

## NOTE

### AUDITORY MODALITY-SPECIFIC ANOMIA: EVIDENCE FROM A CASE OF PURE WORD DEAFNESS

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Naming difficulties are commonly observed in several varieties of aphasia (Geschwind, 1967). Apart from the role played by word frequency which extensive studies (for a comprehensive review see Newcombe, Oldfield, Ratcliff and Wingfield, 1971) have shown to be a crucial one, scattered observations have been made in regard to the importance of the sense modality in which the stimulus to be named is presented.

Following Freund's (1889) observation of optic aphasia, some cases have been reported of dissociation between visual naming and naming by touch but in the vast majority of them there was no clear cut distinction between visual anomia and visual agnosia (Wolff, 1904; Kleist, 1934; Lhermitte and Beauvois, 1973).

With respect to olfaction, Vandette (1964) reported that some aphasics named better when confronted with olfactory and olfactory visual stimuli than when confronted with visual stimuli alone.

As for tactile aphasia, viz. inability to name objects presented tactually in one or both hands with preservation of the ability to name objects on the basis of visual or auditory stimulation, the only cases reported are those by Geschwind and Kaplan (1962), Geschwind (1965) and Gazzaniga (1970) in split brain patients.

Systematic studies of naming according to sensory modality in aphasics have been carried out by Spreen, Benton and Van Allen (1966) and Goodglass, Barton and Kaplan (1968). The former, following an observation of optic aphasia similar to Freund's case, studied naming in 20 anomic patients: in three, visual anomia was more marked than tactile anomia. In two, the reverse situation was present. The latter found a uniformity of naming difficulty across sensory modalities for the great majority of aphasics.

Up to now auditory modality specific anomia, viz. inability to put a verbal label on meaningful sounds with normal ability to match the sound with the corresponding natural source, has not been observed.

The aim of our paper is to report the observation of a patient with pure word deafness (PWD) with a striking inability to name meaningful non verbal sounds without signs of auditory agnosia, i.e., with preserved recognition of such sounds as proven by matching tests, and to speculate about the possible mechanisms of processing meaningful non verbal material in view of recent neuropsychological data.

## CASE REPORT

Mr. R.R. is a forty-nine year old right handed man with a university degree in chemistry, who before his illness had been working as Science teacher in high school.

The patient was admitted to the Neurology Department of the University of Padova on May and November 1973 for evaluation of language disturbances which developed some ten years ago. He had been in good health until January 1963 when because of progressive onset of light headness, headache and generalized weakness he was admitted to another hospital where he was found to be hypertensive (260/120 mmHg).

Following a biopsy, the diagnosis of polyarteritis nodosa was made: this diagnosis however was ruled out in subsequent admissions. When in hospital the patient had some Grand Mal seizures which still occur rarely despite antiepileptic therapy.

Following one epileptic fit when he was still in the same hospital, he was found unable to understand what he was told, without any significant motor deficit and with fluent speech. No further data are available. In the following years the patient's linguistic difficulties, by his own and his relatives' history, were constant: despite normal spontaneous speech and writing and normal reading comprehension, he was grossly impaired in understanding spoken language, despite intensive speech therapy. Only with considerable effort was he able to develop fair lip-reading capability.

Peripheral deafness was excluded on the basis of a normal pure tone audiogram.

In April 1969 he underwent left pericarotid sympathectomy without any significant improvement of speech functions; following operation left Horner's syndrome developed.

Physical examination at the time of admission to our unit was unremarkable. Blood pressure was 165/110 in both arms. On neurological examination visual acuity was 20/20 in the right eye and 10/20 in the left eye. Goldman perimetry failed to reveal visual field defects except a small defect in the left superior quadrant due to partial ptosis. Fundoscopic examination was normal. Left Horner's syndrome with partial ptosis and enophthalmos was present. For auditory examination see below. Motor system was normal. Sensory examination was normal without extinction to double simultaneous stimulation. Reflexes were symmetrical; no Hoffman nor Babinski signs were elicited.

#### *Laboratory data*

Repeated EEG showed persistent theta activity intermixed with sharp waves from the left temporal region. Brain scan was normal. Chest x-ray demonstrated enlargement of the cardiac silhouette with aortic enlargement.

#### *Examination of higher nervous function*

The patient was born in Italy and had a fair-to good knowledge of German and fair knowledge of English. He graduated from a high school where he studied latin. Later he went to the University where he obtained a degree in chemistry. In the following years he had been teaching as a high school science teacher up to the time of his illness.

Patient is strongly right handed and had no history of near left handed relatives.

The patient at the time of admission was alert, oriented and attentive. His retrieval of old information was good. There was an island of amnesia around the beginning of his illness with scattered information about the sequencing of his disease. He showed no difficulty in remembering the names of his examiners and his orientation in the hospital was good.

On the Wechsler Adult Intelligence Scale, his scores were: Verbal 115, Performance 99, Full Scale 108.

On repeated detailed language evaluations the following characteristics were observed:

Spontaneous speech was fluent with normal prosody and articulation. Phrase length, use of grammatical parts and lexicon were normal without verbal or phonemic paraphasias.

Naming by vision, olfaction and touch was correct about 100% of cases; only on one occasion a verbal paraphasia was noted (wrist belt instead of shoe lace). Comprehension of spoken language was grossly impaired: no significant difference was found between sentence and single word understanding. Furthermore we did not find any significant difference in understanding axial commands as "stand up" respect to commands involving the use of limbs. His constant claim during the testing sessions was: "How is it that I can hear the sound of your voice but can't understand what you are telling me?". His repetition was severely impaired mainly if the patient was not allowed to use lip-reading technique.

By means of a tape recorder words, numbers and sentences were presented: the patient was able to repeat correctly about 50% of the numbers, with verbal paraphasias of the same semantic type. He was almost totally unable to repeat words (about 10%) and sentences; nevertheless during the many testing sessions it was noted the patient's ability to "catch" the correct number of syllables, so that the repeated word, even though unrelated to the test word, had the corresponding number of syllables. No difference between high and low probability words and sentences was noted.

Serial speech was normal.

Spontaneous writing was normal.

Reading and reading comprehension was normal: the patient's ability in cross word puzzles was strikingly good.

On the Token Test (De Renzi and Vignolo, 1962) with written commands his score was well within normal limits.

Singing was fair for words, rhythm and melody. Despite his fairly good previous musical knowledge he was unable to recognize any popular melody even if it was the same as one that he had sung a few minutes previously. Similarly he was totally unable to match a melody with the corresponding picture (e.g. lullaby and a picture of a sleeping baby).

Related cortical function examination showed normal ability in calculation, drawing on copy and on command. No apraxia nor prosopoagnosia were noted.

#### *Audiological examination*

Hearing was tested with pure tone audiometry by an A 300 audiometer. Pure tones were presented to each ear by air conduction (250; 500; 1000; 2000 and 4000 Hz).

His threshold at 250 and 2000 Hz was 20 dB bilaterally. At 4000 and 8000 there was a mild impairment of about 35 dB in both ears.

Cochlear function was therefore within normal limits. The high frequency impairment was reasonable for the patient's age.

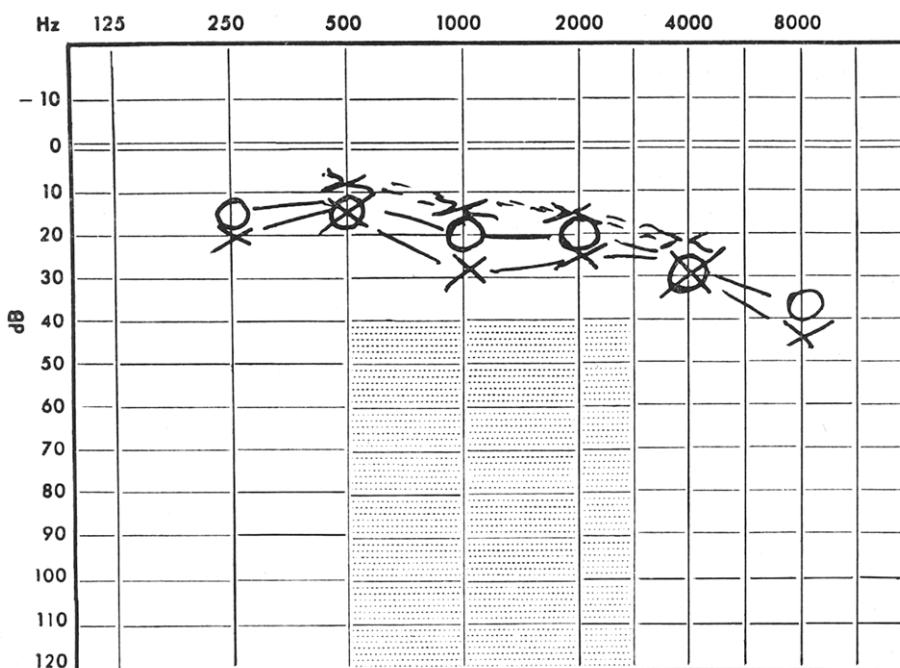


Fig. 1 — Pure tone audiometr: X Left, O Right.

### *Sound localization*

Patient was blindfolded, and the examiner snapped his fingers near the patient's ears five times to the right, five times to the left and five times bilaterally. The patient had no difficulty in sound localization and no extinction on bilateral simultaneous stimulation was noted. Similarly he had normal ability to track a moving sound with his head.

### *Rhythming ability*

A series of rhythms (waltz, polka etc.) were presented to the patient whose task was to follow them by tapping with his fingers: no errors were noted.

### *Timbre, pitch and loudness discrimination*

Twenty pairs of notes (balanced for duration and loudness) played by the same or different musical instruments were presented by tape recorder and the patient was asked to judge whether he heard similar or different sounds: he scored 20/20 on timbre discrimination. The same technique was used for pitch (20/20) and loudness (18/20).

### *Musical sequence discrimination*

A series of two sequences of seven notes each was presented and patient had to determine whether the sequences were same or different: patient's performance fell well within normal limits.

*Masculine-feminine: yong-old voice discrimination*

The patient could easily recognize the type of speaker when given words, but found consistent difficulty in doing so with syllables.

*Rhyme test*

Fifteen triplets of words, two of them rhyming, were presented and the patient correctly discriminated (13/15) the "odd" word: he was of course unable to repeat almost any of the test words.

*Discrimination of foreign words*

Fifteen triplets, each containing two Italian words and one foreign word (English or German), were auditorily presented. The patient could easily detect any foreign word, although he was totally unable to repeat. The same technique was used with Latin words as "foreign" words: patient was totally unable to recognize the "odd" word probably because in Italy Latin is generally pronounced with the same phonetic rules as Italian.

*Phonemic discrimination*

The patient was submitted to a test of phonemic discrimination: 30 pairs of syllables differing only in their initial consonant and pronounced by a trained linguist at an even intensity and uniform pitch contour were tape-recorded. The consonants were paired with the vowel /a/. Our patient was submitted to this test under two conditions, namely discrimination and identification: the task in the former was to say whether the two syllables were the same or different, in the latter the patient had to write down what he heard. In both conditions his score was very poor: the patient was able to discriminate correctly only 16 out of 30 syllables. In the identification condition only 12 syllables were correctly identified, mainly in the stop series: analysis of errors failed to reveal any systematic patterns of errors; in the majority of cases the answer was "I don't know" or "I hear the sound but can't say what it is." When he was invited to guess, his answers were bizarre and showed no tendency to errors separated by one or a few distinctive features from the original one (Jakobson and Halle, 1957). Such result does not agree with Blumstein (1973) finding on phonological investigation of aphasic speech. The same technique was used with vowels and patient both in identification and discrimination tasks showed substantial improvement: in the discrimination tasks his score was 8 out of 10 and in the identification 7 out of 10.

*Semantic bearing test*

The recent finding of Albert, Yamadori, Gardner and Howes (1973) that some semantic comprehension of written material can be found in alexics despite lack of phonemic reading induced us to investigate the possibility that our patient could have some residual comprehension of heard verbal material on a semantic basis. In order to test this hypothesis the patient was given a series of tests in which the only operation was to match a heard verbal stimulus to a written word. In the first test the patient was asked to match a word spoken by the examiner with the corresponding word from a list of three: for example the examiner said the word "hat" and the three words "bat," "hat" and "shoe" were written in front of the patient with the instructions to indicate which corresponded

to the spoken stimulus. The incorrect alternatives were chosen because of either acoustic or semantic resemblance to the test word. The patient's answers were random. He claimed that he did not understand the word and that it was therefore impossible to match what he heard with the corresponding written word.

Similarly a spoken word was presented to the patient (e.g., "coffee") and the subject had to match the word with a written one from a list of three on the basis of some common characteristics (e.g., "black," "white" and "chair"). In none of the many testing sessions was any improvement in comprehension as tested by the usual methods noted.

#### *Recognition of non verbal sounds*

To determine whether the patient's cortical auditory disorder was limited to verbal material his ability to recognize the meaning of non-verbal sounds was investigated.

A modified version of Spinnler and Vignolo's (1966) auditory agnosia test was administered: The test consist of 20 tape recorded familiar sounds (e.g., a singing canary, the sound of a violin) and the subject is asked to select the corresponding picture. For each sound (e.g., a baby crying) there are pictures which represent: (1) the natural source of the sound; (2) the source of a sound acoustically very similar to the sound presented (miaowing cat); (3) the source of a sound belonging to the same semantic category of the natural source of the presented sound, but producing a sound completely different from the presented one from an acoustic stand point (children playing) and (4) the representation of the sound which had no relationship to the sound presented (a slamming door). All the pictures remain before the subject during the entire test procedure.

The patient's ability in matching the sound with the corresponding picture was strikingly good: he was able to match the sound with the appropriate picture (17 times out of 20); he was unable to recognize the sound of a baby crying, a barking dog add the shot of a gun: for all these sounds the patient did not match any of the pictures put in front of him claiming that the natural source even if it was unknown to him was not present.

The patient's ability to name the sounds was examined by means of the same test but without pictures. The patient correctly named only 4 out of 20 sounds. In the vast majority of the cases the patient said that he did not know the sound and when invited to guess the name his answer was bizarre without auditory or semantic similarity with the test sounds.

#### DISCUSSION

The disorder in the patient reported here is of the same kind as that described by Bastian (1869) and Lichtheim (1885) under the term of Pure Word Deafness (PWD): the patient is unable to understand spoken language, repetition and writing from dictation are lost, while spontaneous speech, reading and reading comprehension, writing spontaneously and on copy are preserved: in other words such patients act as they are deaf despite a normal hearing or despite a hearing loss not adequate to account for their impairment.

According to Liepmann and Storch (1902) the lesion responsible for PWD is located on the left temporal lobe, destroying the left auditory radiations and callosal fibers from the right auditory area, with sparing of Wernicke's area

which is disconnected from auditory stimulation. Similarly Henneberg (1926) and Schuster and Taterka (1926) related PWD with a left unilateral temporal lesion, either subcortical or cortical.

Bilateral lesions were found in the Jolly-Henneberg case (Jolly, 1902; Henneberg, 1907) quoted by Kleist (1962), and in Pick's case (1892) with softening of superior temporal lobe bilaterally, involving the posterior half of  $T_1$ , and supramarginal gyrus on the left side, and  $T_1$ ,  $T_2$ , insula and inferior frontal region on the right.

Following a review of the autopsied cases Geschwind (1965) concluded that PWD can be seen following bilateral cortical lesions involving right auditory association area as well as a zone just anterior to Heschl's gyrus on the left side. Alternatively in the unilateral cases the lesion is usually subcortical interrupting the callosal connections from right to left auditory area, as well as the auditory radiations on the dominant side.

The question must naturally arise as to whether a patient who performs normally in all language tasks except those requiring auditory comprehension might not simply be suffering from cortical deafness. It seems clear that there are patients whose comprehension difficulty for spoken language is out of proportion to hearing loss as tested by conventional methods. Furthermore, it is worth stressing here that the concept of cortical deafness itself presents major difficulties. Thus the notion of cortical deafness was first established by Henschel (1916) on the basis of 65 cases published in the literature up to that time but was criticized by Kleist (1928) who questioned the existence of a single acceptable case in the entire literature.

Recently Baru and Karaseva (1972) following a survey of literature and refined audiometric studies in patients with temporal lobe lesions showed that classical methods of testing hearing, such as pure tone audiometry, tuning fork tests, etc., do not enable a pathological focus in the central portion of the auditory system to be localized. Their results showed that destruction of the superior temporal region or even the entire temporal lobe by a pathological process or its surgical removal does not significantly raise the thresholds of detection of prolonged acoustic stimuli. By contrast the thresholds of detection of acoustic stimuli under 10 msec. in duration were found to be increased when measured in the ear contralateral to the affected temporal lobe, regardless of the side.

On the other hand the frequent occurrence of PWD in the course of recovery from Wernicke's aphasia has caused some authors (Marie, 1926; Weisenburg and McBride 1935) to reject the syndrome as only a stage of sensory aphasia. Quite often, varying degrees of contaminating deficits such as pain asymbolia (Hemphill and Stengel, 1940), calculation disturbances (Hécaen and Angelergues, 1965), verbal paraphasias, visual naming disturbances and deficits in reading and reading comprehension (Gazzaniga, Velletri Glass, Sarno and Posner, 1973) are present.

Recently Kanshepolsky, Kelley and Waggener (1973), on the basis of careful clinical and pathological examination of a case of PWD following bilateral temporal lobe lesions of vascular origin, took an intermediate position postulating a "mixed disorder of auditory and perceptual defects."

Although our case lacks anatomic confirmation, clinical and laboratory evidence point to involvement of the left hemisphere only. Furthermore no signs of concomitant higher nervous function impairment were found during the various testing sessions: examination of spontaneous language, writing, reading comprehension,

calculation, naming under visual and tactile modality, spatial orientation, manipulation of acquired knowledge were all within or above normal limits.

The interest of our case is twofold: first, the striking discrepancy between his inability to name meaningful sounds, with normal ability in matching the sound with the corresponding natural source; secondly, the discrepancy between his almost complete inability to understand spoken words and the evidences of recognition of certain aspects of speech sounds.

The literature on auditory agnosia, i.e., failure to recognize the nature of non verbal sounds in cases of PWD has shown contradictory results.

In the Jolly-Henneberg case of PWD (Jolly, 1902; Henneberg, 1907), quoted by Kleist (1962) there is no information about the comprehension of sounds. In their study of sensory modality and object naming Goodglass, Barton and Kaplan (1968) found a patient with a moderate degree of PWD who showed poor auditory naming in spite of normal ability in matching sounds to pictures; their patient was found to have additional visual and tactile naming difficulties. In the case of Jerger, Weikarks, Sharbrough and Jerger (1969), with bilateral temporal lobe lesions, the misidentification of sounds was not clearly distinguished from word finding difficulty. In the case of Gazzaniga et al. (1973) there is no clear cut distinction made between the patient's performance in recognizing and naming tape recorded familiar sounds. Kanshepolsky et al. (1973) do not mention whether their patients, though able to recognize the meaning of the sounds, were able to name them.

In our patient the process of naming, otherwise normal for the visual and tactile modalities, is selectively impaired in the auditory modality in spite of normal recognition. We suppose that the sound is correctly analyzed and recognized in the presumably intact right hemisphere but because of the disconnection of the left Wernicke's area from both primary auditory areas the process of naming is impossible.

Although previous researches of the Milan group (see Vignolo, 1969) showed a significant association between aphasia and misidentification of meaningful sounds, Albert (1972) found no significant difficulty in recognizing meaningful sounds in patients with brain lesion on either the right and left side, including those with aphasia. While this does not exclude the possibility that appropriately placed lesions might cause auditory recognition deficit it does at least suggest that it is uncommon. Moreover, in dichotic listening situation, recognition of musical patterns and environmental sounds is better for the materials directed to the left ear (Kimura, 1964; Curry, 1967), whose hemispheric connections are mainly contralateral.

In his description of PWD, Pick (1931) speculated about the preservation in word deafness of recognition of some of the characteristics of speech. According to this author recognition of what is said as belonging to a foreign language is chiefly due to musical factors characteristic of that language, just as its recognition as speech depends on the speech melody which differentiates speech from other noises. In the recognition of different voices the timbre of the acoustic phenomena is of major importance. The occasional recognition of vowels as such is according to Pick unexplained. The above quoted studies on dichotic listening give some experimental support to Pick's views, the role of the right hemisphere seems in fact to be critical for the perception of these qualities.

In our patient the intactness of the right hemisphere seems therefore to be responsible for the perception of some characteristics of speech sounds such as the ability to differentiate masculine from feminine voices and young from old. Noteworthy is the ability of our patient to discriminate between foreign and

Italian words, although unable to understand or to repeat the message. Such a discrepancy was not present when he was confronted with Latin and Italian words, probably because the Italian pronunciation of Latin is phonetically identical to that of Italian. The ability of our patient on such tasks can be explained on a perceptual basis: certain acoustic aspects of speech, such as stress and prosody, do not require the phonemic analysis which can be carried out only or primarily by left hemisphere.

On the same basis we can reasonably understand the discrepancy in the test of phonemic discrimination: the patient showed almost absolute inability in discrimination and recall of consonants but good understanding of vowels. Such data agree with Shankweiler and Studdert-Kennedy's (1967) studies on dichotic listening. They reported a superiority of the left hemisphere in the recall of synthetic and natural consonants but failed however to show significant hemispheric preference for vowels. Another point of interest is the lack of understanding axial commands which according to Boller and Green (1972) are easily understood even by global aphasics.

A final point should be considered: the discrepancy observed between patient's normal capacity in matching a heard non verbal sound with the corresponding natural source and his absolute inability to recognize even the simplest melody, despite normal perceptual analysis of sounds as demonstrated by normal timbre, pitch and loudness discrimination. We would tentatively suggest the following explanation: meaningful non verbal sounds are likely to arouse kinesthetic and visual association between the acoustic stimuli and other characteristics of objects and events. Recognition of melody, on the other hand, may involve a much more symbolic activity, which can be mediated only through a specific auditory mechanism, presumably the same as the one carrying out the phonemic and semantic analysis of language.

#### SUMMARY

In a patient with a classical syndrome of pure word deafness following a cerebrovascular accident detailed neuropsychological examination showed an almost absolute inability to name meaningful non verbal sounds, in spite of normal recognition as demonstrated by ability to match the sound with the corresponding natural source.

This selective anomia, confined to auditory modality, is discussed in view of the previous researches regarding the general field of naming disturbances, which showed that for the vast majority of aphasics, anomia was not modality dependent.

Besides that the contrasting performance of the patient who showed complete lack of phonemic analysis matched with normal recognition of some acoustic parameters of speech as prosody and stress is discussed.

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