone and speech audiometry) most frequently are satisfactory and within the limits of normal for peripheral hearing and, therefore, do no support the subjective complaint of difficulty in "hearing." Most CASTs have been standardized and validated using populations with normal symmetrical hearing and normal, undistorted word-recognition abilities. The limitations for administration and accurate interpretation of CASTs include these factors.

In 1994, a preliminary study of 14 subjects reported a 71% incidence of abnormal CAST performance in individuals with satisfactory peripheral hearing and complaints of impaired speech discrimination, understandability, or expression and a diagnosis of central-type tinnitus using the MATPP [1,2]. A test battery approach using low-redundancy speech tests was used to assess the integrity of the central auditory system (CAS) at levels from the brainstem to the cortex. Commercially available taped materials were used.

Our study reports on the incidence of abnormal CAST performance in individuals who experience satisfactory peripheral hearing and symmetry between the ears and present with the primary complaint of SIT. Results of 25 consecutive cases are presented. Thirty-two cases could not be included in the study because the patients failed to meet the audiological criteria.

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## BACKGROUND

### Anatomical Auditory Substrates

Central auditory nervous system disorders signify lesions in the hearing mechanism from the level of the

cochlear nuclei along the auditory pathway up to and including the auditory cortex. Frequently, central auditory disturbances are characterized by difficulty in discrimination or in interpreting complex speech signals (or by both). Routine audiological testing, however, frequently reveals normal hearing thresholds and normal speech discrimination.

Normal speech discrimination is explicable on the basis of the extrinsic redundancy of the speech signal. Speech contains information that is both redundant and superfluous for complete comprehension by normal hearing individuals. This redundancy averages some 50% in any given language. During communication, most speech messages receive interference from noise and reach the listener with a certain amount of errors or missing elements. Extreme redundancy permits the listener to correct those errors and receive adequate information from the original message to interpret it correctly.

The CAS itself provides considerable neural or intrinsic redundancy because of the multiplicity of pathways and synaptic connections. This intrinsic redundancy permits adequate interpretation of speech messages despite reduced extrinsic redundancy of the message or even minor impairments within the CAS [3].

## Central Auditory Speech Tests

Conventional speech tests contain a high degree of external redundancy. By alteration of the acoustic signals (i.e., modifying the frequency range, duration, or length; the rate of speech; the addition of masking noise or competing messages), highly redundant speech tests are converted into low-redundancy speech tests [4]. If the CAS is intact, the intrinsic redundancy of the speech signal enables correct interpretation of the message.

If significant disturbance occurs within the CAS, intrinsic redundancy is limited. This result, in combination with the limited external redundancy of the message, results in an inability to understand the speech message. In patients with SIT, possibly the tinnitus reduces the intrinsic redundancy of the signal, perhaps acting as a masking noise and resulting in abnormal test performance [5].

# METHOD

## Subjects

Twenty-five consecutive cases of individuals having the primary complaint of severe disabling tinnitus were included in this study (7 women and 18 men). The age range was 20–61 years (mean, 42). Thirty-two subjects could not be included because they failed to meet audiological criteria. Criteria for inclusion in this study consisted of normal peripheral hearing defined as pure-tone averages of no greater than 20 dB at 250–3,000 Hz; word recognition scores of 92% or better for both ears; and no evidence of middle ear pathology on immittance audiometry. All subjects had a primary complaint of SIT and had completed the MATPP.

## Test Battery

The test battery included (1) pure-tone audiometry, including air and bone conduction thresholds at 250–8,000 Hz; (2) speech audiometry, including speech recognition thresholds and word recognition scores using NU#6 word lists; and immittance audiometry, including tympanometry, acoustic reflexes, and reflex decay. The CAST battery consists of commercially available and standardized taped materials [6]. Various tests were included (Table 1).

### *Low-Pass Filtered Speech Test*

In the low-pass filtered speech test, NU#6 monosyllabic words are filtered to remove high-frequency cues that are presented monaurally. Frequencies below 500 Hz are passed, and frequencies above 500 Hz are rejected at a rate of 18 dB per octave. This test is sensitive to temporal lobe dysfunction, especially in the lower and broader, slightly anterior areas of the lobe. Functioning can break down also with brainstem dysfunction.

### *Staggered Spondaic Word Test*

The staggered spondaic word test is a dichotic listening test in which two spondaic words are presented, one to each ear. The second part of the first spondee overlaps

**Table 1.** Central Auditory Speech Test Battery

| Central auditory speech test | Diagnostic significance |
|---|---|
| Monaural low-pass filtered speech | Temporal lobe lesions |
| Binaural fusion test | Brainstem pathology whether primary or due to secondary compression from cerebral hemisphere tumor masses |
| Rapid alternating speech test | Lesion of pons, especially caudal region |
| Competing sentence test | Cortical and interhemispheric auditory functions, especially temporal lobe lesions in posterior region |
| Staggered spondaic word test | Temporal lobe lesion, primary auditory reception area |

in time with the first part of the second spondee. This process taxes binaural interactive ability to divide attention and to keep information separate between ears. Abnormal performance indicates temporal lobe dysfunction (especially in the posterior region) or subcortical disease.

***Binaural Fusion Test***

The binaural fusion test is composed of spondaic words that are filtered electronically to produce a high-band segment (1,900–2,100 Hz) and a low-band segment (500–700 Hz) presented dichotically. The subject hears one segment in each ear and repeats the entire word. The test requires that the individual effect closure or summation on the target. The test is sensitive to brainstem dysfunction (whether primary or secondary) due to compression from cerebral hemisphere tumor masses.

***Competing Sentence Test***

The competing sentence test (CST) is a dichotic test or binaural separation test. Two different sentences are presented simultaneously, one to each ear. The primary message is presented at 35 dB SL re PTA to one ear, and a secondary competing message is presented to the opposite ear at 50 dB SL re PTA. The individual repeats only the primary message. This test is sensitive for temporal lobe dysfunction (posterior region) and to structural lesions in the brain.

***Rapid Alternating Speech Test***

In a rapid alternating speech test, sentences are presented in alternating burstseach lasting 300 msec—first to one ear, then to the other. The individual repeats the sentence. This test is sensitive to lesions of the pons, especially the caudal region.

## RESULTS

A high incidence of abnormal CAST performance was found in patients with satisfactory peripheral hearing and tinnitus. Of 25 patients tested, 13 (52%) demonstrated abnormal results on one or more of the central speech tests.

Of the 13 subjects who complained of the interference effect, 12 (92%) scored abnormally on one or more of the tests. Of the 12 who were not complaining of the interference effect, 1(8%) scored abnormally on one central speech test.

Abnormal scores occurred for the 13 subjects on the following tests:

Low-pass filtered speech test: 8 of 13 (62%)

Competing sentence test: 5 of 13 (38%)

Binaural fusion test: 2 of 13 (15%)

Staggered spondaic word test: 1 of 13 (8%)

No abnormal scores were obtained for the rapid alternating speech test.

## DISCUSSION

These test findings objectively identify that tinnitus affects specific components of the auditory pathway. It appears that the low-pass filtered speech test and the CST are the central tests that frequently demonstrate abnormal scores. The diagnostic significance of both these tests is lesions in the temporal lobe. Correlation of CAST performance with single-photon emission computed topography (SPECT) is in progress. In selected cases, tinnitus may be both a sign and a symptom of brain organicity highlighted by degenerative central nervous system disease, cerebrovascular disease, and affective disorders [7].

The findings of this study suggest the following pattern:

Individuals not complaining of the interference effect of tinnitus on their hearing or understanding (or both) are performing within the limits of normal on CASTs.

Individuals complaining of the interference effect of tinnitus are demonstrating abnormal performance on CASTs.

Abnormal findings on CASTs are consistent with a diagnosis of a central-type tinnitus and support the diagnostic validity of the MATPP to identify types of tinnitus, specifically a central type.

Classification is critical for accurate diagnosis and selection of treatment and control methods [8].

The remaining question—whether severe tinnitus has a long-term effect on communication abilities—gives rise to others: Will those individuals whose test performance is normal develop this interference effect over time? If CAST performance still is normal, can treatment for these individuals prevent them from becoming symptomatic?

SIT patients' complaint of interference with speech understanding is supported by test findings. Abnormal performance reflects difficulty in perceiving low-redundancy speech due to limited intrinsic redundancy. Reduced intrinsic redundancy of the central auditory nervous system is caused by the tinnitus. Shulman speculated that central masking is in part a function of the efferent system. Is this deleterious effect on hearing reported by

some tinnitus patients a reflection of interference in the efferent auditory system [9]? The tinnitus then would have an internal noise effect on hearing, reducing the intrinsic redundancy of the CAS.

In 1977, Shulman [10] defined tinnitus as an aberrant perception of sound unrelated to an external source of acoustic simulation: a dyssynchrony in the auditory system. He speculated that tinnitus is an expression of the auditory system "out of control." Some believe that this condition could reduce the intrinsic redundancy of the CAS. Recent findings based on SPECT imaging of brain in SIT patients has expanded the definition of tinnitus as a disorder of auditory perception due to an altered state of excitation or inhibition in neuronal networks and resulting in a dyssynchrony in neuronal firing. Tinnitus is hypothesized to reflect an abnormality in affect involving auditory memorya behavioral stimulus [11].

Jastreboff and Hazell [12] stated that tinnitus is a result of aberrant neural activity within the auditory pathway. Such activities are interpreted erroneously as sound by the auditory cortex. This sound, then, has an interference effect, reducing the intrinsic redundancy of the CAS.

In a study of mismatch negativity in the neurophysiological behavioral evaluation of auditory processing deficits, Kraus et al. [11] supported the use of behavioral auditory processing tests in combination with evoked potential testing for confirmation of patients' complaints of inability to process speech under adverse listening conditions. Findings to date have provided additional diagnostic information with respect to site of lesion and have aided in the identification of a central tinnitus and different clinical types of tinnitus.

## CONCLUSIONS

The addition of central speech testing has established a baseline with respect to central processing function for individual tinnitus patients; has supported the clinical medical-audiological diagnosis of a central-type tinnitus; and has provided support for the subjective individual complaint of decreased hearing or understanding (or both). Such testing also has provided a basis for selection of treatment and control methods of tinnitus with an increased degree of efficacy and has provided a means by which to monitor the effect of any treatment or subjective report of improved understanding with or without a decrease or absence of tinnitus. Additionally, it has assisted in clinical management of patients with respect to counseling and treatment.

Other benefits of such testing include provision of a basis for identifying regions of interest with SPECT of brain, reflecting the probable site of lesion of the CASTs. SPECT may identify the contribution of peripheral deficit to the central speech test result. Furthermore, in combination with results of electrophysiological tests (i.e., auditory evoked response testing and evoked otoacoustic emissions), central tests have provided increased diagnostic accuracy and further support for the interference effect of tinnitus on individual communication abilities in SIT patients.

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