BINAURAL HEARING*

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"It is the exception for an ophthalmologist to prescribe a monocle for a patient with defective vision in both eyes, and almost equally unusual for an otologist to recommend a stereophonic hearing aid. Nobody would deny that the Lord intended us to use both ears for hearing. Yet by long tradition otologists generally prescribe monaural aids." These words of Lidén and Nordlund (1960) still sum up very aptly the situation about binaural hearing aids. In this paper I hope to describe some of the advantages of binaural hearing.

In the use of hearing aids, two different systems, diotic and dichotic, both come under the heading of binaural. In the one, diotic, a single hearing aid is used with a Y-lead—there is one microphone and one channel which divides, to lead to two telephones. In the other system, the dichotic system, two separate hearing aids are used—there are two channels and stereophonic hearing is obtained.

Monaural v. Binaural Hearing

A loss of hearing in one ear is generally assumed to be of little importance. This assumption is due to the fact that in routine tests of hearing it is unusual to test both ears together: one ear is tested at a time and the tests are carried out in a quiet room. Under these conditions the individual with only one normal ear appears to hear well, the hearing appears to be as adequate as in those with two ears. When two ears are tested together, however, it is found that there are certain advantages in binaural hearing. In 1950 I first started testing children's binaural hearing, in addition to the hearing of each ear alone. The results using two ears were always better and sometimes surprisingly so. I have noticed also that the prognosis given on tests of hearing using both ears in the free field situation was not fulfilled in those infants who subsequently used one aid, but only in those using two aids.

There is a great deal of experimental information about the differences between monaural and binaural hearing of pure tones, but information about the differences with regard to complex tones is less definite. Two ears are better than one. Shaw, Newman and Hirsch, among others, have shown that the threshold of hearing is lowered both for pure tones and

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for speech. The binaural threshold for pure tones is lower than the monaural by 3 decibels. This is, of course, better than it sounds, and is in fact about twice as good.

This improvement appears clinically as an increase in gain (Carhart, 1958). Bergman (1957) says that evidence of the improvement in gain is shown in binaural hearing aid users, who turn up the volume control of the remaining aid, if one aid is turned off. He also states that the clinical experience with users of binaural hearing aids, indicate that less effort is required for comfortable listening when this system is used.

Localization

The ability to localize is the most widely known and important feature of binaural hearing. Localizing means judging both the distance and the direction of a sound. There is not very much evidence on the ability to judge the distance of a sound except that it appears to be estimated by the ratio of reflected sound to direct sound. If the source of the sound is close more of the sound comes directly from the source than from reflection. At a distance it is the other way round.

The ability to estimate direction depends on the fact that two ears are separated by the head and so the sounds received by the two ears are identical only when the source is directly in front of or behind the listener. If the sound is in any other position, the paths to the two ears are no longer the same, and the sounds reaching the two ears different. It is this fact which makes the binaural system superior to the monaural system.

As is well known, the sound arrives sooner in time and phase at the ear nearer to the source and the sound in this ear is a little more intense.

One use of the ability to localize, is in the early diagnosis of deafness. At 6 to 8 months the normal infant will turn and localize faint sounds, but long before he is able to hold his head up he will look in the direction of many sounds. This does not depend on learning, it is probably a midbrain function (Walsh, 1957). It has been demonstrated in deaf children at various ages that merely to put on two ear level aids enables them to localize with certainty and with accuracy. This happens immediately, there is no need for a period of learning.

The fact that a child does localize is not an absolute proof of the absence of deafness. I have seen many deaf children who were able to localize. This is particularly common in a high tone loss.

The ability to localize has far-reaching effects in the understanding of complex sounds, especially speech. It enables one to differentiate between foreground and background sounds and this is of especial importance with complex sounds. Sound is given perspective. Binaural hearing is necessary for the normal ability to distinguish sound of importance in unfavourable listening situations. Two separate and

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independent neural channels are necessary for a listener to distinguish competing sounds arising from different sources. Broadbent (1955) states that the capacity of the neural channel is limited and if two sets of sounds are arriving simultaneously it is far easier to listen to either of them, if one set is on one ear and the other on the other ear. Although the capacity of the neural channel is limited there is a repository or parking place where extra events can be left until the limited system can deal with them.

Thus if a one-eared person is bombarded by an excessive amount of sound stimulation he is less able to ignore part of it and concentrate on the remainder; he is less able to store part while dealing with another part. Understanding speech in noisy places is difficult, following a complex conversation between several people is difficult, because it is not possible to sort out two remarks at the same time. Binaural hearing enables an individual to hold his attention on the stimulus which is at the moment important, even though the situation is, acoustically quite chaotic (Carhart, 1958).

Hirsch (1952) showed that cutting down the listener's ability to localize, either by preventing head movement or by preventing binaural listening, reduced his ability to separate the sources of sounds in space and reduced his ability to understand speech.

Koenig (1950) described experiments in which he had enabled the listener to switch instantaneously without changing receivers, from a completely binaural (dichotic) system with separate microphone, amplifier and receiver for each ear to a diotic system in which the two receivers were fed from a common pick-up—in other words, the difference between two hearing aids and a single aid with a Y-lead. With the completely binaural system it was possible to distinguish the separate speakers when listening to several conversations at the same time; with the single pick-up there was a hopeless jumble. With the completely binaural system speech could be understood under conditions of extremely high room noise, very intense sounds were more tolerable and background noises faded away in a few seconds to a very low level.

Clinical Findings: Binaural Hearing Aids

Binaural hearing obtained by using two hearing aids has been shown to be better in a noise whether the deafness is conductive or perceptive (Belzile and Markle, 1959). The benefits are difficult to measure because the improvement is to a large extent subjective. The significant fact is that the subjective benefits are described by almost every user of two aids.

With children there is the added difficulty that only the older children are able to describe the subjective improvement. It is, however, possible for the observer to notice significant changes in the behaviour of the younger child.

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1. A look of relief has been seen to cross a child's face as he listens through the two aids for the first time. On questioning, the child says: It is very much easier to hear. Speech can be heard more clearly, it is louder and it is easier to understand.

Very soon, that is in a matter of weeks, the child who has previously only used one aid will become attached to his two aids or if he is only using a Y-lead, to the two telephones, and he dislikes having either removed for any length of time. In addition: 2. There is more rapid progress in learning to understand speech and to talk. The older child who can already talk will produce better speech in a short space of time. 3. The attitude of the child becomes oral, he attempts speech frequently and expects speech. 4. Personality improves, the child becomes more sociable and more amenable. 5. The ability to localize appears. This, as has been described, occurs straight away, no learning is necessary. 6. One child who is musical states that she can now pick out notes and instruments while listening to music. 7. The child comments that it is easier to hear where it is noisy, all the noise seems to have gone. The child likes being able to hear all round instead of only on one side. Similar findings have been described by Bender and Wiig (1960).

Type of Aid

These advantages occur not only with ear level aids which are the ideal, but also with body aids. The benefits given by the ear level aid are summed up by Carhart: The critical feature is that the microphone is in the immediate vicinity of the ear the instrument activates. This provides two acoustic advantages: 1. The sound patterns received have been modified by diffraction effects of the head rather than of the body. 2. The pick-up points are roughly equivalent to the ears in their relative positions. The disadvantages are first, that the amount of amplification in existing ear level aids is limited and therefore this type of aid is barred from children with severe losses. This applies especially to infants during the learning process. During the period of learning, sounds need to be louder, probably by 10 to 15 decibels, than once they have been learnt. The normally hearing child hears sounds at the louder level as he sits on his mother's lap. By the time crawling starts, round about 9 months, many sound discriminations have been learnt. The first year of life is the most important period of all for learning sound discriminations. It was in order to emphasize its importance that Fry and I called the first year of life the period of "readiness to listen" (Fry and Whetnall, 1954). Once speech is learnt sounds have become familiar and can be recognized more easily. Loudness levels can now be reduced, possibly to the extent that ear level aids will now provide adequate amplification. The time at which this can be done varies with the hearing loss of the child.

The second disadvantage of ear level aids is doubtful. There is said

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to be a loss of the higher frequencies and so these aids are not so useful with a high tone loss. This had not been found to be inevitable, for a small group of children suffering from this type of loss are now doing well with ear level aids. The third disadvantage has been the fear that these aids are difficult for the active child. This has proved to be mistaken. Children volunteer that the aid is easy to wear and does not fall off when playing games or in the gymnasium.

Obviously it is important for the baby to have two aids so that the hearing may approximate as nearly as possible to that of the normal infant during the important "period of readiness to listen". The cost of fitting two aids taken in association with the long tradition of monaural hearing aids has meant that binaural hearing aids have so far been fitted only in special cases. The main reasons in my own series of cases have been (Fig. 1):

Reasons for giving two aids instead of Y lead.

1. Severity of the deafness.
2. Late diagnosis.
3. Hearing very different in two ears.
4. Presence of recruitment.
5. The child enters school.

FIG. 1.

1. Because of the severity of the deafness. Children with losses greater than 80 db. should always have them.

2. Because the deafness had been diagnosed late: one example is a child who had a speech defect and was backward. She was unable to read. The suggestion had been that she should go to a special school. Instead she now wears two ear level aids. She had an intensive course of auditory training in one of the hostels at Ealing and has now returned to her own school. Other cases in this group with more severe losses are overcoming the emotional or behaviour problems associated with the later start.

3. Because the hearing loss was very different in the two ears. According to Groen and Hellema (1960) a generally valid procedure does not exist for deciding the necessity for compensation between the two ears. Each case must be analysed individually with binaural speech audiometry. This cannot be carried out in a young child so two aids are indicated.

4. Because recruitment was present. Groen and Hellema have shown that while the binaural speech audiogram still curves back, it is at a higher intensity level than the monaural and discrimination is increased. I have found that there is a high incidence of recruitment in children deaf from maternal rubella. As infants cannot be tested for recruitment all those deaf from maternal rubella should have two aids.

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In the child who refuses to wear an aid, recruitment must be considered. This child (Fig. 2), aged 12, who suffers from recruitment, disliked one aid but uses two ear level aids successfully.

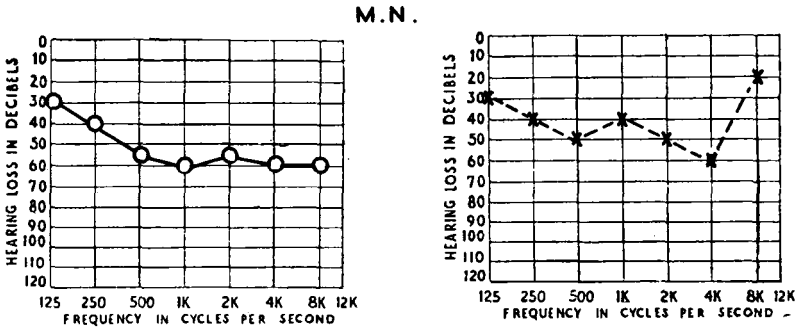


FIG. 2.

5. Because the child enters school and is unable to make progress because of the noise in a large class.

Another study was carried out on a group of eight children in a partially deaf unit of the William Morris School. I am grateful to Mr. Pegg, the headmaster, who keeps full and careful details of learning processes, hearing and speech in these children. Improvements were noticeable in every child: they were easier to teach, learnt more easily, heard more easily. A series of speech tests were carried out and showed an improvement against the monaural scores in six who had enough speech to test in this way. The other two did not have enough speech for verbal tests. They are improving more rapidly than would have been expected with one aid. The children like their aids and are oral in attitude.

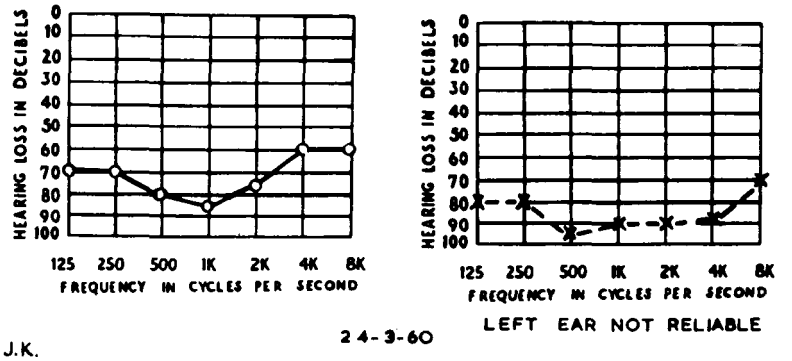
Some further evidence of the advantage of two ears is shown in a study of binaural speech audiometry carried out on 20 children. The apparatus is built on the lines of that designed by Groen in that there are two separate channels either of which can be modified. The results agree very closely with those reported by Groen and Hellema (1960) in their classical study. The ages range from 5 to 18 years. Some of the results are as follows:

1. An improvement occurred in every case in the binaural speech threshold. It was slight in three cases, but three showed a 15-decibel shift at the 50 per cent. score level. The improvement occurred irrespective of whether the type of loss was flat or mainly for high frequencies.

Fig. 3 shows the speech audiogram of a boy who became deaf from meningitis at 15 months. The pure tone audiogram shows a slightly curved loss to 70 db. in the right ear and a loss of 80 to 90 db. in the left. He has normal speech. Two aids have helped this child to

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achieve excellent discrimination. The 50 per cent. score shows nearly 15 db. improvement.



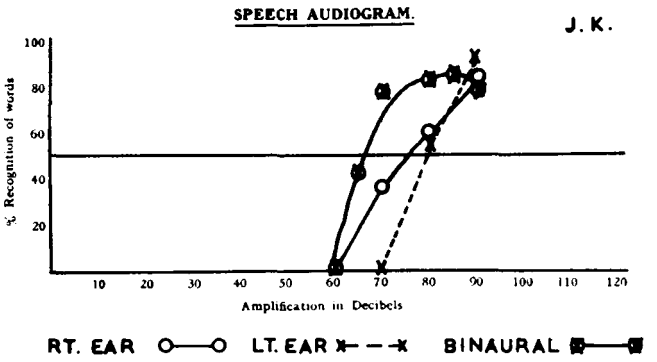


FIG. 3.

In this case (Fig. 4) the pure tone audiograms show a high tone loss. Improvement in the speech audiogram is not so great as in the previous case, but there is a great improvement in the ability to understand in noise.

2. (Fig. 5.) These cases should be compared with a girl who had used one ear only, the right ear, for 14 years since the age of $2\frac{1}{2}$. The pure tone audiograms are identical, a flat loss of 90 decibels. Note the articulation curve in the left ear. At this level she was intolerant of sound made any louder.

Even with the lack of training of the left ear her binaural speech audiogram is improved and she was more tolerant of high intensities. She suffers from difficulties in noisy places or general conversation. In spite of the improvement with two ears, which she appreciates, the thought of a second aid does not appeal to her. This difficulty would not have arisen if she had had two aids from the beginning. Even with

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one aid her speech is excellent and she is in an ordinary school, but many problems which have occurred would not have existed if she had had two aids.

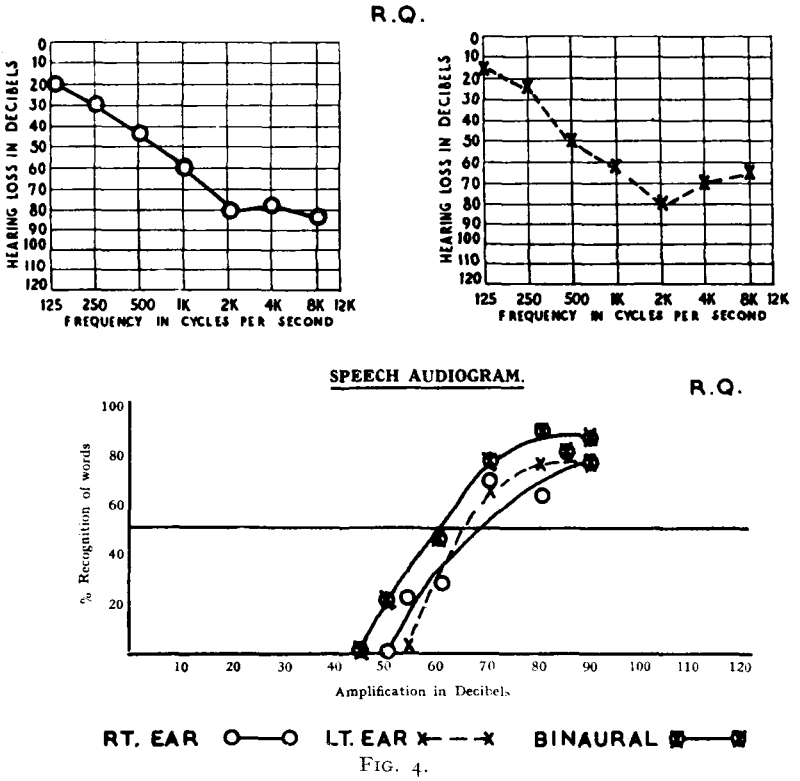


FIG. 4.

3. (Fig. 6.) In this case the pure tone audiograms are identical. A hearing aid has been worn in the left ear only, since 1956. There is an appearance of scatter in the right monaural speech audiogram. Groen and Hellema have shown that there is a correlation between the amount of scatter and the readiness and quickness with which the patient will produce the right answer. The scatter disappears in the binaural speech audiogram. Obviously she requires binaural listening, to prevent further deterioration of the right ear.

4. Groen and Hellema's findings about the lessening of recruitment have been confirmed.

5. Summation occurred even though the pure tone audiogram and the monaural speech audiogram were not equal, that is provided the difference was not too great. In this case (Fig. 7) very little summation takes place and two aids are indicated; he has improved with two.

6. In a very severe loss, binaural hearing brings the result to the 50 per cent. score (Fig. 8). The pure tone audiograms are identical.

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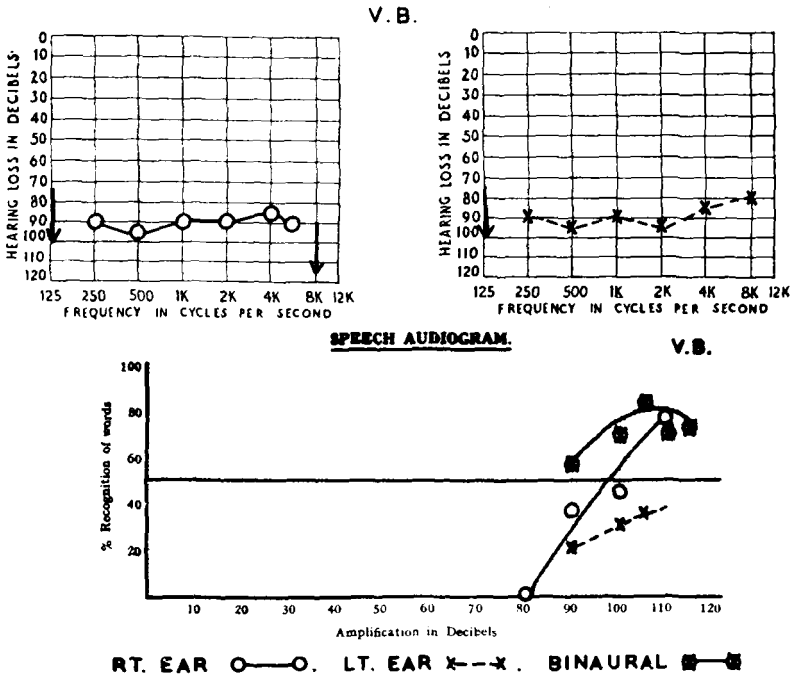


FIG. 5.

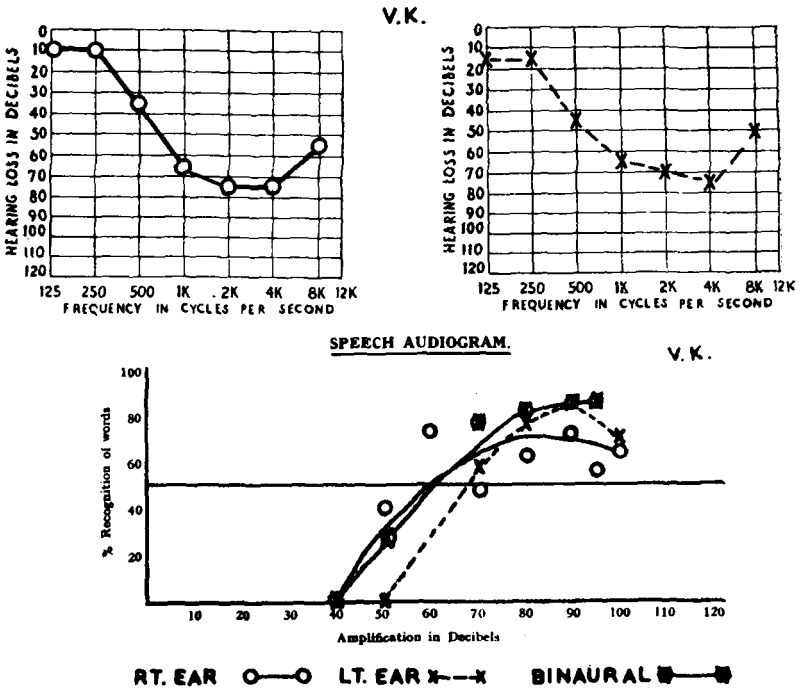


FIG. 6.

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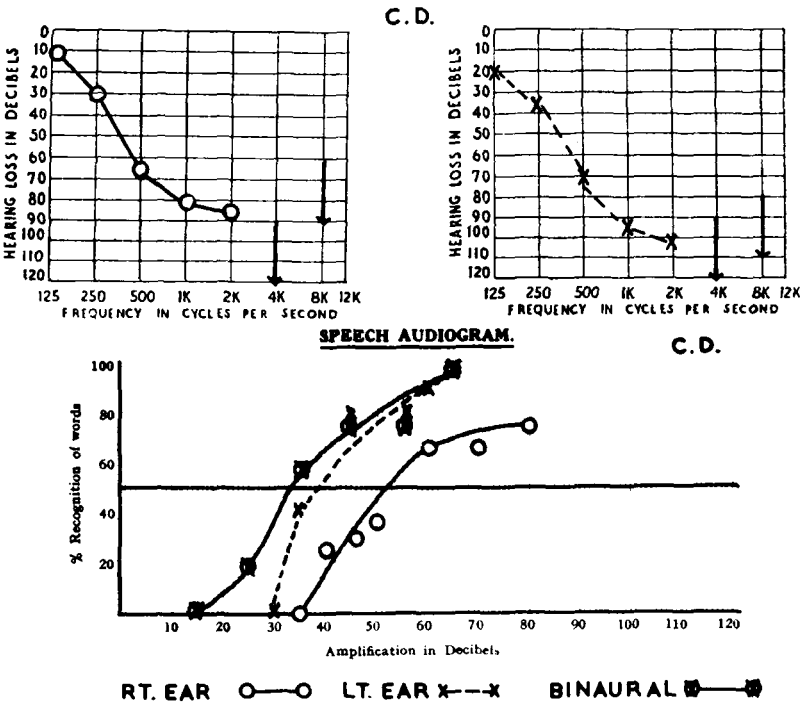


FIG. 7.

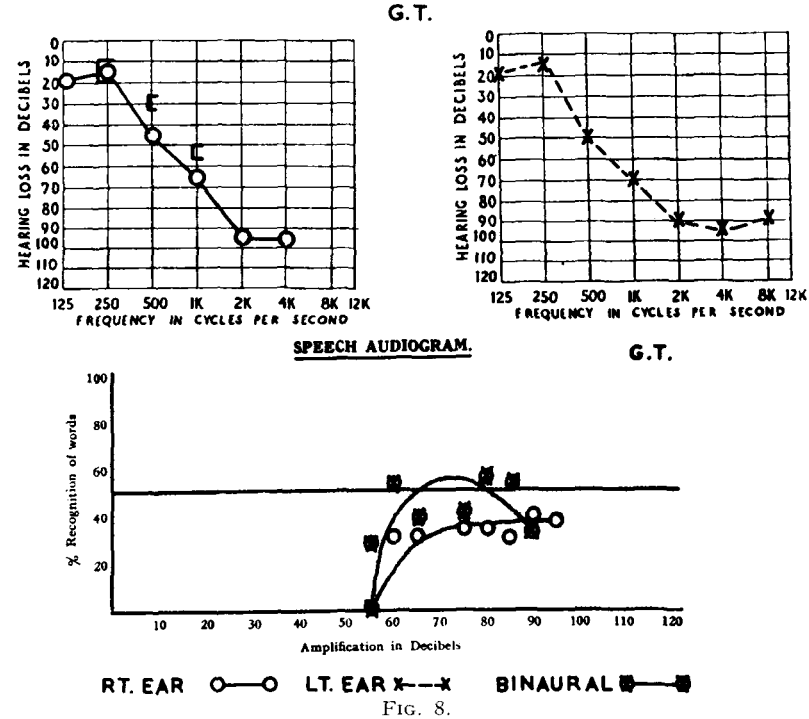


FIG. 8.

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Conclusions

Two ears are better than one. The benefits are without doubt, the only reason for not using two aids on every deaf child is a matter of cost. About 400 children have been fitted with Y-leads. A Y-lead is better than one aid with a single lead for two reasons. 1. Summation occurs and sounds are therefore heard better, and as a result there is more rapid progress in learning. 2. Both ears are used. If only one ear is used the hearing for speech in the unused ear is not so good as in the ear which is being used. The use of a Y-lead enables improvement in perception to take place with both ears.

The disadvantage, however, of a Y-lead is that the user loses the advantage conferred by two ears of hearing speech against a noisy background or of selecting which speech is listened to. Surely this must be of the greatest possible importance to the young deaf child who is learning to hear. In addition to this it can now be shown that the deaf child learns more rapidly with two aids. The child is more oral—he makes every attempt at speech and expects speech. He is more sociable. In my experience every young child who gets the chance to have two aids likes them.

Acknowledgments

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