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A method of impedance reflexometry was used to examine 101 students with hearing impairment in order to clarify the interrelation between speech discrimination and the state of the middle ear muscles. It was shown that ability to discriminate speech signals depends to some extent on the functional state of intraaural muscles. Speech discrimination was greatly impaired in the absence of stapedial muscle acoustic reflex (AR), in the presence of low thresholds of stimulation (up to 20 dB) and in very small values of reflex amplitude increase. Discrimination was not impeded in positive AR, high values of relative thresholds (40 dB or more) and normal increase of reflex amplitude in response to speech signals with augmenting intensity.

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ROLE OF THE MIDDLE EAR MUSCLE APPARATUS IN MECHANISMS OF SPEECH SIGNAL DISCRIMINATION

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In the opinion of most investigators the basic physiological role of the muscular apparatus of the middle ear is related to protection of the receptor formations of the cochlea against the adverse effect of loud sounds (Moller, 1962; Perlman, 1970; V. S. Olisov et al., 1976; B. M. Sagalovich et al., 1977; S. N. Khechinashvili, 1978). This is achieved by reflex contraction of the intraaural muscles and the accompanying diminution in the amount of acoustic energy reaching the inner ear. /24*

A number of authors feel that, along with this protective function, the muscles of the middle ear play a real role in creating optimal conditions for the analysis and discrimination of helpful signals as contrasted to noise (Simmons, 1964; S. N. Khechinashvili, 1978). Due to their action in frequency selection muscular contractions facilitate dynamic changes in the frequency characteristic of the transmission system of the middle ear, reduce the masking effect of low frequency sounds and by the very fact create more favorable conditions for the emergence of required sound signals. It has been theorized that the middle ear muscles participate directly in binaural determination of sound source localization (Moller, 1963; Simmons, 1964; B. M. Sagalovich and A. A. Drozdov, 1973).

It is very interesting to consider the data in respect to the effect of internal muscles on the process of the reception and analysis of sounds in the speech spectrum. The research of Niemeyer (1971), McCandless and Miller (1972), Borg and Zakrisson (1973) has shown, that when the normal functioning of the middle ear muscles is impaired there is real deterioration in the intelligibility of speech, especially for signals of great intensity -- on the order of 80 dB and higher. These observations may be important in the practice of surgery for improving hearing, in acoustic prosthesizing and in medical evaluation of hearing impairment.

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* Numbers in the margin indicate pagination in the foreign text.

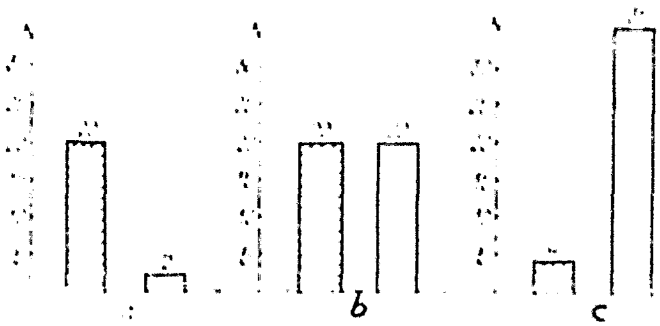

Fig. 1. Graph of subject distribution as a function of the value of the relative threshold for acoustic reflex (AR) with stimulation by a 500 Hz tone for 800 microsec and of speech intelligibility: a) value for acoustic reflex threshold (ART) when $ART_0 \leq 20$ dB, b) when = 21-40 dB, c) when ≥ 40 dB; N - number of subjects; white column - good speech discrimination, shaded - poor.

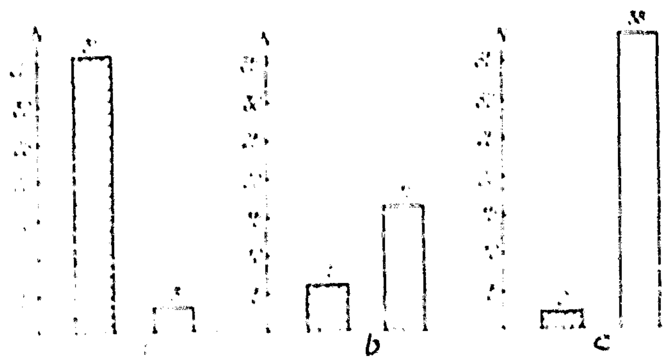

Fig. 2. Graph of subject distribution as a function of the value of the relative ART with stimulation by white sound and of speech discrimination. Rest as above.

However, there has not yet been enough study done on participation of the muscular apparatus of the middle ear in the mechanisms for reception of speech signals.

In this study we considered it important to clarify the existence of an interrelation between speech sound discrimination capability and the condition of the muscular apparatus of the tympanic cavity in persons with neurosensory hearing impairment. The solution of the problem may open up new possibilities in the area of acoustic prosthesis, since the treatment of such patients is still ineffectual and is related basically to the prescription of the proper hearing aid.

We studied 101 students of grades 9 to 11 who were hard of hearing at ages 17 to 21. In all of them the degree of impairment was practically the same. 90% traced their condition back to childhood in the wake of infectious diseases (measles, parotitis, scarlet fever, flu) or following administration of ototoxic antibiotics (streptomyycin, monomycin, etc.). When testing was done audiometrically in a soundproof booth on the East German MA-30 apparatus, the loss of tonal hearing over a range of 125-8000 Hz was from 50 to 90 dB. White sound thresholds in the subjects varied from 55 to 80 dB. In 57 speech test intelligilibity was from 75 to 100%; in the other 43 it did not reach 75% even with maximum strength signals (up to 110 dB).

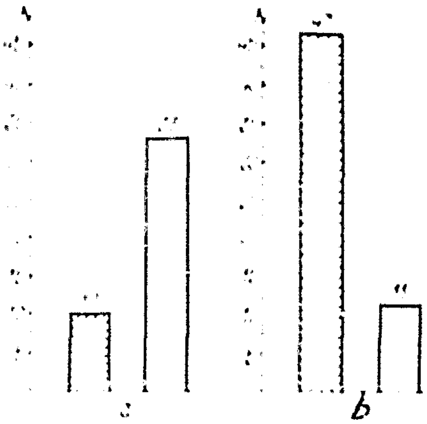

Fig. 3. Graph of subject distribution as a function of value for increment in amplitude of reflex and speech discrimination; a) normal AR increment of amplitude, b) higher AR amplitude values, lower values or absence of acoustic reflex. White column for good speech discrimination, shaded for poor.

In otoscopy all subjects presented mobile unimpaired tympanic diaphragms with clear contours and typical normal coloration. Persons with symptoms /25
of impaired function in sound conduction (scarred tympanic diaphragms, perforations, tumefaction, etc.) did not take part in the study.

Further a determination was made of the functional condition of the adaptive muscular apparatus of the middle ear on the basis of data obtained for the threshold and amplitude of the acoustic reflex of the stapes muscle. For the examination we used equipment of our own construction intended for dynamic impedance measurements (B. S. Moroz and V. G. Bazarov, 1974). We measured the absolute acoustic reflex threshold (ART_a) in response to various sound stimuli: square waves for wide band noise, tones at 500 Hz lasting 800 microsec. For the ART we used the decibel intensity of an acoustic stimulus that would cause contraction of the stapes muscle and we noted the change in the acoustic impedance of the middle ear by 0.2-0.3 dB as compared with the initial value. Here the stylus went up 5-8 mm from the baseline.

After determining the ART_a we measured the amount of increment for AR amplitude in percent when there was an increase in stimulus intensity by 10 dB above the threshold of the reflex value, using the formula:

$$I = \frac{A_{10} - A_0}{A_0} \cdot 100\%$$

where I is the increment value for AR amplitude, A_0 is the AR amplitude on the inception threshold (5-8 mm) and A_{10} is the AR amplitude in mm when the threshold is surpassed by an intensity of 10 dB.

At the same time we studied the relative thresholds for the acoustic reflex (ART_0) typical of the value for acoustic pressure above the audibility threshold (AT) of sound required for the reflex to set in. The ART_0 value was found with the formula:

$$ART_0 = ART_a - AT(dB).$$

As a result of the measurements for absolute threshold values of the AR we established that in 21% of the subjects the ART_a values were 80-90 dB, i. e. they matched the physiological norm. In 63% there was a variation in the range of 100-120 dB. The other 16% of the students hard of hearing showed no AR that we succeeded in recording, a fact associated with severe hearing loss.

Results analysis revealed that in 43 subjects gradual intensification of the stimulus was accompanied by a corresponding linear increment in AR amplitude (I = 80-150%), while the other 58 persons showed no such proportional relationship between AR amplitude and stimulus intensity. Thus, in a number of subjects we recorded a nonproportionally high increment in AR amplitude in response to a comparatively small increase in acoustic stimulus intensity (I = 300-400%), whereas in the other, on the contrary, the AR amplitude increased very little when acoustic intensity was increased (I = 0-20%). /26

Measurement results for relative ART showed that out of the whole 101 subjects 22 presented ART_0 values equal to or less than 20 dB and 40 showed a threshold of 20-40 dB while 39 showed 40 dB. The indices obtained were compared with the data from speech audiometry (Figures 1, 2, 3). We were intrigued by the question: is there any relationship whatever between a person's ability to distinguish speech sounds and the functional condition of the protective-adaptive mechanism of the middle ear muscles?

The results shown in the 3 figures indicate the presence of a definite link between capacity to distinguish speech signals and the data from impedance reflexometry. Thus, in the group under study in which we recorded low ART_0 values (to 20 dB), the number of persons finding it hard to discriminate speech sounds was from 10 to 12 times greater than the number who found it easy (Fig. 1a, 2a). Among the persons whose ART_0 indices were in the range of 20-40 dB (Fig. 1b, 2b) there were no significant quantitative differences in respect to good or poor discrimination of speech sounds. Finally, in the group with high ART_0 values (above 40 dB) the number of persons with good speech discrimination was many times higher than the number of those in whom it was poor (Fig. 1c, 2c).

In analyzing results we also noted a definite relationship between speech discrimination and the AR amplitude increment value (Fig. 3). Thus, in the group in which showed normal physiological values for AR amplitude increment in response to more and more intense stimuli (I = 51-150%) the number of persons with good speech discrimination was 3 times larger than those with poor. And contrariwise, among subjects showing high AR amplitude increment values (I = 300-400%) or extremely low values (I = 0-50%) or no AR at all the number of persons with poor speech discrimination was larger than the number in whom it was good.

For further interpretation of our results we rely upon the following literature data.

1. The dynamic range of clearly discriminated speech is 45-50 dB (Yu. B. Preobrazhenskiy and L. S. Godin, 1973; M. M. Efrusi, 1975). /27

2. Maximal speech discrimination is achieved at sound levels equal to the absolute values for the ART (Rappaport, Tait, 1976), which is on the whole only 10-15 dB below discomfort level (McCanbless, Miller, 1972) or 5-10 dB above the comfort level for loud speech (Jantis et al., 1966).

3. The value for the relative ART that typifies the level of acoustic pressure above the AT level required to trigger the AR nearly coincides or is slightly below (by 10-15 dB) the value of the dynamic auditory range (Liden et al., 1973). Normally the relative ART is 65-75 dB (Moller, 1978).

4. When the intensity of audiosignals is quite high the incipient contraction of middle ear muscles induces further distortion of the sound and this results in weaker speech discrimination (Liden et al., 1973; Rappaport, Tait, 1976).

On the basis of the literature data it is clear that quality reception and understanding of conversational speech requires a definite dynamic audiorange of 45-50 dB. In this context one may explain the facts of poor speech discrimination in student subjects when this audiorange was compressed (Fig. 1a, 2a). When they presented a wider range, evidenced by the increase of the ART_0 to 40 dB and higher (Fig. 1c, 2c), there was a considerable increase in their ability to comprehend and show good discrimination of speech signals. A similar explanation may be invoked for the fact that in the group of the hard of hearing with a normal AR amplitude increment there is a predominance of persons with good speech discrimination (Fig. 3a).

Evidently in this case the appearance of the AR following muscular contraction in the middle ear provides for better reception and better discrimination of speech sounds. On the contrary, poor discrimination was observed in subjects without AR or in those where the reflex appeared but did not change in amplitude in response to stimuli of varying intensity (Fig. 3b).

At the same time research has also indicated that the ability of subjects to discriminate speech sounds is determined not only by the dynamic audiorange and the condition of the middle ear's muscular apparatus but it likewise a function of other mechanisms. Thus, some subjects with a narrow dynamic audiorange and negative AR were found in our study to show good speech discrimination. At the same time in the group of subjects with positive AR and relatively good dynamic audio characteristics there were those who could not discriminate speech signals very well (Fig. 1c, 2c). Such discrepancies may be associated with individual quali- /28 ties of the CNS, particularly with the condition of the cortical portion of the sound analyzer.

On the basis of the data obtained we may conclude that impedance reflexometry makes possible objective typing of the condition and reserves of residual hearing in the hearing impaired and may find an application in working with hearing aids. For example, on the basis of impedance changes we may decide on the appropriate type of hearing aid for an individual patient as well as the proper diet and type of work to be done and we may make judgements about the need of compression and about sound pressure levels.

Our research indicates, in persons hard of hearing yet having good dynamic audio characteristics and speech discrimination, effective audioprosthesis may be achieved by using those hearing aids which amplify speech signals linearly and by frequency selection. Persons whose speech discrimination is unsatisfactory and who have poor dynamic characteristics need most of all special exercises to develop whatever hearing they have left using hearing aids which, while providing frequency selection amplification, can set up a spectral combination, provide compression of amplified sounds and also effect other acoustic transformations for achieving maximal speech understanding.

Thus, the results obtained open up new possibilities for increasing the effectiveness of prosthetic help for persons with serious forms of neurosensory hearing impairment. Here it seems proper that there be further study of the role of the middle ear muscles in the mechanisms of speech sound discrimination.

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