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AUDITORY ADAPTATION

CLINICAL EVALUATION

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MEASUREMENT of auditory adaptation is being used to an increasing extent for audiological evaluation of patients with cochlear or vestibular problems. Even if one is not convinced that this test gives precise diagnostic information, its results have been useful in assessing the ear's functional behaviour under continuous stimulation.

Many circumstances affecting the results of adaptation test have been discussed recently (1964) by one of the authors. In this paper we have limited our theme mainly to threshold adaptation tests since these have been felt to be easier to apply and interpret than the suprathreshold tests. However, a kind of suprathreshold test was also applied by measuring adaptation of pure tones against a background of white noise in the tested ear.

TECHNIQUE OF ADAPTATION TESTS

Threshold adaptation tests in quiet have generally been caried out using two different techniques. The initial technique of Schubert (1950) consisted of allowing the subject to listen to a steady 5 db. sensation level tone; if the tone faded away, its intensity was raised in 5 db. steps until a plateau was reached or, in cases of high hearing levels, the

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maximum limit of the audiometer did not allow following the tone. Schubert found that young persons under 25 years of age did not manifest any adaptation at frequencies lower than 1,000 c.p.s. Between 1,000 and 12,000 c.p.s., normal adaptation was 5 db. In conduction deafness, normal values were obtained while in cochlear deafness adaptation amounted to 25 db.

Another technique in frequent use is fixed frequency self-recording audiometry. In this technique the patient listens to a tone alternately fading away and increasing to clear audibility, and thus the ear does not receive a constant physical stimulus. Because of these differences, the two techniques may not yield entirely parallel results.

Having earlier made several adaptation studies with the self-recording technique, we now chose the original technique of Schubert, which has been used, sometimes slightly modified, by Hood (1955), Carhart (1957), Sørensen (1962), and Parker *et al.* (1962), among other investigators. The results with the present technique will be compared with those obtained earlier by the self-recording technique.

The pertinent literature was extensively reviewed in the earlier publication (Palva, 1964), to which the reader is referred. Some new data, particularly such as are related to the mechanism of adaptation, will be reported here with a discussion of results.

Material and Methods

The material consists of selected cases of perceptive deafness, some of them seen at the Outpatient Department for diagnostic purposes and others treated in the Clinic. Particular attention was given to patients who, with reasonable certainty, had either cochlear, retrocochlear or central deafness. Cochlear deafness includes two main groups: Ménière's disease (31 cases, 35 ears) and skull trauma (26 cases, 47 ears). Smaller groups consist of cases of acoustic trauma, vascular accident, streptomycin damage, and degenerative angio-sclerotic cochlear disease. The retrocochlear and central group includes 36 cases (67 ears), the site of the lesion being in the acoustic nerve, in the cerebellum, pons or medulla, or in the cerebrum. In addition, there was a mixed group of 40 cases (73 ears), complaining mainly of vertiginous symptoms, generally with good hearing; in these the site of lesion remained more or less vague in spite of a thorough work-up. Altogether 157 cases (260 ears) were examined.

In addition to caloric testing with cold and hot water stimulation and a general neurologic examination, pure tone air and bone conduction curves were obtained, together with speech audiometric curves using normal non-distorted speech. Measurement of loudness recruitment was made at 20 db. intervals in all cases suitable either for Fowler's binaural or Reger's monaural balance. Conclusions as to the type of the recruit-

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ment were drawn solely on the basis of these tests; various indirect tests were not used.

The tests for auditory adaptation in quiet were performed as threshold tests during a period of 3 minutes. The subject was instructed to listen to a tone of 5 db. sensation level and asked to raise his hand if the tone faded away. The examiner subsequently increased the intensity of the tone by 5 db. steps until the 3 minute period elapsed or until the limit of the audiometer no longer allowed following the receding tone. For reporting of the results, the amount of adaptation recorded after 1 minute, 2 minutes and 3 minutes stimulation was extracted from the curve obtained.

This test in quiet was followed by a similarly conducted test in which a pure tone was listened to in the presence of a 70 db. over-all level white noise. By this means the cochlea and the auditory nerve were subjected to more intense and complex stimulation; auditory adaptation could also by this method be studied in cases with moderate hearing loss at clearly suprathreshold starting levels.

In several of our earlier studies the positive results appeared most frequently at 4,000 c.p.s.; this tone therefore, was used most frequently. However, in many cases of major interest, all octave frequencies between 500 and 4,000 c.p.s. were used.

As pointed out earlier, the use of a masking noise may be necessary in testing auditory adaptation. A good contralateral ear should be masked as soon as the adaptation stimulus in the test ear exceeds the 50 db. level. Similarly, it is in many cases necessary to mask the contralateral ear during adaptation tests in noise. To this purpose, white noise was used in accordance with the principles described earlier (Palva and Palva, 1963).

Results

The hearing level of the patient may be important in the determination of auditory adaptation: it is possible that the amount of adaptation may be different at different intensity levels, and in marked pure tone losses, the limit of the audiometer may not permit following of the tone. Similarly, the frequency of the test tone may alter the results. Table I gives a summarizing list of the various groups studied with respect to the starting levels in adaptation tests.

In each group there were a number of cases with only a minor hearing loss, less than 30 db., while a somewhat smaller number had a hearing level between 30 and 55 db. The group with a starting level of 60 db. or more was fortunately the smallest: the intensity limit of the audiometer in these cases may not allow the normal procedure of adaptation test.

Ménière's Disease

These patients had a characteristic history of Ménière's disease with

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TABLE I.
ADAPTATION TEST STARTING LEVELS.

Disease group	Starting levels (db)			Total		
	0–25	30–55	60–90	Cases	Ears	Frequencies
Ménière's disease	10	39	16	31	35	65
Skull trauma	32	20	5	26	47	57
Vascular accident	2	2	4	4	4	8
Acoustic trauma	4	2	2	2	4	8
Angiosclerotic degeneration ..	5	10	4	10	19	19
Streptomycin damage	5	—	—	2	3	5
Vestibular neuronitis	5	3	1	5	6	9
Hereditary deafness	—	1	3	1	2	4
Retrocochlear or central deafness	52	25	7	36	67	84
Miscellaneous groups	74	13	—	40	73	87
Total	189	115	42	157	260	346

fluctuating hearing loss, tinnitus, vertigo, and altered caloric response. Of the 31 patients, four had bilateral Ménière's disease.

Direct recruitment tests were impossible in five cases because of the nearly equal hearing levels. Curves for recruitment function showed an asymptotic slope in five ears, a straight line in 12, delayed in five, and incomplete in four; the discrimination score for speech was lowered in all cases with a hearing level of 35–40 db. or higher. Since the hearing loss in several cases was greatest at the low frequencies, many tests were performed at frequencies lower than 4,000 c.p.s. Table II gives a detailed list of these frequencies in relation to the amount of adaptation loss. In quiet, adaptation was less than 30 db. at 45 frequencies; in noise the corresponding number was 35. Adaptation exceeding 30 db., the tone being audible during the whole 3 minute test, was almost equally frequent under both test conditions whereas total disappearance of the tone was noted 11 times in quiet and 23 times in noise.

Disappearance of the test tone occurred in only one case with a hearing level of 50 db. (at 4,000 c.p.s.); in all others the starting level was over 60 db. and thus the 100 db. limit of the audiometer did not allow more than a 40 db. adaptation to be recorded on 33 occasions.

Fig. 1 shows the detailed results in regard to adaptation at 4,000 c.p.s. in quiet and in noise. It is seen that the measured loss exceeded 40 db. three times in quiet and twice in noise. Total disappearance of the tone is marked with arrows and even during the first minute of the test this occurred three times in quiet and four times in noise. In this diagram values obtained earlier in 21 ears of Ménière's disease (Palva and Palva, 1963) with the self-recording technique are marked with crosses.

SKULL TRAUMA

All 31 subjects included in this group had been hospitalized for varying periods because of severe cranial trauma. In the majority of

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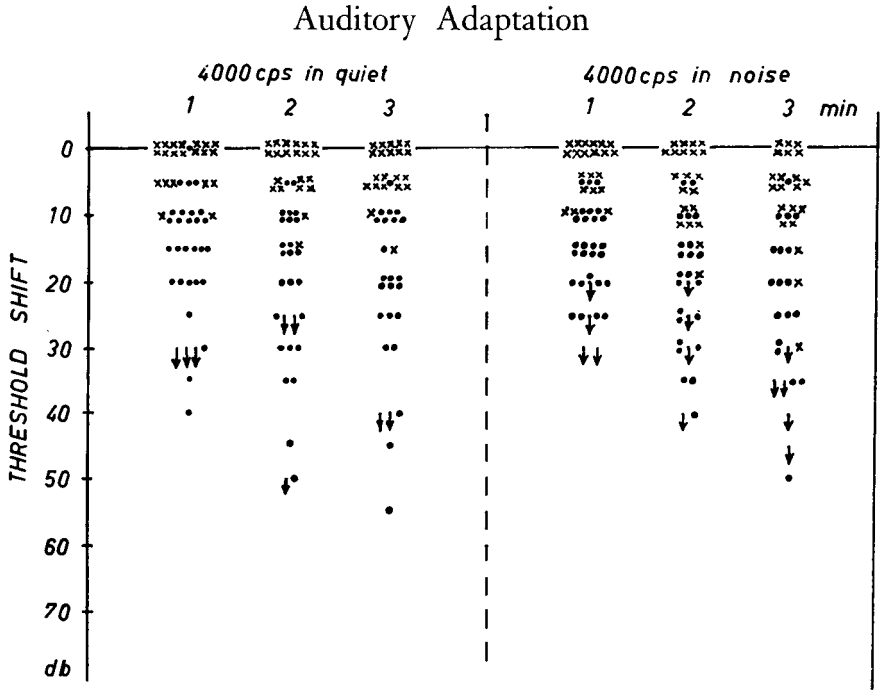


FIG. 1.

Individual results of the 3 minute adaptation test at 4,000 c.p.s. in 31 ears of Ménière's disease. The group at left depicts the results in quiet and the right hand group those obtained in the presence of 70 db. overall level white noise. The black dots indicate the values obtained by the present manual technique while the crosses refer to the values obtained earlier by the self-recording technique (Palva and Palva, 1963). The dots marked with arrows indicate total disappearance of the tone.

cases there was a minor hearing loss at the middle frequencies, while at 4,000 c.p.s. the impairment was more pronounced. In no case was there any conductive component during the time of testing although there may have been a hæmotympanum in the initial phases. In some there were distinct sequelae of either cerebellar or cerebral contusion.

The detailed results of the adaptation test at 4,000 c.p.s. appear in Fig. 2. In quiet, adaptation was 30 db. or less at 35 frequencies. In eight instances adaptation amounted to 35–45 db., and in two cases the tone disappeared totally; in both of these latter the starting level exceeded 60 db.

In noise 23 values were 30 db. or less. Adaptation of 35 to 50 db. occurred in 11 instances and total disappearance of the test tone eight times. Four of these latter were severe losses, the starting levels being between 45 and 60 db., while in four cases the initial level was lower.

In neither group did the cases showing marked adaptation differ neurologically from the group in which adaptation was within normal limits.

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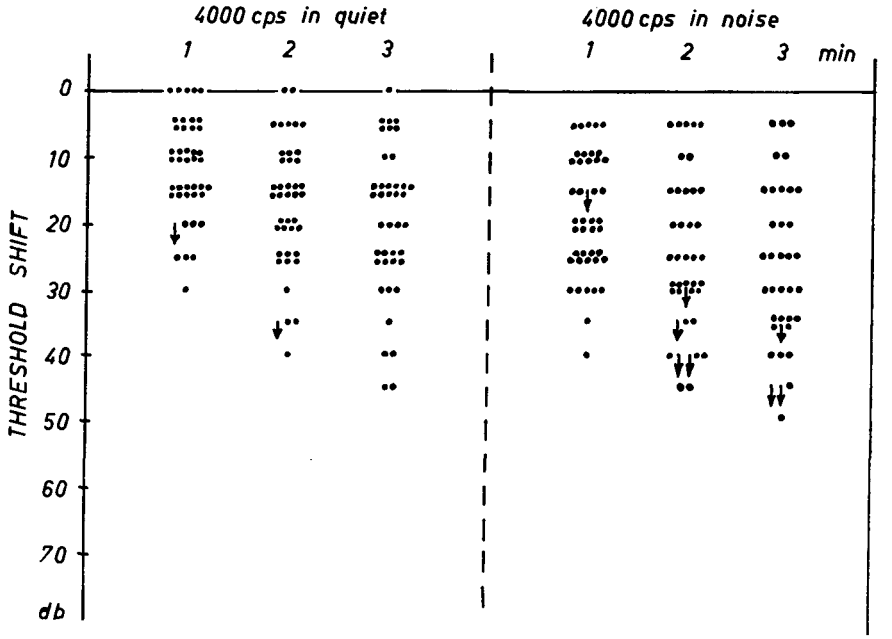


FIG. 2.
Individual results at 4,000 c.p.s. in 42 ears of skull trauma.

ANGIOSCLEROTIC DEGENERATION

The ten patients included in this group had marked cerebral angiosclerosis, and hearing in both ears was affected in all of them. All tests were made at 4,000 c.p.s. Fig. 3 gives the individual adaptation values; in the great majority they are seen to be less than 30 db. in quiet and in noise. Adaptation amounting from 15 to 50 db. occurred three times in quiet and four times in noise. Total disappearance of the tone was noted three times in noise, the starting levels being 55, 60 and 85 db.

RETROCOCHLEAR AND CENTRAL DEAFNESS

This group consisted of 36 cases, 13 of which had been verified by operation. In the others, diagnosis was established by conventional methods of neuro-clinical examination. Fig. 4 shows the results of adaptation tests at 4,000 c.p.s. (64 ears); in 20 instances the test was made between 500 and 2,000 c.p.s. The intracranial processes have been divided into infra- and supratentorial local lesions and diffuse central lesions.

Verified infratentorial cases included four tumours: one acoustic neurinoma, one metastatic lesion of the cerebellum from a mammary carcinoma, one pontine tumour, and one papilloma of the chorioidal plexus involving the IVth ventricle. In addition, there was a cerebellar

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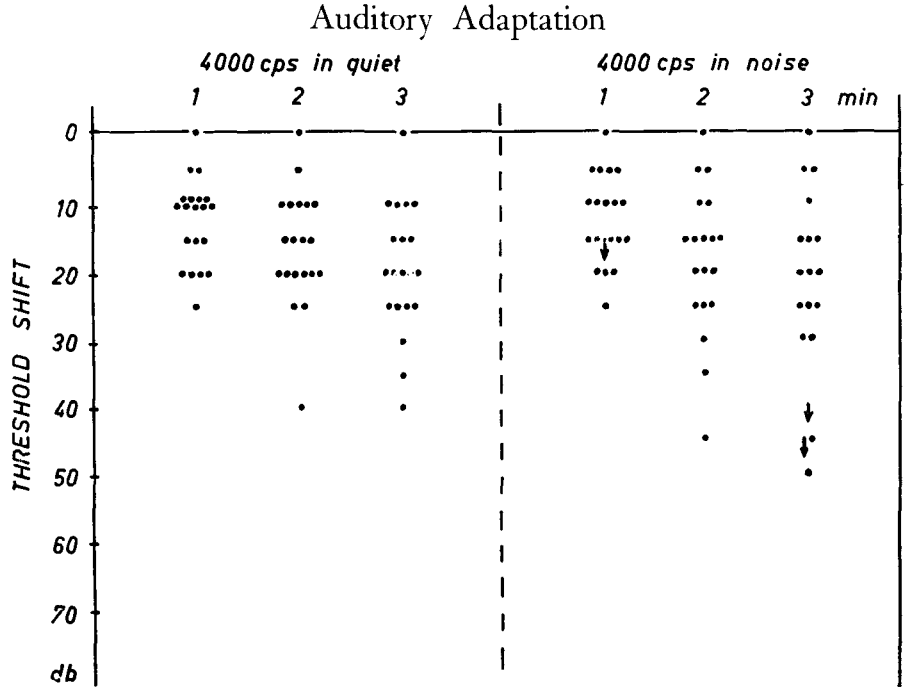


FIG. 3.
Individual results at 4,000 c.p.s. in 20 ears of angiosclerotic degeneration.

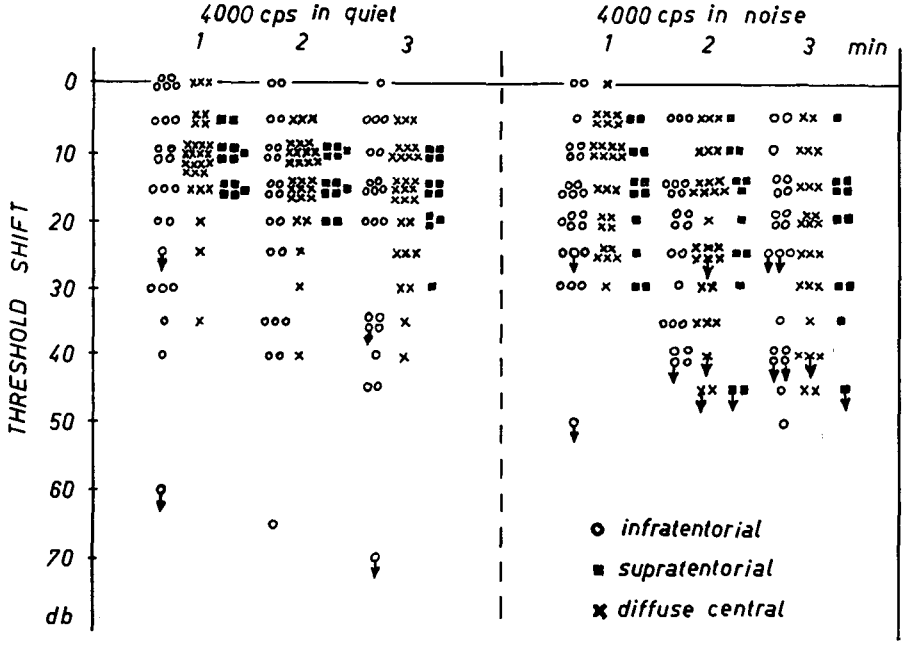


FIG. 4.
Individual results at 4,000 c.p.s. in 64 ears of retrocochlear or central deafness.

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syndrome in one case and compression of the medulla in another; craniotomy was made in both. Totally abnormal adaptation was noted in the first two cases: in the acoustic neurinoma the hearing level was initially poor; the patient heard the stimulus only for a couple of seconds at all frequencies between 500 and 4,000 c.p.s. In the metastatic lesion the threshold was better but even here the tone disappeared very quickly. Speech discrimination was very poor in both. In the four remaining cases of cerebellar or pontine lesion, the adaptation values in both ears were similar to those obtained in other groups.

Operatively verified supratentorial lesions included two meningiomas of the frontal lobe and one of the temporal lobe, the latter tested preoperatively and the others post-operatively. Speech scores were normal bilaterally in all ears and the adaptation test entirely normal in two cases. In the case of falx meningioma of the frontal region, an abnormal adaptation appeared in the noise test after two 2 or 3 minutes testing.

In other cases diagnosis was reached by various neurological methods; these were cases of disseminated sclerosis, thrombosis of the vertebral artery, hemiplegia, encephalomyelitis, funicular myelosis, epilepsy, meningoencephalitis, progressive spinal atrophy, cerebellar or cerebellomedullar syndrome, among others. Except for a few cases with abrupt adaptation, the results in these cases did not appreciably differ from the groups described above.

Fig. 5 consists of those cases in which the recorded adaptation value exceeded the maximum 100 db. limit of the audiometer in the group of Ménière's disease on the one hand and in retrocochlear and central lesions on the other. It is seen that in the latter group the adaptation losses in three cases clearly exceed those of the former group, but the tests in noise reveal no clear-cut difference between the two groups. The patient with an acoustic neurinoma shows a very rapid disappearance of the adaptation tone, a 25 db. loss in 8 seconds, and the metastatic brain stem lesion shows a 90 db. loss at 1,000 c.p.s. in 50 seconds. In the third case, thought to be a vascular brain stem lesion, an abrupt loss of 70 db. occurred.

Miscellaneous Group

Although this group has no special diagnostic label attached to it, the adaptation values obtained at 4,000 c.p.s. in 69 ears are presented in Fig. 6. Common to these cases was the normal pure tone threshold, in most instances combined with vestibular symptoms and in a few with vestibular signs. The abnormalities were mostly slight and they were thought to be associated with both peripheral and central disorders. Adaptation values in quiet were nearly all within normal limits: in noise, however, the test tone disappeared totally or adaptation reached the value of 40–45 db. in a number of cases.

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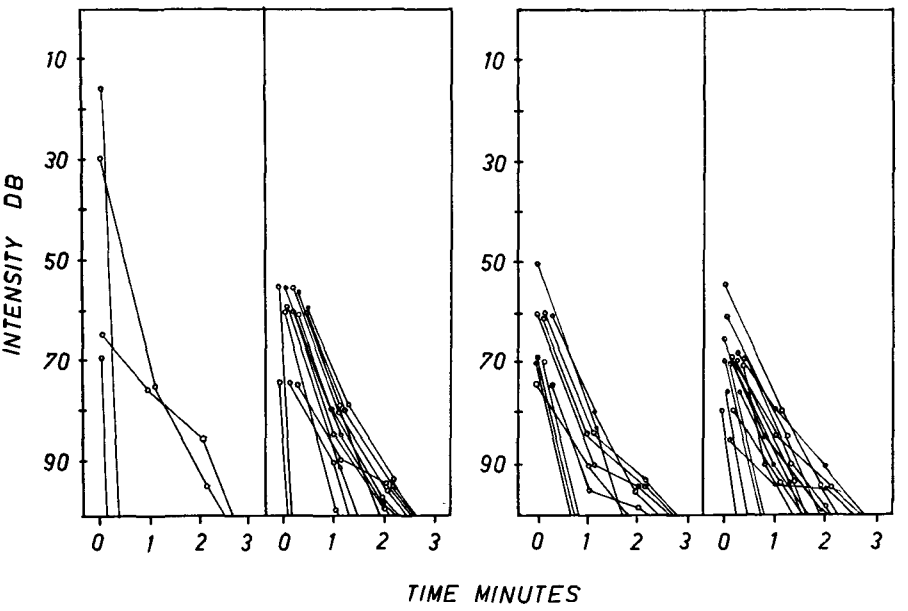


FIG. 5.
Individual results at 4,000 c.p.s. in 64 ears of miscellaneous cases with generally normal pure tone thresholds.

OTHER GROUPS

All remaining small groups included in Table II, except the group of streptomycin damage, had one or two ears with an abrupt adaptation curve. The starting level again was rather high in these cases, and such large losses as were demonstrated in Fig. 5 for retrocochlear lesions were not seen excepting the case with hereditary deafness. The majority of adaptation curves were less than 30 db., or reached a plateau between 30 and 50 db.

TABLE II.
MÉNIÈRE'S DISEASE

Amount of adaptation	Adaptation frequency									
	In quiet					In noise				
	500	1,000	2,000	4,000	Total	500	1,000	2,000	4,000	Total
0–25 db.	1	22	4	18(12)	45	1	17	4	13(9)	35
30 db. or more ..			3	5(3)	8		1	1	5(2)	7
Total disappearance	1	2	1	8(3)	12	1	6	3	13(7)	23
Total	2	24	8	31	65	2	24	8	31	65

Figures in parentheses indicate the number of cases with a symptotic or straight line complete recruitment.

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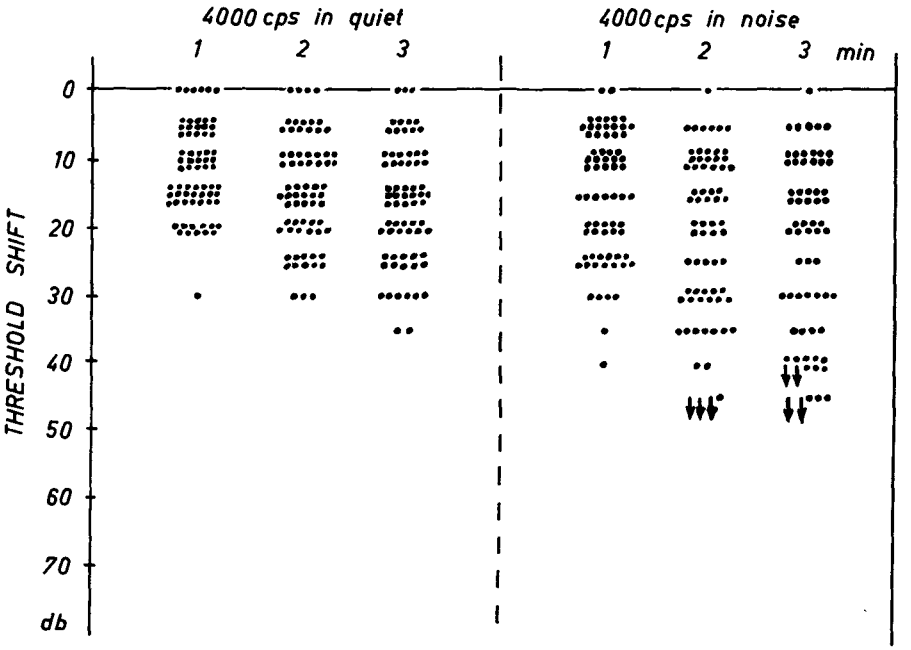


FIG. 6.

Individual adaptation curves with total disappearance of the test tone in Ménière's disease (right) and retrocochlear and central deafness (left). In both groups, adaptation in noise (right half) leads much more frequently to disappearance of tonal sensation. Further details are given in the text.

Discussion

It is generally agreed (Schubert, 1950; Hood, 1955; Sørensen, 1962; Pestalozza and Cioce, 1962) that in normal ears of young persons threshold adaptation, using the technique of Schubert, amounts to 5 or 10 db. at the most. In this respect there are not very great differences as compared with the self-recording technique, although the latter generally gives adaptation values not exceeding 5 db. (Palva, 1957; 1961).

A survey of the clinical material in Figs. 1 to 5 reveals that the general trend in all diagnostic groups is the same: a number of the patients show normal adaptation of 10 db. or less and the majority of cases show adaptation with a plateau between 11 and 30 db. All groups include a few cases of excessive loss to the limit of the audiometer in some test conditions and several cases with adaptation values reaching a plateau at 45 or 50 db.

It was stated by Maspétiol and Semette (1964) that adaptation up to 20 db. has no diagnostic significance since this appears in all disease groups, but values larger than 20 db. are generally indicative of a lesion

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in the area of the brain stem. On the other hand, Sørensen's results indicate that plateau-reaching adaptation, between 20 and 50 db., was so common as to have hardly any diagnostic value: adaptation reaching 30 db. appeared in some cases of Ménière's disease and was even more frequent and of greater degree in otosclerosis. It is noteworthy that, in Sørensen's 12 cases of acoustic neurinoma, similar adaptation was obtained but without a plateau, the adaptation increasing continuously to the maximum limit of the audiometer.

The hearing level, the starting point of adaptation tests, may thus greatly influence the numerical values of adaptation. If hearing is only moderately depressed, less than 30 db., large adaptation losses amounting from 70 to 100 db. can be measured. Unfortunately in many cases the hearing level was much more depressed; if a tone faded away when the starting level was 70 db., the measured adaptation was 30 db. and one does not know whether the fading continued or the tone reached a plateau at still higher intensity. This state of affairs is clearly discernible in Figs. 1 to 6, in which the arrows indicating the end of response to the test tone reveal adaptation losses of the order of 30–40 db. in all diagnostic categories.

In this series we had only one case of acoustic neurinoma: the hearing level was quite high, from 55 to 95 db. between 250 and 4,000 c.p.s. In agreement with Gradenigo's original observation (1893), a tone at these frequencies was heard only for a few seconds and then vanished totally. Another case with metastatic cerebellar carcinoma had relatively good pure tone hearing up to 2,000 c.p.s. but no discrimination for speech. A similar rapid disappearance of the 500, 1,000 and 2,000 c.p.s. tones appeared. In two further verified cases, a low pontine tumour and a choroidal plexus papilloma, adaptation was very moderate. The verified tumours in the temporal and frontal lobe were not associated with any marked adaptation: among the diffuse supratentorial lesions, on the other hand, there were several cases in which the adaptation loss was abrupt and no plateau was reached.

Classification of perception deafness into various categories on the basis of recruitment function, and comparison of these groups with the amount of adaptation, did not reveal essential differences when using the self-recording technique. A similar classification was made in this study but the amount of adaptation and the degree of recruitment did not show any definite correlation.

Comparison of the amount of adaptation in Ménière's disease presented in this paper with that obtained with the self-recording technique (Fig. 1) revealed that the latter technique resulted in adaptation values between 0 and 10 db. in the majority of cases and only seldom were adaptation values such as 30 db. obtained. This applies also to other diagnostic groups, the amount of adaptation with the fixed intensity manual tech-

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nique being definitely larger than that obtained with the self-recording technique. This is in line with the prediction made earlier (Palva, 1964), because in the self-recording technique the waxing and waning of the tone from audibility to inaudibility gives the ear a somewhat better chance to adapt less slowly. However, even this situation is not comparable to the total interruption of the stimulus, which would enable the on-effect to appear and delete entirely any adaptation.

Adaptation in noise alters the test conditions significantly: the starting level for the test tone in noise is clearly above the tonal threshold. While a short presentation of tones and noise follow the critical band concept (Palva *et al.*, 1953), a prolonged testing brings some other factors into play. In normal listeners, Wright (1959) showed that the initial rate of adaptation and its final level was excessive at 4,000 c.p.s. but not at 250 or 1,000 c.p.s. In clinical material Feldmann (1960) observed different types of behaviour in adaptation in noise but could not find any relationship between these phenomena and known clinical entities.

Having now practised adaptation testing in noise for some years, we have been able to confirm, using both the self-recording and the manual fixed intensity technique, that the adaptation values thus obtained are higher in a significantly greater number of cases than they were in quiet. However, on analysis of the adaptation values in noise in Figs. 1 to 6 one is compelled to conclude that this type of test does not represent any important clinical contribution. At the present time, we are using routinely threshold or suprathreshold tones without any background noise.

It was thought earlier (Hood, 1955) that adaptation is a phenomenon occurring in end organ lesions and due to a diminished number of functioning hair cells. Later, excessive adaptation has been assumed to be associated with neural pathology, the diminished number of functioning nerve fibres being the underlying anatomical basis. It is interesting to note that there is some evidence that central factors are also of importance, at least to some extent, in this phenomenon. The work of Galambos (1956), and of Pfalz (1964), shows that the efferent cochlear bundle controls the input coming from the ear, reducing it by varying amounts. Confirmatory evidence was recently put forward by Wernick and Tobias (1963), who demonstrated that a condition of mental task increased simultaneous adaptation, and by Leibrandt (1965), who was able to show, by injecting procaine into the internal acoustic meatus, that this blockade of efferent bundle resulted in less cochlear adaptation than without anæsthesia.

It is obvious that, in the near future, neuro-physiologists will present further evidence to explain the complex nature of the adaptation phenomenon. The clinical results of this study perhaps serve as good examples in warning audiologists against too categoric topical classifi-

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cation of perceptive lesions. Rapid, excessive adaptation, occurring in a matter of seconds, should raise a strong suspicion of acoustic nerve tumours or brain stem lesions, but even in these cases an adaptation common to many other clinical groups may occur. Similarly, excessive adaptation may occur in various diseases that have nothing to do with acoustic nerve lesions; Sørensen's cases of otosclerosis and some cases presented in this study exemplify this type of response well. The evidence for the purpose of localizing a hearing disorder must still be pieced together using various audiological tests combined with the clinical findings. The measurement of adaptation seems to be as important a clinical test as is the speech audiogram and the measurement of loudness recruitment. Its simplicity allows reliable results to be obtained even with a minimum of technical training, and interpreted with caution, it may contribute important additional evidence as regards the nature of the disease.

Summary

Results are presented of a manual adaptation test at threshold (Schubert) and in the presence of a 70 db. overall level noise in a series of 157 cases, tested at 346 frequencies. It was found that in all diagnostic groups the majority of patients showed an adaptation not exceeding 30 db., and that all groups included some cases showing in both tests an excessive loss of tonal sensation. The manual test technique was found to give clearly higher adaptation values than the self-recording technique used previously. Rapid, severe adaptation losses suggest an acoustic nerve or brain stem lesion whereas recordings of slower slope may be found in typical end-organ pathology or in some central lesions. Adaptation test results should, therefore, be interpreted with due caution and looked upon as one component, though an important one, of the oto-neurological examination.

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