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Office noises and their effect on audiometry

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OFFICE NOISES AND THEIR EFFECT ON AUDIOMETRY

by

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There is much difference of opinion among otologists and others concerning the relative value of soundproof or "quiet" rooms for the testing of hearing. Some maintain that a soundproof room is necessary, while others go so far as to state that the sense of hearing, which normally is used in a noisy environment, should be tested in the presence of noise.

In 1929 a special committee of otologists was appointed in London for the study of problems concerned with hearing tests. After consideration of the testing environment, the committee stated that it did "not recommend the use of a silent room for ordinary hearing tests, but that these tests should be carried out in a reasonably quiet room." This, as well as other conclusions reported by the committee was severely criticized by Hallpike[15] and others.

Since 1929 advances have been made not only in otology and the problems of hearing, but also in the various aspects of noise[1, 5, 8, 12, 21] and of acoustics and soundproofing.[26, 30] Furthermore, the audiometer, which was constructed by Dean and Bunch[7] in 1919, is now generally used by the medical profession. Sabine,[27] in 1937, reported the use of a "reverberation meter" which, with the sound level meter, accurately measures the acoustic value of a room. In order to calculate the acoustic value, it is necessary to know the dimensions of the room and the sound absorbing efficiency of its inside surfaces. In the future such instruments should be employed for investigation of the acoustic value of the rooms used by otologists for the testing of hearing. Part of my work, which is presented in this paper, is a step in this direction although the results are not as accurate as would be obtained by the use of both the instruments.

In a search of the literature, I was unable to find any information relative to the measurment of adventitious noises, which are present in rooms used for the testing of hearing, or the effect of these noises upon audiometry. Fletcher[10] and Fowler, Jr.[12] have, however, made important contributions with regard to the effects of noise upon hearing tests. But neither of these investigators measured his noise levels with a sound (noise) level meter. Their work is important, and every otologist interested in the problem of hearing should review both references.

Fowler, Sr.[11] stated that in an office or hospital, the outside noises always mask the testing sounds to some extent, and commonly as much as 15 to 20 decibels below the true level in a quiet place. It will be noted here that his opinion concerns the "quiet place." If this is true, the percentage of error should be even greater than 15 to 20 decibels if tests are done in an absolutely soundproof room. Newhart[23] was in agreement with Fowler, when he maintained that tests for the detection of slight but significant hearing impairment are not accurate if made in the presence of interfering noises. Perhaps every person who tests hearing will agree with this. Jones and Knudsen[18] remarked that

> "It is freely admitted everywhere that a careful study of a hard of hearing patient should include the vestibular tests and audiometric tests with a standardized audiometer in a soundproof booth.....Soundproof booths, without which any hearing test is woefully inadequate, are practically unknown."

These opinions are substantiated by the work of Fletcher,[10] Fowler, Jr.[12] and the research which I present herein. In fact, in my survey of the literature, I could find only opinions and no investigative work to support the idea that a soundproof environment was unnecessary for even routine hearing tests in the doctor's office.

In contrast to the above statements, Watson[31] said that

> "The difference between a soundproof room and a quiet office will be very, very slight - at absolute maximum about 8 decibels in the low tones.....I frankly think that the question of noise, the necessity of a soundproof room has been over emphasized."

It might be pointed out that Mr. Watson, who probably uses the audiometer chiefly to fit hearing aids, usually tests individuals with rather severe deafness. A noise of 30 decibels will probably not interfere in the testing of a person with a decibel loss of 40 or more. He gives no statistics or research to support his view. In my hands, the audiometer is not used one time in ten to test the patient for the fitting of a hearing aid. It is used principally for the detection of early hearing losses; for arriving at a diagnosis; for determining the progress of hearing loss; for checking results of therapy; and for estimating prognosis. In all these instances the hearing loss usually is more or less near the normal threshold or the "zero line," and small losses or gains (10 to 20 decibels) in hearing are important.

It is of interest to note that almost without exception the otologist in every office in which my investigations were conducted apparently believed that his testing room was "very quiet." At least, nearly every one stated that his room was "entirely satisfactory" and that his results were "sufficiently accurate." Nevertheless, the noise meter records and the audiometric readings secured under the circumstances which customarily prevailed in the testing room of each otologist visited have proved otherwise.

Of course, it is not impossible to do acceptable or even good work in the presence of some noise. The noise level should, however, be constant, and the only constant noise level is obtained in a soundproof room. Sjöberg[28] stated that L. Holmgren uses an electric fan in his soundproof room as a constant source of adventitious noise. If Holmgren would check his electric fan, the noise of which

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"sounds" so constant, he would find that there is a marked fluctuation of noise level. Besides, if he really has a soundproof room, he has no need to seek further for a constant, controlled, and ideal noise level.

Larsen[20] produced valuable research on occupational deafness, and he used only one of his office rooms for the testing of hearing. Concerning the matter of extrinsic noises in his office, he remarked that

> "Although the clinic is situated in a main thorough-fare, it has been sufficiently quiet, because the examinations were generally made in the evening."

Possibly Swedish thorough-fares are much more quiet than those in America. My findings indicate that street noises are one of the most important causes for inaccuracy in hearing tests. Mr. Dennis,[8] of the Noise Abatement Commission of New York City, reported an average of 81 decibels of noise on busy streets of that city.

Perhaps the most significant advance in otology today is the early recognition and treatment of deafness, especially in children. The investigations of Crowe and Burnam[6] and Guild et al[14] in Baltimore and those of Gardner,[13] of the department of health in Oregon, are particularly outstanding examples. Hearing losses, when found early, are usually not great. Accurate and reliable measurements of such hearing acuities are impossible to obtain without a noiseless testing environment. The excellent research and clinical investigations of many workers have been criticized because of the neglect of these workers to conduct their investigations in a noiseless environment.

Rosenthal[25] reported that when the hearing loss is in the "medium range" an improvement of even 5 decibels will elicit a subjective response. He did not, however, use a soundproof room. His tests "were made in rooms adjoining the clinic or office." Also, there was an ordinary amount of noise from adjacent activities." Several of my most inaccurate results were obtained in the presence of similar adventitious noises. For measuring small losses or gains in hearing, especially if they are in the "medium range" or near the threshold, a soundproof testing room is necessary before accurate and unquestionable results can be obtained. This is especially true in checking results of therapy, in which instance changes in hearing frequently are small. Hughson and Witting[17] maintained that 10 decibels should be the figure of minimum improvement that can be of real significance, and this, only if originally described lvels can be improved again by such a figure. The required duration of improvement has been set at five years. It certainly would be difficult to compare the noise level in a so-called "quiet" office five years hence.

It has been demonstrated many times, and again recently by Kinney,[19] that hearing for voice sounds is from about 5 to 15 decibels less acute than hearing for the pure tones of the audiometer. Hence, as Fowler, Jr.[12] showed, under identical conditions, noises would interfere more for the testing of voice comprehension than for the testing by audiometric tones. Those otologists, therefore, who still use only voice testing and all those who use it as an adjunct to the audiometer (as is proper), should take into consideration the fact that noises will effect voice testing even more than they will audiometric examinations. This point should also be borne in mind by those who use the phonograph group testing in a school room or in other "noisy" places.

Witting and Hughson,[32] Bunch,[2] and others have shown the normal range of error in audiograms to be plus-minus 5 decibels. To obtain this accuracy on repeated tests, it is necessary to have the same competent operator and a soundproof testing chamber for each test. If under such relatively ideal conditions there is a range of error of 10 decibels (plus-minus 5), what must the error be when 30 to 40 decibels of noise (which is common) are thrown upon the ears of the patient being tested? Fowler, Jr.[12] found that an estimated masking noise of 25 decibels had a 35 decibel deafening effect. The investigations reported here will contribute some light to our present knowledge of this problem.

Table 1 lists the noise levels present in various common environments as found by Fletcher,[10]

Table 1. NOISE INTENSITIES FOUND IN COMMON ENVIRONMENTS

Kind of Noise	Source					
	Currier (Dr.'s Office)	McCord et al	Fletcher	Sutherland	Electronics	Approximate average
Threshold of hearing	--	0	--	0	0	0
Soundproof booth	∠24	--	0	--	--	0 (?)
Rustle of leaves	--	10	--	15	10	10
Acoustically designed office	25	--	--	20	--	20
Average whisper	--	20	--	25	15	20
Country road (garden)	--	--	--	30	20	25
Average dwelling	--	--	--	35	25	30
Quiet office	30	--	20	40	30	30
Noisy office	40	--	40	--	--	40
Average office	35	--	30	50	35	40
Train or automobile	--	--	50	--	45	50
Conversation	--	50	--	60	55	55
Typewriter	40	--	--	70	--	55
Radio in home	--	65	--	45	--	55
Business street	--	75	--	65	65	70
Subway train	--	--	60	85	--	75
Street car	35	80	--	--	--	60
Police whistle	35	80	--	--	--	60
Heavy street trafic	--	85	--	90	80	85
Express train	--	105	--	75	--	90
Elevated train	--	--	--	95	90	90
Thunder	--	70	--	--	120	95
Pneumatic drill	--	90	--	130	85	100
Riveter	--	--	--	105	100	105
Boiler factory	--	--	80	110	100	100
Automobile horn	--	100	--	115	--	105
Airplane engine	--	115	--	120	110	115
Threshold painful sound	--	120	--	--	--	120
Limit endurance to sound	--	130	--	--	--	130

All figures represent decibels.

Sutherland,[29] McCord et al,[21] the Electronics magazine,[9] and myself. It will be noted that the data given in these references varies somewhat, and surprisingly so for certain noise sources. My experience with determinations of noise levels has impressed upon me the generalization which is necessary in arriving at the figures given in table 1. I learned that a "general noise level" is very difficult to determine because the sounds responsible for the noise were not at all constant even when they seemed so to the ear. Widely varying noise intensities, from almost zero to oftentimes as loud as 70 to 80 decibels, were always present in the office of practically all the doctors visited. The indicating needle on the noise meter was in almost continual fluctuation. Apparently under some conditions our ears become so accustomed to sharply changing sound intensities that we have learned to disregard them in a large measure. We merely raise our voice and adjust our actions to compensate for the noises without being aware of doing so.

However, as Behnke[1] pointed out, "Rattling, squeaking or intermittent or erratic sounds may cause an annoyance out of all proportion to their intensity." Thus an automobile horn or a policeman's whistle are especially pernicious sources of noise. The New York City Noise Abatement Commission[8] found that the degree of annoyance of a noise depended upon several factors. In addition to the intensity of the noise, its component frequencies, and its general character (steady or intermittent), the amount of annoyance was influenced by whether or not the noise was regarded as necessary. The patient does not want, nor does he expect, noises to interfere with his hearing test. He is, or should be, concentrating intently on his hearing test. Therefore, intermittent and even small amounts of noise which are overlooked by the examiner may be quite distracting to the patient. Bunch[2] has noticed this fact clinically. It is well known that one of the greatest sources of error in audiometry is the patient's failure to give undivided attention and concentration to his test.

All of us have probably had the experience of taking the patient into a "quiet room" for a hearing test and having him be unduly impressed with the quietness. He will frequently remark as to how "soundproof" the room is. Apparently most otologists are equally impressed by the quietness in their own testing chambers. Table 2 demonstrates the approximate amount of noise that enters the room in which hearing tests are done. Everyone who observed the noise meter in operation in his testing rooms could hardly believe that there was that amount of noise interference.

The material presented in this paper is the result of investigations carried out in 15 hearing test

Table 2. NOISES FOUND IN TESTING ROOMS OF VARIOUS OTOLOGISTS

Kind of Noise	Most Quiet Offices		Most Noisy Offices		Approximate Average of All Offices	
	Doors		Doors		Doors	
	Open	Closed	Open	Closed	Open	Closed
IN OUTER OFFICE, Etc.:						
General noise level	25–30	< 24	30–40	25	35	< 24
Talking	25–35	< 24	30–40	25–30	35	< 24
Walking	30–35	25–30	35–40	30–40	40	30
Opening and closing doors	40–50	25–40	40–50	30–40	45	35
Clicking of instruments	40–50	< 24	–	–	45	35
Typing	30–40	< 24	35–40	30	35	25
Rustle of papers	30–35	25–30	30–35	25–30	35	25
Office buzzer	–	–	30	25	30	25
Noises in adjoining offices, hall, elevator, etc.	35–50	35–40	35–50	35–40	45	35
Auto horns	35–45	< 24	40–50	40	45	35
Police whistle	35	< 24	–	–	35	25
Street cars	30	< 24	–	–	35	25
IN TESTING ROOM:						
Electric fan	30–35	25–30	–	–	40	40
Water running	–	–	30	30	30	30
Squeaking of metal stool	30–40	30–40	–	30–40	—	35
Coughing	–	35–40	–	35–40	—	40
Rubbing hands briskly	–	30	–	30	—	30
Rubbing of clothing	–	25	–	25	—	25
Squeaking of shoes	–	25–30	–	25–30	—	30
Clearing of throat	–	40	–	40	—	40
Snapping light off and on	–	40–50	–	40–50	—	45

All figures represent decibels.

rooms in or near St. Louis. Eleven were done in the testing rooms of practicing otolaryngologists. Four were done in grade or high schools or universities. One of the most inaccurate hearing tests (because of noise) was obtained in a university. The problem was worked out as follows:

Dr. Frank Impastato and I ran all audiometric tests on each other. Audiograms were taken in each testing room visited. Six were taken in the "soundproof" room[3] of the Washington University School of Medicine. The records obtained here were averaged, and the average arrived at was used as the normal hearing threshold for each of us. The remaining 14 audiometric readings were compared with this "normal." In each office visited we asked the office personnel to permit us to work under the identical environment that prevailed during their routine tests. In all the tests we conducted we used the Western Electric 2A audiometer, which was checked several times during the research against the Western Electric 1A and the Maico audiometers. A General Radio Company sound level meter, type 759A, was used in the measurement of the noise present in the hearing test rooms. Unfortunately this instrument would record noise intensities only as low as 24 decibels. However, valuable results were obtained. Every room,in which testing was done, including the Washington University soundproof room, permitted noises to enter which could be heard but which were of an intensity of less than 24 decibels and therefore not indicated on the noise meter. It required a rare and extremely loud noise to come through even very faintly, perhaps 5 to 10 decibels, into the Washington university soundproof room. In all other rooms many sounds came from the outside besides those recorded. These were heard distinctly during the hearing tests, but were of less intensity than 24 decibels so could not be measured.

Many other interesting observations were made during the visits to the offices of the various doctors. In seven of the offices the doctor took the audiogram. In the remaining eight offices a nurse, office girl, or technician ran the test. In one university "just anyone" ran the test. The methods and the technics used varied to unbelievable degrees. In comparing audiometry results from one office to that of another, irrespective of the vast differences in noises, a discouraging impression was obtained. I was convinced that some acceptable standardized technic for audiometry should be formulated and presented to the medical profession. Bunch[3] has written an excellent and timely text on audiometry which contains valuable suggestions regarding technic.

Only in five of the fifteen rooms tested (includ- the soundproof room) was there any pretence whatsoever at attempting to soundproof the testing room. The remaining eight rooms were, mostly, ordinary treatment rooms, storage rooms, or small clothes closets (3 by 4 feet). Yet in the face of all these and other factors, almost all the doctors insisted that they had a "good, quiet room" and were getting "good results." Some of these rooms were uncomfortably hot and stuffy. Many rooms had squeaky chairs or other noisy equipment. One indicator button squeaked to 35 decibels each time it was pushed.

The results of the audiograms taken by my associate and myself on each other will now be discussed. One of the first questions which might be directed to us is "how accurate were the audiograms which you took in the soundproof room?" These audiograms were used as the standard or normal with which all other audiometric tests were compared so their accuracy must be established.

Witting and Hughson,[32] in their excellent research relative to the inherent accuracy of audiograms, found that 93.1 per cent of all tones in their most accurate records were within the accepted plus-minus 5 decibel range of normal. Sixty-two and one-tenths per cent of the tones in their records were within plus-minus 2.5 decibels. Their testing conditions and environment were essentially similar to ours, except that they took not less than ten audiogram readings on each patient and we took but six on each other (12 in all).

Our results were as follows: For Dr. A, 98.8 per cent of all tones were within a plus-minus 5 decibel range, and 90.6 per cent were within a plus-minus 2.5

decibel range. For Dr. B, 95.8 per cent were within plus-minus 5 decibels and 81.2 per cent within plus-minus 2.5 decibels. Why our results appear to be somewhat better than those of Witting and Hughson, I cannot say. These authors concluded that

> "The average of 3 audiograms reveals an error so much smaller than that shown by a single test that such a procedure is recommended whenever accuracy is desired."

We tested each other six times and obtained apparently even a little more accurate results. Therefore, on the basis of the conclusions of Witting and Hughson, I believe our audiograms may be considered reliable.

Table 3 gives a comparison of the accuracy between the audiometric results in our soundproof room and those in the various testing rooms we visited. It will be noted that in the soundproof room, Dr. A was 22 per cent more accurate for plus-minus 5 decibels and 30 per cent more accurate for plus-minus 2.5 decibels. Dr. B in the soundproof room was 15 per cent more accurate for plus-minus 5 decibels and 20 per cent more accurate for plus-minus 2.5 decibels. Averaging the results obtained by both Dr. A and Dr. B, we find 18.4 per cent greater accuracy for plus-minus 5 decibels in the soundproof room and 22.7 per cent greater accuracy for plus-minus 2.5 decibels.

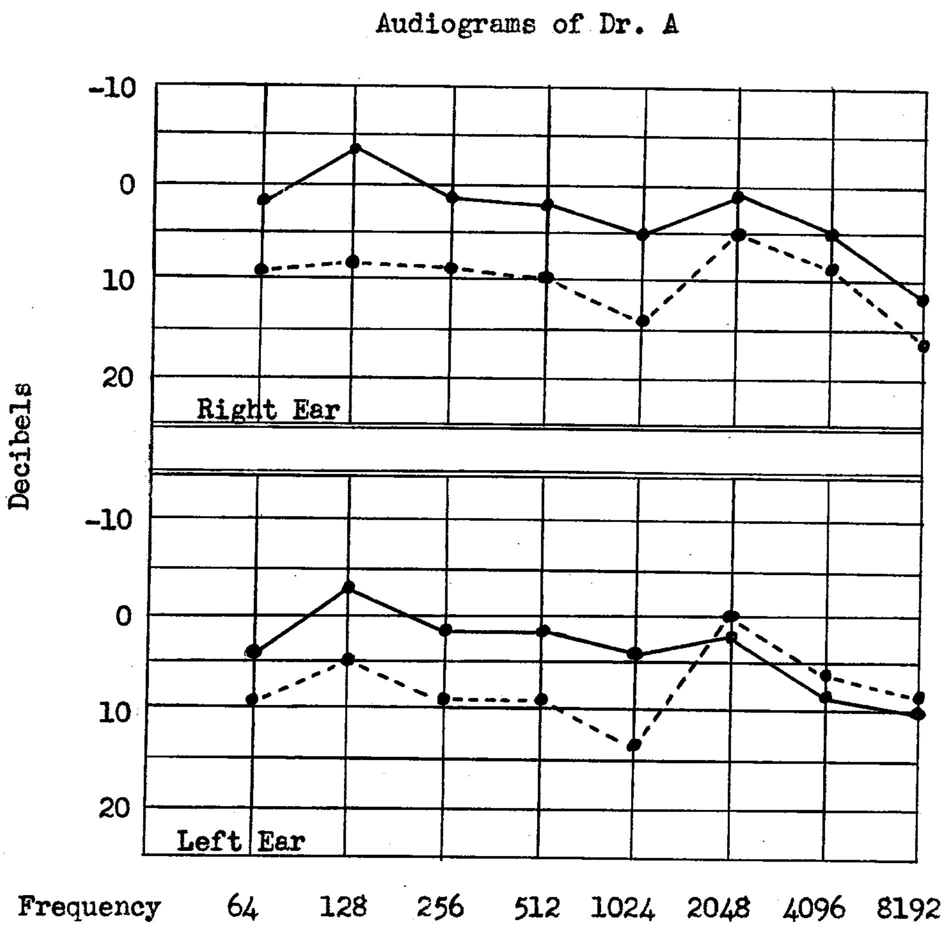
After reviewing the inaccuracy of the records taken in the testing rooms of various doctors, as shown in table 3, the "averaged" audiograms, figures A and B,

Table 3. COMPARATIVE ACCURACY OF AUDIOGRAMS

Decibels	Soundproof Room Witting & Hughson (10/ tests on 17 persons)	Office Testing Rooms (14 rooms, 14 tests, 1 in each room)		Soundproof Room Washington U. (6 tests each)		Increased Accuracy in Soundproof Room	
		Dr. A	Dr. B	Dr. A	Dr. B	Dr. A.	Dr. B
± 5	93.1%	76.9%	81.2%	98.8%	95.8%	21.9%	14.6%
± 2.5	62.1%	61.1%	66.3%	90.6%	81.2%	29.5%	20.1%

Percentages figured after the manner described by Witting and Hughson [32]

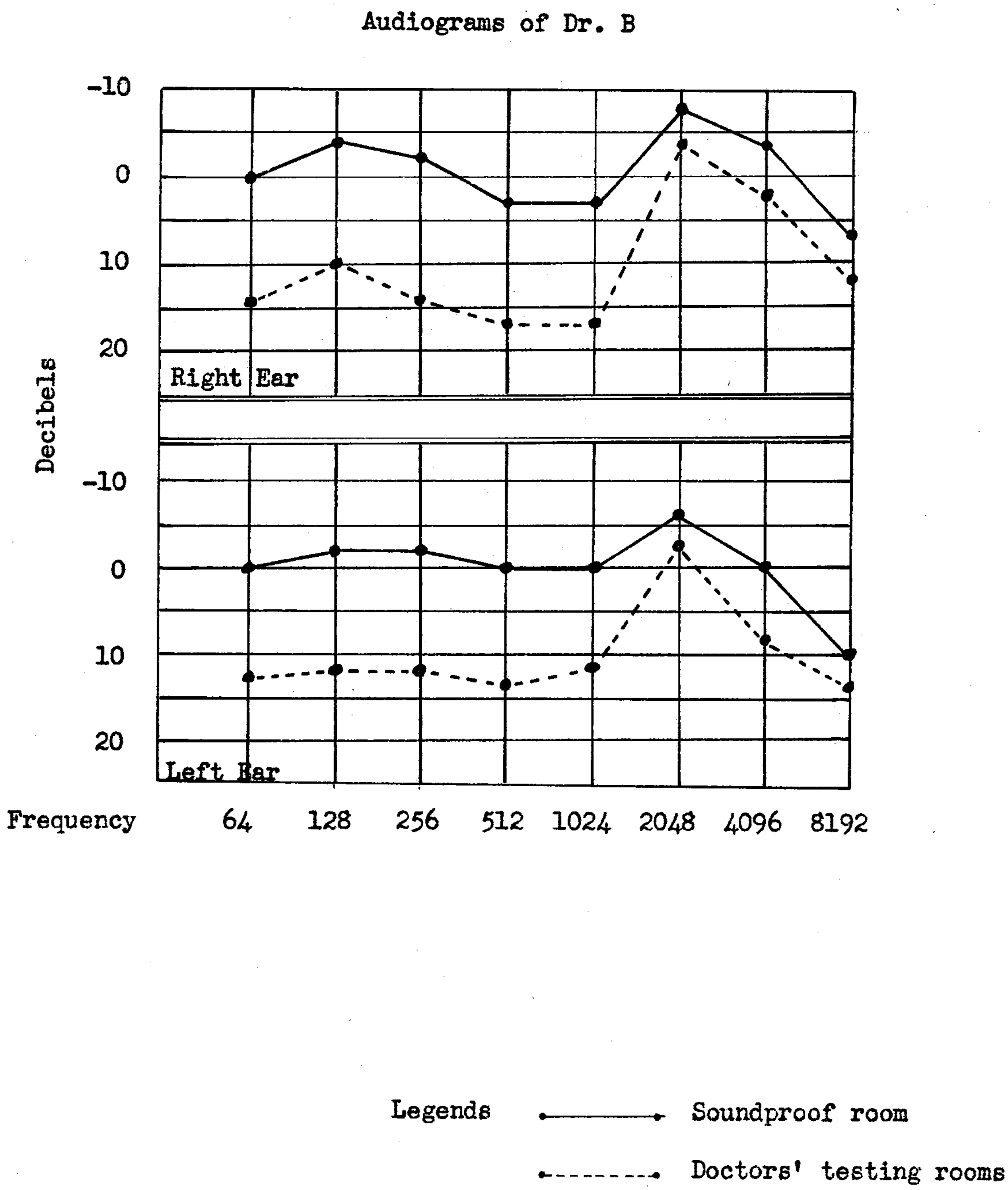
Fig. A. COMPARISON OF AUDIOGRAMS IN SOUNDPROOF ROOM AND IN DOCTORS' TESTING ROOMS



Legend ——— Soundproof room

- - - - - Doctors' testing room

Fig. B. COMPARISON OF AUDIOGRAMS IN SOUNDPROOF ROOM AND IN DOCTORS' TESTING ROOMS



are surprising upon first consideration. One would probably expect a greater error to be demonstrated on the "averaged" audiograms. However, the following facts must be kept in mind. First, four of the fourteen testing rooms were quite well soundproofed. This helped a great deal to bring up the average. In fact, the records obtained in these four rooms were nearly identical to those of the soundproof room. Second, the tone thresholds obtained in the various offices were so scattered it demonstrated that the value of audiograms taken singly is unreliable. The scattergrams (figs. C and D) will demonstrate the wide variance of records in comparison.

Another instructive comparison is that which is demonstrated in figure E. The audiograms in this figure show the effect of noise in the testing room of one of the schools visited. They also show the well known fact that noise in a hearing test room affects the low tones but has very little effect upon the high tones. It is because of this masking effect of noise on low tones that some otologists formerly believed a conductive deafness showed a greater loss for low tones than for high tones. They were merely testing in the presence of noise and not realizing its effect.

Only in the past few years have otologists become awakened to two important realizations. One is that he must become skilled in the fitting of hearing aids. As the deafness of the patient is usually severe,

Fig. C. SCATTERGRAM SHOWING DISTRIBUTION OF TONES OF ALL TESTS IN SOUNDPROOF ROOM

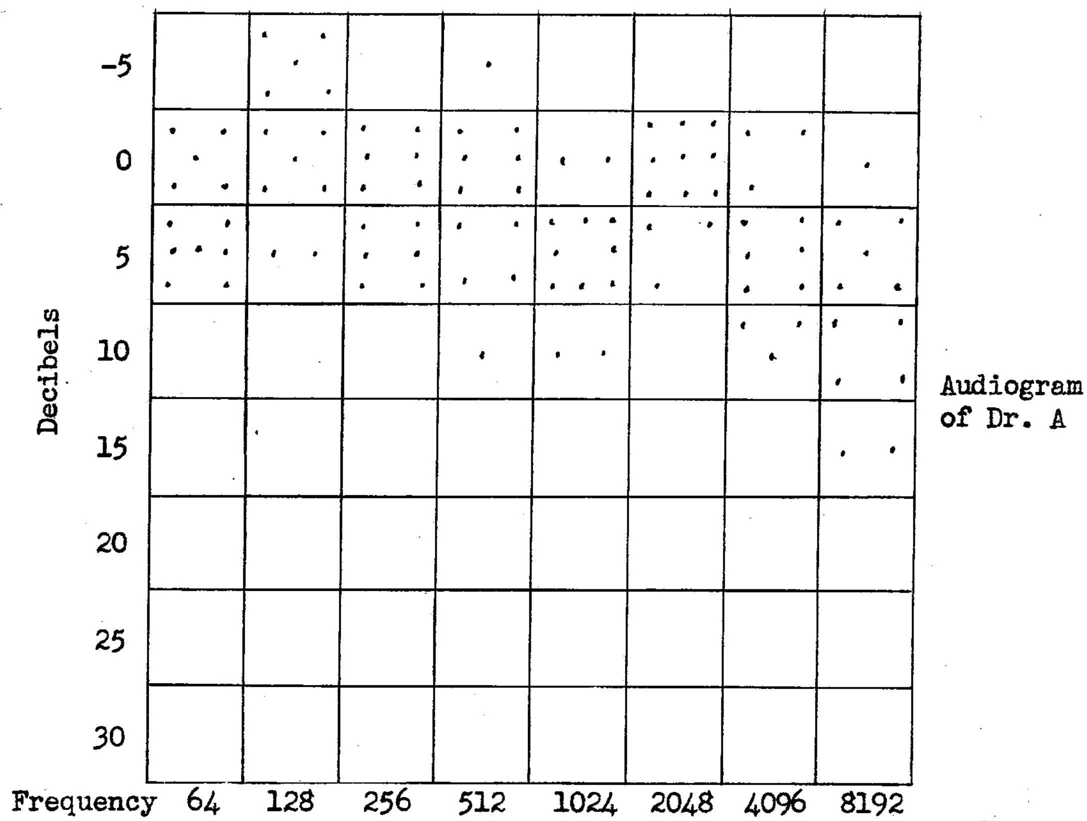


Fig. D. SCATTERGRAM SHOWING DISTRIBUTION OF TONES OF ALL TESTS IN DOCTORS' TESTING ROOMS

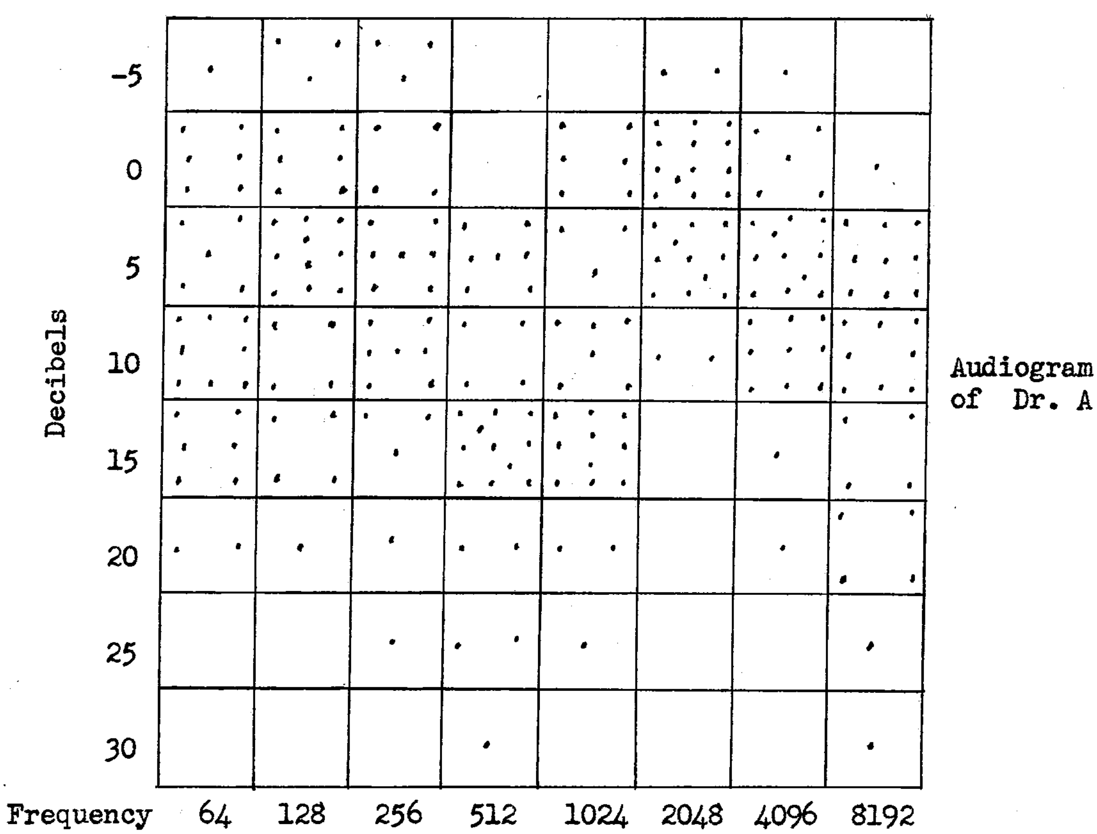
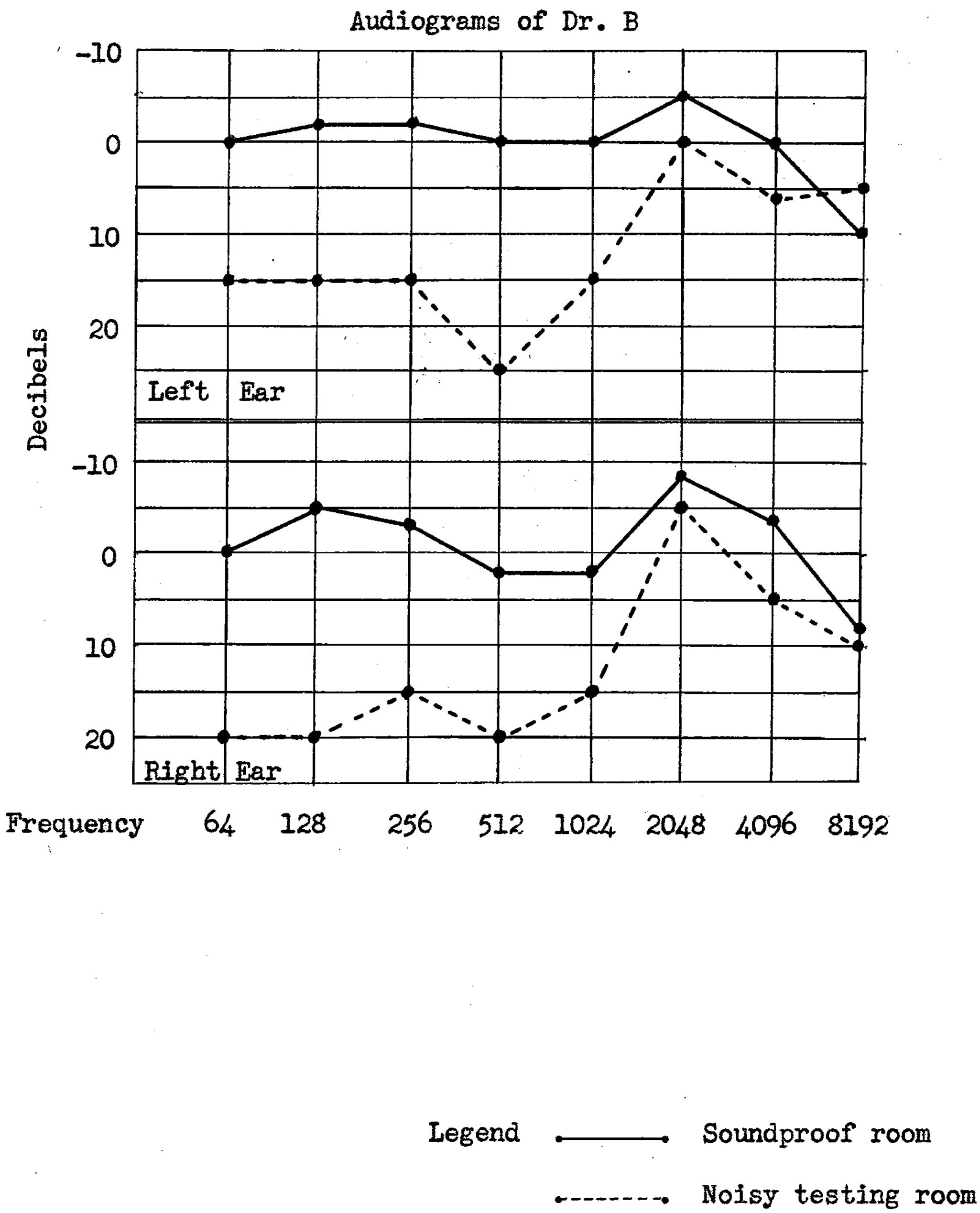


Fig. E. COMPARISON OF AUDIOGRAMS IN SOUNDPROOF ROOM AND IN NOISY TESTING ROOM



his audiometer test possibly could be satisfactorily taken in a "quiet" room. The second realization, which is vastly more important and requires a soundproof environment, is that of early diagnosis and treatment of deafness, particularly in children. The outstanding preventive measures are intelligent observation and early repeated testing of the hearing.

From statistical studies, Fowler, Sr.[11] estimated that one-third of all school children show a loss of at least 15 decibels at some frequency. Up to 8 or 10 years of age, deafness is apt to be unilateral, and so usually goes unnoticed. The United States Department of Health reported that there are 500,000 children who need special instruction in hearing, while 66,000 children need special instruction because of defective vision.

The otologist should be, and is, the last court of appeal to those seeking accurate hearing tests. Many State health departments are doing excellent work in both group and individual testing of the hearing of school children. Because of the testing environments which they are usually forced to use, their tests are at times somewhat inaccurate. Very often, however, they are more accurate than the tests the local otologist is prepared to give.

Most physicians believe that a soundproof room is too expensive, that it requires too much space, and that it is not practical. Actually this is not the case. The Columbia Presbyterian Medical Center built a soundproof room of celotex for a cost of $60.00. Newhart and Hartig,[22] as well as Jones and Knudsen,[18] gave details for constructing a small portable booth (4 by 4 feet) that will fit into an office room. These are satisfactory for routine office audiometry tests. More expensive and more elaborate rooms have been described in detail by Burr and Mortimer[4] and by Bunch.[3]

At the best, hearing tests are time consuming. Valuable time is wasted when the examiner has to stop the test each time an extraneous noise enters his examining room. This probably has a tendency to make the otologist fail to use his audiometer as often as he should. An audiometer is an expensive instrument. It is not reasonable to buy such a precision instrument and then use it only part time and get from it less than the efficiency it is able to give. The day is past when the otologist asks "should I have a soundproof room?" He must now ask "what kind of soundproof room shall I have?"

SUMMARY AND CONCLUSIONS

A survey has been made of the noises present in the offices and audiometric testing rooms of eleven practicing otolaryngologists and of the noises present in the audiometric testing rooms of four schools.

From the data obtained, I believe the the following conclusions may be drawn:

1. The approximate average noise level in the various offices is 35 decibels.

2. The approximate average noise level in the various hearing test rooms of the otolaryngologists, under audiometric testing conditions, is less than 24 decibels.

3. Unless the hearing test room is soundproofed, the extraneous office noises will significantly decrease the accuracy of routine audiometric tests.

4. The accuracy of the audiograms taken in the testing rooms of the otolaryngologists is approximately 20 per cent less than those taken in the soundproofed room.

5. The office noise level, as obtained by audiometric tests, causes a lowering of the hearing threshold by approximately 10 to 15 decibels.

6. Because of the noise in one testing room, the hearing threshold was lowered 20 to 25 decibels.

7. Noises present in the testing room affect, chiefly, the accuracy of the low tones (below 2048), the high tones being but little affected.

8. The threshold tones obtained in the average testing room varies widely in comparison to the threshold tones obtained in the soundproof room.

9. The technic use for audiometric examinations varies greatly in different offices, thus decreasing significantly the accuracy of routine tests.

10. Audiograms taken by different operators, using various technics, show such a wide variation that their accuracy cannot be accepted except as very rough estimates.

11. The majority of the otolaryngologists visited do not have a room specially designed for hearing tests. Most of them use an ordinary treatment room, a storage room, or a cloak room.

12. Most of the otolaryngologists who do not have soundproofed rooms believe their testing rooms are adequately quiet for audiometric examinations and that their records are sufficiently accurate.

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