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Methods of eliminating breathiness in the voices of deaf children

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By

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I. Introduction

Normal speech consists of a series of rapid, highly skilled movements of the breathing muscles, muscles of articulation; muscles of the lips, tongue, jaw, velum, and the extrinsic and intrinsic muscles of the larynx. In speech these muscles are all coordinated into a single movement pattern which normally produces intelligible speech. The coordinations and the proper timing of these individual muscles are of primary importance in the production of normal speech. The hearing person controls this complex set of speech movements by the sounds produced, while the deaf person unable to depend upon this means of control, must depend wholly upon the tactile and kinaesthetic cues which he receives from the movements themselves. Therefore the absence of hearing with the consequent necessity of acquiring speech by artificial methods, renders the problem of teaching speech to a deaf child, a difficult one. Speech is not an instinct; it is a series of acquired habits. The mechanism which produces it consists of a group of separate organs, each having distinct vital functions in the economy of the organism. Speech is therefore an added function, one which is superimposed upon these widely separated organs. In teaching speech to a deaf child it is imperative that these separate organs which make

up the speech mechanism function properly in the complex, coordinated patterns which produce speech.

One of the prevalent types of speech defect in deaf children is that of breathiness, resulting in extremely poor voice quality, and in quick exhaustion of the breath supply. Sometimes an entire breath is expended upon a single word or even a single syllable. There are reasons for believing that one of the causes of this breathiness, and the consequent poor voice quality, is a lack of control over the intrinsic muscles of the larynx which brings the vocal cords into the proper, or normal, voicing position. If the vocal cords are not properly approximated (i.e. too widely separated) it follows that a greater amount of air will be required to initiate and to continue a vocal tone than under normal conditions. Likewise the vocal tone thus produced will be lacking in resonant quality, since the vocal reed is not properly tuned. It should be possible to train a group of deaf children to tune the vocal reed, that is, to teach them to adjust the glottal slit to the optimal degree for the proper vocal attack. If they can be taught to do this, they will be able to produce a more normal voice, but the proper glottal adjustment will also prevent the excessive expenditure of breath.

II. The Function of the Vocal Cords in Phonation.

Before going farther it is necessary to understand something of the function of the laryngeal mechanism in normal voice production. A great deal has been written upon this

subject, and some extremely interesting experiments have been carried out both with mechanical models of the larynx and upon the larynx itself, both in the intact organism and with excised larynxes. We find that the conclusions of the early investigator, Manuel Garcia, whose investigations date from 1841 and who published a theory of phonation in 1885,[1] are generally accepted today. Garcia was the first to develop and use a laryngoscope. He concluded that the direction of movement of the vocal cords during phonation is upward and outward and back again. At the lower extreme of the vibration cycle, the glottis is closed or at least narrowest; while at the upper extreme, it has its widest opening. The movement of the vocal cords therefore, is exactly symmetrical and synchronous, the frequency of vibration of the vocal cords being identical with the pitch of the tone produced.

Gutzmann (2) using a modified Koenig Flame which made tracings on a kymograph drum found that there are three kinds of vocal attack (stimmeinsatze) in German, namely, (1) the aspirated (gehauchte), (2) the strong (feste), and (3) the light (leise) vocal attacks. The aspiratory (gehauchte) vocal attack is that which occurs when the vocal cords close quickly from a breath position to that of a vocalizing position. In this way there appears first an aspiration which continues into the beginning of the vocal tone. This type Gutzmann explains, occurs with vowels as well as with

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1. Quoted by Metzger (7, p. 88)

continuitive consonants. In the strong (feste) vocal attack the vocal cords are closed at the beginning of a tone and the air within the chest is compressed somewhat more strongly so that the first opening of the vocal cords has an explosive character making a "clear audible report". In the light (leise) vocal attack which is used in singing, the vocal cords are placed parallel to one another and only an oblong narrow slit remains between their inner rims. It must be remembered that Gutzmann is discussing the German language. In English speech the type of vocal attack according to this description would probably lie between the strong (feste) and the light (leise) attack. The aspirated (gehauchte) attack of the German corresponds in English to the aspirate h before vowels.

Scripture (14) observed the vocal cords using the laryngostroboscope. He characterized their movements as yielding partly by compression outward and partly by distortion upward. Although he referred to the singing voice, his findings can be applied here. The terminology used by Scripture is as follows: a dull or back tone is characterized also as a breathy tone; a bright or front tone is characterized as a pleasing tone. Scripture believes that the vocal teachers have long made the mistake of thinking that they could get a bright tone by making modifications in the resonating cavities, i.e., by making modifications in the shape of the pharyngeal and the oral cavities. He found that the vocal cords touch only slightly or not at all for the

breathy tone, and that for the bright tones, they are pressed together tightly for a considerable portion of the vibration cycle and are opened for only a brief instant and then shut quickly again. Scripture concludes (14, p. 713) that the quality of the tone depends on the nature of the action of the vocal cords themselves; pleasing tones are pleasant because the glottis acts properly and that unpleasant, breathy tones can be improved only by improving the glottal action.

M. Lermoyez, according to Rousselot (11, p. 251) verified the fact that when the glottis is opened to its widest extent, no matter what the tension of the vocal cords, and no matter what the air pressure might be, no sound could be obtained. He found further, by working on the larynxes of cholerics that by stimulating the two arytenoid cartilages, the internal surfaces of the vocal cords are brought together in such a way as to completely close the glottis. Rousselot (11, p. 259) concludes as follows: (1) when the vocal cords begin vibrating for voice, the glottis is closed; (2) when the breath flows out freely, the glottis is open: (3) when the vocal cords are placed in an intermediary position, a whispered sound is produced; and (4) the amount of breath passing out of the glottis indicates the degree of closure of the glottis.

Negus (9) who made a comparative study of the larynxes of all forms of animal life has the following to say in regard

to normal voice production (9, p. 421): "The glottis is closed and a certain degree of elasticity given to its margin, not only by the elastic fibers of the vocal cords, but by the contracted fibers of the thyro-arytenoid muscle." He continued: "If air be blown through the aperture, the margins will separate to recoil in a rhythmical manner, and a tone of low pitch will be produced; movements take place mainly in an outward and inward direction, a wide oval aperture appearing each time the cords separate."

West, (16) in 1926, set out to determine the manner by which the vocal cords vibrate during vocalization. He made stroboscopic observation on the larynxes of living subjects, experimented with models and an excised cadaver's larynx. He came to the conclusion that each cycle of laryngeal vibration consists of one complete movement of each of the two vocal bands, and that these two movements are in opposite phase.

Metzger (7) in 1928, repeated the investigation made by West. He also used X-ray photography. Metzger's findings of the mode of vibration of the vocal cords were in direct opposition to those of West. He found that his observations concerning the action of the vocal cords during vocalization are the same as those of Garcia, published in 1855, with unessential modifications. Metzger concluded, (7, p. 152) "That alternate vibrations of the voice-lips are physically impossible, but that there are no mechanical objections against the results of the laryngoscopic observations of the last

three decades, according to which their vibrations are in phase.

Kallen and Polin (6) using a laryngo-stroboscope [1] observed the vocal cords as being flush together, as nearly flush, or as separated by a gap of one or more millimeters, depending upon the phase of the excursion that is caught by the stroboscopic illumination. In answer to West's (16) observations to the effect that the vocal cords vibrate alternately and in opposite phase, these authors agree that (p. 124) "there is no justification for assuming that the movements of the cords are even simple up and down movements in the direction of the breath stream, let alone their being alternate ones." They concluded that the stroboscope used by Dr. West was mechanically deficient and that the conclusions that he arrived at were false.

The general agreement as to the action of the vocal cords in the production of tone is that they vibrate in phase, beginning from a completely closed position. From this position, their inner edges are forced upward and outward by the force of the air column from the chest. They are restored to their original position, as a puff of air escapes, by their own tension or elasticity. The rate at which their opening and closing occurs determines the pitch of the vocal tone. The only disagreement from this general theory seems to be the

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1. Described by Kallen and Polin; Science, 1934, 80, p. 592.

arguments of West (16 & 17) in which he believes he has found evidence for the fact that the cords vibrate in alternate phase, each cord making one complete oscillation for a single cycle of the vocal tone, but in opposite phase. The authors cited, Metzger (7) and Kallen and Polin (6) disagree with West, question his data, and believe that his conclusions are not well founded.

The exact manner of laryngeal vibrations does not affect the present investigation; it is concerned primarily with the all important principle contained in both sides of the argument and which has been verified by all the investigators afore mentioned; that is, the inner edges of the vocal cords are, and must be brought together for normal voice production.

III. Studies in the Speech Breathing of Deaf Children

Hudgins (5) made a comparative study of the speech coordinations of sixty-two deaf subjects and twenty-five normal hearing subjects while speaking phrases of different lengths. He found that the deaf group in comparison with the normal group, among other abnormalities, had (5, p. 43) "extremely slow and labored speech usually accompanied by high chest pressures and uttered with an excessive amount of breath." He believes that these abnormalities are caused largely by the incoordination of the speech muscles.

Rawlings (10) using Hudgins' method made a similar comparative study of the speech coordinations of fifty-eight deaf subjects and fifteen normal subjects while reading a short prose paragraph. He found that the normal hearing person uses about

the same amount of breath while speaking in a conversational tone as that which he uses while breathing quietly for the same length of time. The deaf on the other hand, use much more breath while speaking than they do in quiet breathing for the same length of time. Rawlings also confirmed the results of Hudgins in regard to excessive breathiness of tone and the high chest pressures of the deaf speakers.

Scuri, in 1935, (15) published a study of the breathing coordinations of deaf subjects. The purpose of the study was to determine the elements of breathing which produce speech and to study the various abnormalities found in a group of deaf children. He found that purely abdominal breathing, or purely costal breathing are synonymous with irregular or abnormal breathing, and the speech of subjects using either type of breathing was extremely poor. Those who had the mixed type or normal breathing showed fewer irregularities and the majority of these were classified as good speakers. Scuri found that the deaf subjects used a great deal more breath during speech than they used for quiet breathing; normal subjects, on the other hand, used approximately the same amount of breath in speech and quiet breathing. Scuri found that "the normal ratio between the two phases of respiration, inspiration, and expiration during quiet breathing is 3:4; this same ratio during speech is normally 2:6 to 2:8." These normal ratios were completely ignored by the deaf subjects, especially during speech. Scuri concluded (15, p. 343) "(1) The air column from the chest lacks force due to the weakness and

to the incoordination of the breathing muscles; and (2) the glottis is not sufficiently closed to permit the weak column of air to set the vocal cords into vibration."

The seeming inconsistency between the findings of Hudgins and Rawlings, and those of Scuri as to the strength of the air column is due perhaps, to a different interpretation of the data. All three investigators found that the deaf used a great deal more breath in speech than in quiet breathing, and they all agree that the breathiness of the vocal tone is due to excessive breath. There is abundant evidence for the fact that the deaf use extremely heavy breathing movements. (See Fig. 1, Tracings II & III). Instead of the air column lacking force as Scuri said, it seems that it would have more power. Indeed, a greater force of air as well as a greater amount will be necessary to produce vibrations when the vocal cords are not properly closed.

To summarize: (1) a frequent defect found in the speech of the deaf is that characterized as <u>breathy speech</u>; (2) extremely heavy breathing movements with high chest pressures during speech are accompanied by an excessive amount of expired breath; (3) more breath is expended while speaking than during quiet breathing; (4) one of the causes of the excessive expenditure of breath by deaf speakers is the mal-approximation of the vocal cords.

IV. Experimental Section

1. The Problem

The purpose of the present study is that of working out methods for voice improvement leading to the development of a more intelligible speech among deaf children. Specifically: To reduce the factor of breathiness; to develop a more normal voice quality, and to work toward developing normal speech breathing coordinations. Therefore, the main purpose of the study is to determine whether or not it is possible to teach the deaf subject to control the intrinsic muscles of the larynx which adjust the glottal slit for the correct voicing position, and to develop methods for doing this. Proper functioning of the larynx will not only produce a more normal voice but will also lead to a greater economy of breath in vocal production. With the vocal cords in the proper voicing position, a more normal voice quality, and more natural breathing coordinations, the intelligibility of the speech likewise should be greatly improved.

2. Subjects

The subjects selected for the investigation were chosen according to the following qualifications: (1) Children who were congenitally deaf, or those who had lost their hearing before acquiring speech; (2) Children with speech habits formed and with voices characterized as breathy; (3) Children who have normal intelligence.

Thirteen subjects were used in the investigation. The subjects were divided into two groups, an experimental group

of six and a control group of seven. Those in the experimental group were given breathing and voice building exercises; those in the control group received the regular class-room training and had no special breathing or voice building exercises. The control group was used as a means of evaluating the experimental exercises given to the experimental group.

The data for the individual members of the two groups follow with the date of birth, cause of deafness, date at which they became deaf, and a classification as to the degree of deafness. The classification of deafness here used is that described by Guilder and Hopkins (1). It will be seen that they all fall into the most profoundly deaf group, IVC, with the exception of one who falls into the next group, IIIB.

Experimental Group

	Born:	Degree of Deafness:		Causes
C.E.	March 1918	254	IIIB	Born deaf
G.B.	June 1919	213	IVC	Born deaf
J.B.	Aug. 1922	124	IVC	Meningitis (at 22 months)
V.R.	March 1925	164	IVC	Born deaf
E.W.	Aug. 1925	216	IVC	Intestinal flu from 7 months to 24 months. Deafness first noticed at age of three years.
J.A.	Dec. 1926	172	IVC	Born deaf

Control Group

V.G.	Feb. 1921	156	IVC	Born deaf
Y.B.	Aug. 1921	199	IVC	Born deaf
W.S.	Oct. 1921	193	IVC	Born deaf
O.B.	Oct. 1922	140	IVC	Born deaf
O.P.	Sept. 1924	172	IVC	Born deaf
E.O.	Oct. 1925	159	IVC	Meningitis and other diseases at two and one half years.
M.W.	Jan. 1926	195	IVC	Born deaf

3. Methods and Apparatus

Each subject selected for the study was given speech tests in order to determine the extent or degree, of speech abnormality. Tests consisted of: (1) graphic records of the voices; (2) records of the breathing coordinations of the subjects and (3) intelligibility tests. Similar tests were given at intervals during the training period to determine

the amount of progress. Final criteria of success was determined by the records as obtained in the several tests. Exercises were worked out during the experiment for: (1) bringing about voice control; and (2) the development of normal speech breathing.

A description of the speech tests and a description of the methods used to correct the voices and speech of the children follow:

A. Methods of Testing

(1) Voice Tests

It is possible to determine the type of vocal attack of a speaker by means of a voice recorder and a kymograph. A good vocal attack is characterized on the kymogram by the immediate appearance of vibrations of the vocal cords, the moment the breath begins to flow. (See Fig. 2, Tracings I and VI). In giving the open vowel ar, or any other vowel, voice appears on the record immediately, without being preceded by aspirated breath. An improper vocal attack for a vowel is characterized by a flow of breath preceding the voice. The action of the vocal cords during the aspirated syllable har in normal speech is an excellent example of the improper vocal attack often used by deaf children for vowels alone. A recording of har shows a sudden rise of air pressure of from .04 to .10 seconds followed by laryngeal vibrations. By drawing baselines on the records which represent the recording stylus at a neutral level, it is possible to

determine the time during which the aspirated breath precedes the production of the vowel tones.

Tests for the vocal attack consisted of making voice records on a kymograph by means of the voice recorder. The subjects were first required to alternate the syllables ar and har. The purpose of this test was to determine whether or not they were able to differentiate between these two forms of vocal attack. A subject's inability to make this differentiation would show the lack of control over the intrinsic muscles of the larynx which control the vocal cords. Records were made of the vowels "oo" and "ee" in the same manner.

(2) Breathing Tests

It is possible to determine the relative amount of breath used by a person in speaking, by the use of suitable recording apparatus and a kymograph. Normal speech breathing is characterized on the record by a comparatively quick inspiration of breath and by a slow prolonged expiration. Tracings from both the chest and from the abdomen show the degree of expansion and contraction of these areas during respiration. (See Fig. 1, tracing I.) One inspiration and expiration constitute a phrase. The normal speaker regulates the length of the phrase largely by the natural pauses in the material being spoken, rather than by the actual oxygen needs at any moment. The deaf subject, on the other hand expends a large amount of breath on single words. As a result, his phrases are short and his speech broken up into

artificial units without regard to the natural divisions of the material. Tracings of the breathing movements at the chest and abdominal levels not only show the number of phrases per unit of speech material, but it is also possible to measure the relative amount of breath expended during the process. Hudgins (5) and Rawlings (10) have described this method elsewhere.

The breathing records were made by placing the subject in the wooden frame, (See page 17) and placing the thistle-tube tambours and bosses against the body wall. One of these tambours was placed on the lower sternum to record the movement of the rib cage at that point; the other was placed in the mid-epigastric region to record the movements of the abdominal wall at that point. This method provides a very accurate means of recording breathing movements without unduly hampering the subject. Records were made of both quiet and speech breathing. The subjects were required to read a prose paragraph of ninety syllables for the speech breathing records. Usually four repetitions of this paragraph constituted a single test. The same paragraph was used in all of the tests.

(3) Apparatus

Records of the voice were made by recording air pressure changes outside the mouth. An aluminum mask was cut to fit the contour of the area around the mouth and ventilated to provide for excessive pressure. The aluminum mask was connected to a voice tambour which consisted of a large metal tube

16 mm. in diameter, with a rubber diaphram stretched over the end to which was attached the recording stylus.[1] The pneumodeik was also used to record the voices of those subjects who spoke with a very high pitch. This instrument is more sensitive to delicate pressure changes and responds to higher frequencies than does the voice tambour. Records of normal speakers are presented in Fig. 2, made with both types of recorder. (See Tracings I, and VI.)

The breathing movements were recorded with the apparatus described by Hudgins (5, p. 10). The subjects stood in a wooden frame which held the recording tambours independently of the subject. The tambours were adjusted to record the breathing movement of the area of the lower sternum and in the mid-epigastric region. The pressure changes within the recording system were transmitted to the smoked records by means of the pneumodeik described by Hudgins and Stetson (4).

(4) Speech Intelligibility Tests

In order to determine whether or not the improvement in the subjects' voices affected their general speech intelligibility, it was necessary that each subject be given intelligibility tests both before and after training in both the control and the experimental groups. The tests were given as follows: each subject was given a group of ten unrelated sentences of simple language to read. No attempt was

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1. For a full description of this apparatus see Rousselot (11, pp. 135-137) and Scripture (13, p. 141).

made to load the sentences with any particular kind of sound combinations.. The child sat at a table in front of the four auditors. The same four auditors were used throughout the experiment. Two of the auditors merely listened to the subjects without watching the lip movements; the other two auditors looked at the subject as well as listened. No discussion or comparing of notes by the auditors was allowed until the test was over. Each sentence was read three times; the child was given a signal when to begin each reading. The auditors wrote down between each reading what they thought the child said. Any word left out or misunderstood caused the entire sentence to be counted wrong. The test papers were scored as follows: If the sentence was understood correctly the first time, a score of ten was given; if it was understood upon the second reading, a score of five was given. If it was understood upon the third reading, a score of two was given. Failure to understand the entire sentence during the three readings meant a zero score. An average of the scores taken from the four auditors constituted the intelligibility score for any single child.

The voice and breathing tests described above were given at the beginning of the training, twice during the training period, and again at the end of the training period. The intelligibility tests were given twice to each subject: once before training began and again at the end of the training period. These tests were given to the control group at the same time. In this manner it was possible to determine to

what extent the effect of the training had carried over into the speech intelligibility of the experimental group.

B. Training Methods

The training period for the experimental group lasted fourteen school weeks, each child receiving twenty minutes a day for five days a week. There were two exceptions to this however; C.E. was able to take the training only four days a week making eleven school weeks of training and G.B. was able to take the training only three days a week, making a total of eight school weeks. The subjects had been using their speech from four to eleven years before this special training program began.

In normal speech breathing there is a quick intake of breath followed by a slow expiration causing a gradual inward movement of the chest and abdominal walls. The type of speech breathing commonly used by profoundly deaf subjects departs from this normal type in varying degrees. The chest is allowed to slump or to descend with the utterance of the first sound following inspiration. The chest therefore, exercises little or no control over the breath stream. Such subjects show no ability to hold the chest in a poised position, by the means of the intercostal muscles used in normal speech.

Special speech breathing exercises were given for the purpose of correcting this poor chest posture and coordinating the breathing mechanism in speech. The real purpose of such exercises was that of teaching the child to control the

flow of air by the chest-abdominal action. This was attained by having the child take a deep breath and then hold the air in the chest keeping the mouth and glottis open. If the breath is held in the chest cavity with the mouth and the glottis open in this manner, it is necessary that the chest muscles themselves maintain the chest cavity in an expanded position. None of the subjects were able to do this at the beginning.

(1) Breathing Exercises

The following are the exercises used for developing the correct chest posture and for coordinating the breathing mechanism in speech:

The first exercise teaches the subject the correct chest posture for beginning the phrase. The exercise consists of having the subjects lift the chest and inhale approximately the same amount of air that is exchanged in normal respiration. With the chest held in this position and with the glottis open, small panting movements are made. The panting movement consists of exchanging extremely small puffs of air while maintaining the chest at a given level. In making the panting movement, the subject is controlling the stream of breath by the action of the chest itself, rather than by the opening and closing of the glottis. The air pressure within the chest remains at approximately a neutral level. The rate of the panting movement should be from one to three cycles per second.

The second exercise is a modification of the panting

movement. The subjects exhale several short puffs of breath stopping the breath flow between each puff, but not inhaling between them. The series of puffs is followed by an inspiration which restores the chest to its former level. At the beginning two to four of these puffs are given on a single expiratory movement and later the number of puffs can be increased to six or eight. Care must be taken in giving this exercise to see that the subjects do not revert to the panting movement. The inspiration in this exercise is always greater than any single expiratory puff; it is the normal phrasing movement, the type of the chest-abdominal action used in normal speech breathing. The rate of these small expiratory puffs is that of normal syllable utterance. Thus the subject is taught to execute the normal phrasing movement.

(2) Voice Development

The following are the exercises used for developing the vocal attack and for giving the subjects control over the intrinsic laryngeal muscles:

The first exercise teaches the subjects to close the glottis voluntarily. The exercise consists of having the subjects take a breath, and then, having them hold it by shutting off the air passage with the vocal cords. In this position the cords are ready to vibrate as soon as the air begins to flow. Care should be taken that the glottis is not too tightly closed. With the glottis in this closed position, the subject gives a prolonged stream of voice using the

open vowel ar. It is possible to determine from the voice quality whether or not the vocal cords are properly closed, too highly tensed, or too widely separated, during the exercise. If the voice seems to be of a strident, or tense quality, it is an indication that the glottis is closed too tightly. This tension can be observed also by a tightening of the muscles in the throat and neck. However, if the child has learned to manage the chest in the correct manner in the previous exercises, he will not need to use the vocal cords as a real barrier against the chest pressure, because there is no chest pressure even at a full chest until the syllables begin. If the voice during this exercise is breathy, it is an indication that the vocal cords are too widely separated. It is necessary to impress upon the subject that a good voice is wanted. Exercises of the same type were given with the vowels oo and ee. The subjects often lose the glottal adjustment when changes are made in the resonating cavities for the different vowels. The subjects must learn to keep the good voice during any movement of the lips, tongue or jaw.

The second exercise teaches the subject to use this good voice in successive syllables on a single expiration. This is much the same as the procedure followed in the second of the breathing exercises described above (p. 20). It is possible during this exercise to teach the subjects to raise the velum with each vocal syllable. This is an excellent opportunity for building the correct action of the velum into

the more general speech movement pattern. By using this open vowel ar, or a close approximation, and a mirror, the subjects learn to raise the velum with each syllable. The teacher should work on this until the subject can produce a good resonant voice without excessive nasal quality.

The third exercise teaches the subject to give a warbled sound on one of the vowels. The warble here used is a warble of intensity rather than of pitch. The process consists of a series of strong syllables with the voice at a high level of intensity during the syllable, and falling to low intensity level, but not dying out, between syllables. The glottal adjustment is maintained throughout a single series. The rate of the alternation is one to two per second. This exercise is excellent practice for intensity control. It helps the subject to control the air flow from the chest. Furthermore, it helps to maintain a relaxed glottal closure since the voice would cease between syllables if the closure is too tight or if the cords are too widely separated.

The fourth exercise teaches the subject to alternate the voiced and whispered ar. Several of these syllables are given on a single expiration making sure that the air flow ceases momentarily between each syllable. This is an excellent exercise for the intrinsic laryngeal muscles, since it involves the opening and the closing of the vocal cords with each whispered and vocalized syllable.

The fifth exercise teaches the subjects to alternate

the syllables ar and har on a single expiration. In giving the syllable ar, the vocal cords are in a closed position; while in giving the syllable har, the vocal cords must allow breath to escape for the aspirate h, and then close quickly from the aspiratory position to the voicing position for the vowel. The type of vocal attack used for har is the same as the "aspiratory vocal attack" (gehauchte stimmeinsätze) discussed by Gutzmann (2). The length of the aspirate h in normal speech ranges from .04 to .1 of a second. Alternating the syllables ar and har on a single expiration in this manner, shows the subject's ability to control the vocal cords to even a greater degree than the ability required for the preceding exercise. The vowels oo and ee are used in the same manner.

In the sixth exercise the consonant sounds are practiced in combination with the vowels already discussed. In this exercise, the subjects are given words, phrases and short sentences, teaching them to use the normal phrasing movement which has been taught in the previous exercises. An attempt should be made to attain a more normal word accent in speech. As the subjects progress, they can be given longer sentences but care must be taken to keep the exercises within the subject's range or chest capacity.

4. Results

The voices of all the subjects in the experimental group showed a decided improvement as a result of the training. Each of the subjects had trouble at the beginning in dis-

tinguishing between the syllables ar and har ; at the end of the training however, all of the subjects with the exception of one, (V.R.), were able to make this distinction. (See Table 1.) The breathing records of all the children with the exception of one, (G.B. who received the training only three times a week) moved toward the normal type of breathing. In fact, the scores of four of the subjects, (C.E., J.B., V.R., J.A.) fell within the normal range in regard to the amplitude of breathing movement for the test paragraph. The scores of two of the subjects (C.E. and J.A.), fell within the normal range in the number of phrases required for the paragraph. The time required to read the paragraph decreased for all of the subjects excepting two (J.B., E.W.) (See Table 2.) The breathing data for the control group is shown in Table 3.

The average speech intelligibility score of the control group, for the initial test, was 49 percent; the final score for this group was 62 percent, a gain of 13 points, or a 26 percent gain over the initial test score. (See Table 4.) The experimental group on the other hand, gained from an average score of 37 percent in the initial test to 65 percent in the final test, showing an average gain of 28 points, or a gain of 75 percent over the initial test score in speech intelligibility. The speech intelligibility test scores for the individual subjects both before and after training are presented in Table 5.

In the routine speech testing program carried out in the school each year, the same tests are used as those described in this paper. A combined speech score, consisting of a combination of the intelligibility score and the quantitative data from the breathing records is determined for each pupil.[1]

This combined speech score for normal speakers is 130. During this experiment the combined speech score of the control group increased from an average of 15, for the initial test, to an average of 20, the score on the final test, a gain of five (5) points. (See Table 6.) The combined speech score of the experimental group increased during the same period, from an average of 9 to 44, a gain of 35 points. A discussion of each individual subject follows:

C.E. had difficulty in the initial tests in distinguishing between the syllables ar and har. (See Fig. 2, Tracing II). The records showed voicing from the beginning of each syllable with no indication of the flow of breath for the aspirate h. (See Fig. 2, Tracing I, for normal form of ar and har.) Out of 36 trials, he was unable to get one clear har. The records indicate that while this subject had a good resonant voice, there was an obvious lack of control over the intrinsic laryngeal muscles since he was unable to make

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1. For a description of the routine speech tests and this method of scoring, see Annual Report, Clarke School, 1935, pp. 28-29, 1936, pp. 34-35.

the necessary glottal adjustments for the production of the aspirate h followed by a vowel. Furthermore, he was not using this resonant voice in his speech. His speech was extremely breathy, characterized by weak vowels which were often inaudible near the end of a phrase. This indicates that while he was capable of producing a good voice when vocalizing on a single vowel, he quickly lost this glottal adjustment when the lips, tongue, or jaw, performed the normal articulatory movements. This breathy speech is also evidenced by the large amount of breath used in reading the prose paragraph before the training began. The relative amount of breath used by this subject at the end of the training period was reduced from 162 to 104 millimeters. This is offered as evidence that he had learned to use his good voice while speaking during changes in the movement of the lips, tongue or jaw. Further evidence that this subject learned to control the laryngeal adjustment is provided by the fact that at the end of the training period twenty-six out of thirty trials showed a clear distinction between the syllables ar and har. (See Fig. 2, Tracing III, also Table 1.) These latter tests were all given with a much better voice as can be shown by comparing tracings II and III in Figure 2.

The breathing records for this subject also show a decided improvement in phrasing and in fluency. Before the training, he read the ninety syllable paragraph in forty seconds; and he required sixteen phrases for the reading. At

the end of the training period, the time was reduced to thirty-five seconds and the number of phrases had been reduced to seven, which is the average number of phrases required by normal speakers for this paragraph. The following table shows the results of monthly breathing tests for this subject during the training period.

		No. Phrases	Am't of breath	Time
1st test	Nov. 17th	16	162	40
2nd test	Dec. 14th	9	123	38
3rd test	Feb. 8th	8	115	38
4th test	Mar. 17th	7	104	35

This subject also showed a 67 percent gain in speech intelligibility. At the beginning of the training period, his intelligibility score was 40; at the end, it was 67, a gain of 27 points. The average gain in intelligibility of the control group during the same period was 13 points. The combined speech score for this subject before the training was 11; this same score at the end of the training was 68, an increase of 57 points.

G.B. had difficulty in the initial tests in distinguishing between the syllables ar and har. The initial score showed that there was almost invariably a flow of breath which preceded the laryngeal vibrations. Out of 81 attempts to give the syllable ar only 19 were successful, or 23 percent. The records indicate that this subject was unable to produce a good resonant voice. Her voice was extremely breathy, indicating a poorly adjusted glottis, which made the

production of a clear resonant tone impossible. In giving the syllable ar, for example, a third, or in many instances, over half of the syllable consisted of a stream of breath.

The speech breathing score of this subject is inconsistent with that usually found among subjects who have the very breathy voices. The reason for this is that the speech breathing of this subject was extremely peculiar; that is, the speech breathing was carried on largely in the clavicular region. The movements of this region were not recorded in the routine tests of the investigation. The speech breathing movement in the lower sternum and clavicular regions shows an average score of 142 millimeters for the two regions. The score of the lower sternum and the mid-epigastric regions, the areas tested in the routine breathing tests, shows an average score of 59 millimeters for the two regions. This is obvious explanation of the seeming inconsistency of the very breathy voice produced by the apparently small amount of breath.

Evidence of the fact that this subject did gain in the control of the glottal adjustment is provided by the fact that at the end of the training period a clear distinction between the syllables ar and har was found in 73 percent of the trials, while before the training, only 51 percent of the trials showed a clear distinction. (See Table 1.)

The speech breathing of this subject showed very little or no improvement. Before the training period, she read the ninety syllable paragraph in thirty-six seconds; the relative

amount of breath used was 80 millimeters and she required eleven phrases for the reading. At the end of the training period the time was reduced to thirty-two seconds; the relative amount of breath used was 61 millimeters and she required twelve phrases for the reading. The table below shows the results of monthly breathing tests for this subject during the training period.

		No. phrases	Am't of breath	Time
1st test	Nov. 17th	11	80	36
2nd test	Dec. 14th	13	59	38
3rd test	Feb. 8th	12	87	39
4th test	Mar. 17th	12	61	32

The gain in speech intelligibility for this subject was three times the initial score. At the beginning of the training period, her score was 11; at the end, it was 44, a gain of 33 points. The average gain in speech intelligibility of the control group during the same period was 13 points. The combined speech score for this subject before the training was 8; this same score at the end of the training was 38, an increase of 30 points. While the initial and final scores show decided gains, the final scores of this subject indicate extremely poor speech. Additional time and further intensive training would be needed in order to show further gain.

J.B. had difficulty in the initial tests in distinguishing between the syllables ar and har. The records showed voicings from the beginning of each syllable with little indication of the flow for breath for the aspirate h. There was

no indication of a phrasing movement; the syllables are each given on a single breath. (See Fig. 2, Tracing VII.) Out of 35 trials, he was able to get the syllable *har* only three times, or 8 percent of the trials. (See Table 1.) The initial tests indicate that while this subject was able to produce voice from the beginning of the air flow, the voice was breathy, and of a thin high pitched quality. There was an obvious lack of control over the intrinsic laryngeal muscles since he was unable to make the necessary glottal adjustment for the production of the aspirate *h* followed by a vowel. This breathy quality of the voice was evidenced by the large amount of breath used in reading the prose paragraph before the training began. The relative amount of breath used by this subject at the end of the training period was reduced from 156 to 102 millimeters. This is offered as evidence that he had not only gained control over the glottal adjustment, but was also able to use this *good voice* while speaking. Likewise, he learned to group a number of syllables on a single breath rather than expending the entire breath on a single syllable. Figure 2, Tracing VIII shows quite clearly that this subject had learned to control the vocal cords during speech. The tracings of the syllables *har* and *ar* are clear cut, not unlike the tracings from the normal subject, made with the same recorder shown in Figure 2, Tracing VI. Further evidence that this subject learned to control the laryngeal adjustment is provided by the fact that at the end of the training period, 100 percent of the

trials showed a clear distinction between the syllables ar and har, while before the training, only 54 percent of the trials showed this distinction.

The speech breathing records for this subject also showed an improvement in phrasing. Before the training period, he read the ninety syllable paragraph in thirty-five seconds; and he required 16 phrases for the reading. At the end of the training period, the time was slightly higher, being thirty-six seconds; but the number of phrases had been reduced to 13. The table below shows the results of monthly speech breathing tests for this subject during the training period.

		No. phrases	Am't of breath	Time
1st test	Nov. 17th	16	156	35
2nd test	Dec. 14th	16	123	37
3rd test	Feb. 8th	14	96	36
4th test	Mar. 17th	13	102	36

This subject also showed a 32 percent gain in speech intelligibility. At the beginning of the training period, his speech intelligibility score was 53; at the end it was 70, a gain of 17 points. The average gain in speech intelligibility of the control group during the same period was 13 points. The combined speech score for this subject before the training was 17; the same score at the end of the training was 41, an increase of 24 points.

V.R. had difficulty in the initial tests in distinguishing between the syllables ar and har. The records showed

a thin, high pitched voice, with vibrations from the beginning of each syllable with no indication of the flow of breath for the aspirate h. (See Fig. 2, Tracing IV.) Out of 13 trials, she was unable to get one clear har. The records indicate that while this subject was able to produce voice from the beginning of the syllable stroke, there was an obvious lack of control over the intrinsic laryngeal muscles since she was unable to make the necessary glottal adjustments for the production of the aspirate h followed by a vowel. Furthermore, this subject was not using a good voice in her speech. Her voice was extremely breathy and strained, often going into the falsetto range, indicating that the vocal cords were highly tensed. The amount of breath used in reading the prose paragraph before the training began was not great. The relative amount of breath used by this subject at the end of the training period was reduced from 136 millimeters to 112 millimeters. There was a gradual decrease in the amount of breath required for reading the test paragraph, as is shown by the monthly tests presented in the table below. The strained falsetto quality disappeared and she spoke in a more normal pitch. This subject did not gain sufficient control of the intrinsic laryngeal muscles to show a clear distinction between the syllables ar and har. (See Fig. 2, Tracing V.) She was unable to give a vowel preceded by the aspirate h. (See Table 1.)

The breathing records for this subject showed an improvement in phrasing and in fluency. Before the training

period, she read the ninety syllable paragraph in fifty-one seconds; and she required 21 phrases for the reading. At the end of the training period, the time was reduced to forty-six seconds; and the number of phrases had been reduced to 16. The table below shows the results of the monthly breathing tests for this subject during the training.

		No. phrases	Am't of breath	Time
1st test	Nov. 17th	21	136	51
2nd test	Dec. 14th	17	125	41
3rd test	Feb. 8th	18	113	47
4th test	Mar. 17th	16	112	46

This subject showed a 140 percent gain in speech intelligibility. At the beginning of the training period, the intelligibility score was 29; at the end, it was 68, a gain of 39 points. The combined speech score for this subject before the training was 7; this same score after the training was 27, an increase of 20 points.

E.W. had difficulty in the initial tests in distinguishing between the syllables ar and har. He was able to give the syllable ar without the aspiration 24 times out of 29 trials. He gave the syllable har 18 times out of 31 trials. There was an obvious lack of control over the intrinsic laryngeal muscles, since he was able to make very little differentiation between the syllables ar and har. The initial tests show that there was often a greater flow of breath preceding the voice vibrations for the syllable ar than was

used in the syllable har. This is an indication that the voice of this subject was extremely breathy. Records taken at the beginning of the experiment show that he was taking a breath between each of the syllables ar and har. The voice of this subject during speech was also very breathy. In addition to the lack of control over the vocal cords, there was also almost a complete lack of control over the velum. This open velum prevents any possibility of developing pressure in the mouth cavity during the consonant closure except with an exaggerated expenditure of air. This also was the cause of an extremely nasal quality in the voice. This subject, therefore, had two abnormal escapes for the breath; the incompletely closed glottis and the open nasal cavity as a result of the inactive velum. The excessive use of air during speech is very evident in the initial speech breathing tests of this subject as compared to the initial speech breathing tests of the other subjects. (See Tables 2 and 3.) Evidence of the fact that the subject did gain in breath control by gaining control over the larynx and the velum during the experiment can be seen by comparing the breathing scores of the initial and final tests. The relative amount of breath used by this subject at the end of training was reduced from 262 millimeters to 139 millimeters. Further evidence of control over the laryngeal muscles is provided by the fact that at the end of the training period, all of the 126 trials to give the syllable ar were successful. Out of 56 trials to

give the syllable har 64 were successful, or 98 percent of the trials showed a clear distinction between the syllables ar and har. (See Table 1.)

The breathing records for this subject showed no improvement in fluency. Before the training, he read the ninety syllable paragraph in forty-two seconds; at the end, he read it in forty-four seconds. The subject did show a decided improvement in phrasing, however. (See Fig. 1, Tracings II and III.) Before the training, he required an average of 25 phrases to read the prose paragraph; at the end of the training, this was reduced to an average of 13 phrases. The table below shows the results of monthly breathing tests for this subject during the training period.

		No. phrases	Am't of breath	Time
1st test	Nov. 17th	25	262	42
2nd test	Dec. 14th	22	221	44
3rd test	Feb. 8th	17	180	46
4th test	Mar. 17th	13	139	44

This subject showed an 88 percent gain in speech intelligibility. At the beginning of the training period, his score was 41; at the end it was 77, a gain of 36 points. The average gain in speech intelligibility of the control group was 13 points. The combined speech score for this subject before the training was 5; this same score at the end of the training was 32, an increase of 27 points.

J.A. showed little distinction in the initial tests between the syllables ar and har. The tests showed aspirated breath preceded the vowel for both syllables. There was

little or no difference between these two syllables. Out of 80 trials to give the syllable ar in the initial tests only 23 showed a clear distinction from the har. This subject had a very breathy voice. He was using so much breath that it was often necessary for him to take a breath between each syllable. This subject was unable to control the flow of air because of the poor chest-abdominal action and also because of the mal-approximated glottis. This was evidenced by the large amount of breath used in reading the prose paragraph before the training began. The relative amount of breath used by the subject at the end of the training period was reduced from 209 millimeters to 91 millimeters. This latter score is within the range of normal speakers for reading this paragraph. This is offered as evidence that he had learned to control the laryngeal mechanism and also the chest-abdominal action in speech. This gain in speech control of the larynx is further evidenced by the fact that before training, 34 percent of the trials showed a clear distinction between the syllables ar and har; while after the training, 84 percent of the trials showed a clear distinction between the two syllables.

The breathing records for this subject also showed a decided improvement in phrasing and in fluency. Before the training he read the ninety syllable paragraph in thirty-nine seconds; and he required 25 phrases for the reading. At the end of the training period the time was reduced to

thirty-one seconds; and the number of phrases had been reduced to 9, which is within the range of the number of phrases required by normal speakers for reading this paragraph. The table below shows the results of the monthly breathing tests for this subject during the training period.

		No. phrases	Am't of breath	Time
1st test	Nov. 17th	25	209	39
2nd test	Dec. 14th	16	193	36
3rd test	Feb. 8th	12	116	36
4th test	Mar. 17th	9	91	31

This subject also showed a 39 percent gain in speech intelligibility. At the beginning of the training period, his score was 46; at the end it was 64, a gain of 18 points. The average gain for the control group was 13 points. The combined speech score for this subject before the training was 7; this same score at the end of the training was 59, an increase of 52 points.

V. Discussion of the Results and Conclusion

Normal voice quality depends to such a great degree upon the ear for its sensory control that educators of the deaf have accepted as almost inevitable the fact that deaf pupils will speak with what is commonly called a "deaf voice." The term is a broad one and implies that deaf children have unnatural voices. It is synonymous with the terms harsh, coarse, hollow, thin, monotonous, nasal, and breathy. In general, the voices of deaf speakers are lacking in most natural qualities. Teachers of the deaf, however, have continued in their efforts to improve the voices

of their children. Any manual of speech training for the deaf devotes considerable space to the problem of voice training.

There is a general assumption among teachers of deaf children to the effect that the vocal mechanism of deaf children is structurally normal, and all that is needed to produce normal speech functions in this mechanism is proper training methods. There is abundant evidence in support of the first part of this assumption, namely, that the speech mechanism of deaf children is structurally sound. The voices of small deaf children in their babbling, and the first efforts at vocalization have a natural quality. It is only after they have been taught speech by artifical methods that their voices take on a more unnatural quality. Haycock, a teacher of the deaf of long experience, writes (3, p. 21) "It is a commonly observed fact that many young deaf-born children have very pleasant voices . . . . It is also commonly observed that the pleasant qualities of a child's voice are quickly destroyed by unskillful teaching." There is no question but that the methods of teaching speech have an important effect upon the voice quality of the deaf child. The delicate glottal adjustment necessary for the production of a natural voice quality and which the child makes automatically in his spontaneous vocalizations is easily lost as the child begins to talk. The attention, the strain, and the tensions required in laboriously producing the correct articulatory movements involved in even the simplest word, destroy this delicate glottal adjustment. The

The tensions spread to the vocal cords themselves and the voice becomes strained, breathy, and unnatural. The proper adjustment of the glottal slit is one of the prime requisites in the production of a voice of a natural quality. If the opening is too wide, a heavy force of breath will be required to initiate a tone; the tone in turn will be breathy and of a poor quality. If the glottis is too tightly closed the voice will be thin and high pitched.

Along with the problem of labored articulation and the mal-adjusted glottis goes the problem of supplying breath for speech production. The speaker must adapt his natural mode of breathing to the requirements of speech. It is the central theme of this paper that: (1) the proper glottal adjustment for the production of a natural vocal tone and breath control by the breathing muscles themselves are inseparably associated; and (2) the two problems must be dealt with concurrently in any speech training program. Voice training exercises must fit into breathing exercises; breathing exercises must be speech-breathing exercises. Indeed, there are excellent logical reasons for believing that these two types of exercises should precede all other speech drills in the speech program. If it is possible to develop, or to retain a natural voice quality in the child, and at the same time to establish normal breath control habits the problem of moulding this natural voice into speech, --words and phrases--, by adding the consonant and vowel movements we will be establishing speech habits upon an excellent foundation. The real problem involved is how to establish this

dual foundation for speech development.

The methods described and the results presented in this paper represent an effort to answer this important question. The exercises for developing breath control are based upon experimental facts obtained from numerous investigations of normal speech coordinations. The exercises for developing the voice are based upon the facts, in so far as they are known, concerning the normal function of the vocal cords in voice production. The basis for the breathing exercises lies in the fact that normally the air column is not under a heavy head of pressure built up in advance of the actual words and phrases, but rather this air stream is controlled by the action of the chest-abdominal muscles during the process of speech production. The air flow is controlled and regulated and supplied as a series of syllable strokes by the intercostal muscles in the production of syllables which make up the phrase. The basis for the voice exercises lies in the fact that normally the inner edges of the vocal cords are brought together, reducing the glottal opening to a thin line, in voice production. This does not mean that the vocal cords act as a valve holding back the air pressure in the chest. The air flow is controlled by the chest itself, and the glottal adjustment merely brings the vocal cords into a position where a slight movement of the air column will produce natural voice vibrations.

The results presented in this paper indicate that it is possible to develop a more natural voice, and to develop more normal speech breathing coordinations. Furthermore, the data shows that improvements in voice production and in breath control are accompanied, in every subject tested, by a rapid gain in speech intelligibility.

The group of subjects used in the experimental group were of necessity small. The time for carrying out the experiment was also limited to part of a school year. The subjects chosen for the experimental group were those who had established speech habits, and whose voices were classified as breathy, and otherwise unnatural. No two of the subjects presented the same degree of speech irregularity, yet they all had extremely low speech intelligibility scores. The final scores show that their speech is still greatly inferior to that of normal speakers. There are indications that the task of raising the level of intelligibility from its present level to one still higher will be far more difficult than the task involved in the present experiment. There are factors other than unnaturalness of voice and lack of breath control which must be corrected. There is the further handicap of false speech habits which have become fixated in these subjects, and which must be broken if they are to develop further toward normal speech.

The methods used in this experiment are adaptable to the training of young children entering school. At this stage of their speech development they have decided advantages

over the older children in that they have more natural voices, and they have not developed vicious speech habits. The teacher has the advantage, therefore, of being able to start from the beginning and to establish habits of breath control and voice production upon which the more detailed aspects of speech can be built. With the foundation of natural voice and proper breath control, the problem of developing normal speech habits, and at the same time retaining a more natural voice quality in young deaf children should be made easier.

In conclusion, it was shown clearly as a result of the investigation that it is possible in children with voices characterized as breathy (a) to develop more normal voices, (b) to reduce the factor of breathiness, (c) to develop more normal speech breathing coordinations; and (d) a more natural voice quality and more normal speech-breathing coordinations insure a greater degree of intelligibility in the speech of deaf subjects.

VI. Summary.

Thirteen subjects were used in this investigation. The subjects were divided into two groups: (1) an experimental group of six subjects and (2) a control group of seven subjects. Speech breathing tests, and speech intelligibility tests were given before and after the training to both groups for the purpose of determining the gains made by the subjects during the investigation. The subjects in the experimental group were also given tests to determine the degree

of control over the vocal cords in voice production before and after the training. Exercises based on experimental facts as far as possible, were developed for the correction of breathiness in deaf children's voices, and for the purpose of working toward normal speech breathing coordinations. The exercises developed were given to the experimental group only. The gains of the subjects in the control group were used as a means of evaluating the exercises as given to the subjects in the experimental group. The results of the investigation show clearly that during the training period the subjects in the experimental group developed a more normal voice quality; reduced the factor of breathiness, and developed more normal speech breathing coordinations. A more natural voice quality and more normal speech breathing coordinations insure a greater degree of intelligibility in the speech of deaf subjects.

References Cited

1. Guilder, R. P., Hopkins, L.A. The Importance of auditory function studies in the educational program for the auditorily handicapped child. The Volta Review, 1936, 38, 69-74, 149-155.
2. Gutzmann, H., Physiologie der stimme und sprache, Berlin, 1909, 1-208.
3. Haycock, G. S., The teaching of speech, Hill and Ainsworth Ltd., London, 1933, 15-296.
4. Hudgins, C. V., Stetson, R. H., A unit for kymograph recording. Science, 1932, 76, 59-60.
5. Hudgins, C. V., A comparative study of speech coordinations of deaf and normal subjects. Jour. Genet. Psychol., 1934, 44, 3-48.
6. Kallen, L. A., Polin, H. S., A laryngo-stroboscope and comment upon West's reference to same., The Quart. Jour. of Speech Educ., 1937, 23, 119-126.
7. Metzger, W., The mode of vibration of the vocal cords., Psychol. Monog., 1928, 38, 81-159.
8. Metzger, W., How do the vocal cords vibrate., The Quart. Journ. of Speech Educ., 1928, 14, 29-39.
9. Negus, V. E., The Mechanism of the larynx., C. V. Mosby Co., St. Louis, 1930, 1-528.
10. Rawlings, C. G., A comparative study of the movements of the breathing muscles in speech and quiet breathing of deaf and normal subjects. Am. Annals of the Deaf., 1935-1936, 81, 82, 147-156, 136-150.

11. Rousselot,___, Principes de phonetique experimentale, Vol. 1, (new ed.) Paris: Didiet, 1924, 1-638.

12. Russel, G. O., Speech and voice, The MacMillan Co., New York., 1931, 1-250.

13. Scripture, E. W., The voices of the deaf; graphic records of speech., Volta Review, 1913, 15, 141-145.

14. Scripture, E. W., Aetion of the glottis., Volta Review., 1920, 22, 710-713.

15. Scuri, D., Respirazione e fonazione nei sordomuti., Rassegna di Educatione dei Sordomuti e Fonetica Biologica., 1935, 14, 82-113. (Abstracted by Hudgins for Volta Review, 1936, 38, 341-343.)

16. West, R., The nature of vocal sounds. The Quart. Jour. of Speech Educ., 1926, 12, 244-295.

17. West, R., The nature of the glottal closure for phonation, The Quart. Jour. of Speech Educ., 1928, 14, 508-522.

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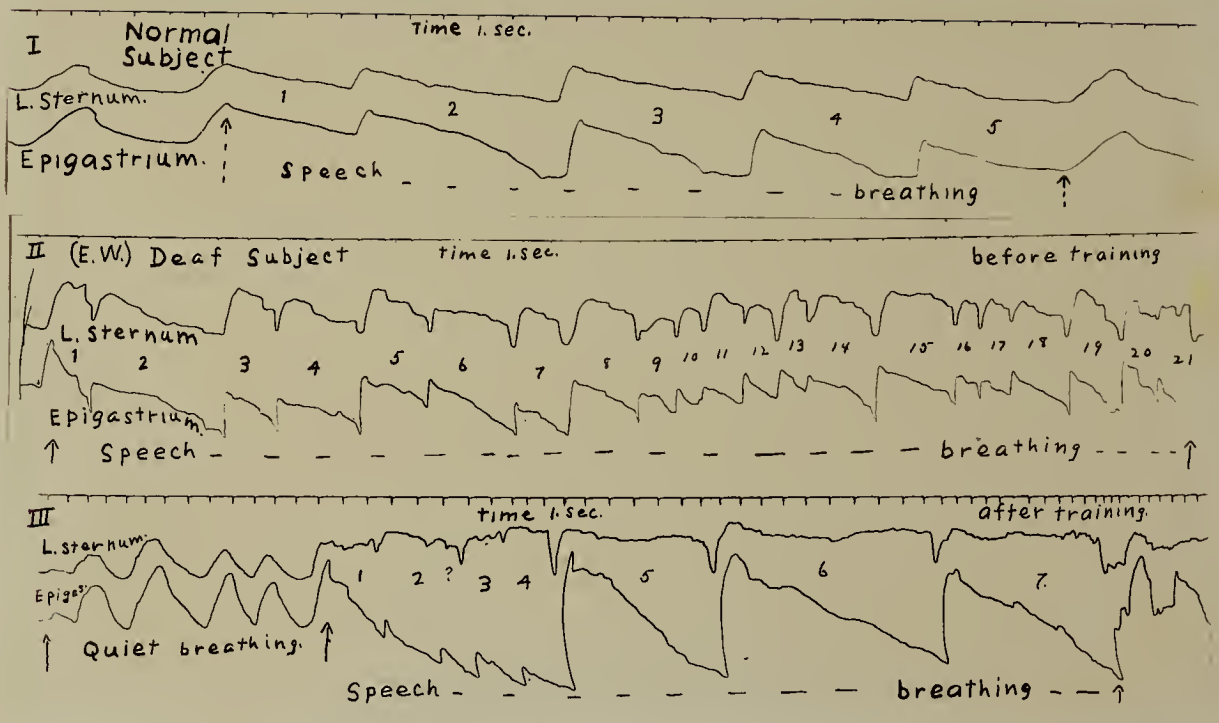
I
Normal Subject
Time 1. sec.
L. Sternum.
Epigastrium.
1
2
3
4
5
Speech
breathing
II (E.W.) Deaf Subject
time 1. sec.
before training
L. Sternum
Epigastrium.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Speech
breathing
III
time 1. sec.
after training.
L. Sternum
Epigas?
Quiet breathing.
1 2 ? 3 4 5 6 7.
Speech
breathing

Figure 1

Figure 1.

COMPOSITE KYMOGRAM SHOWING THE SPEECH BREATHING OF A NORMAL SPEAKER AND A DEAF SUBJECT SPEAKING THE 90 SYLLABLE PARAGRAPH BEFORE AND AFTER TRAINING.

Tracing I. Kymogram from a normal subject.

L. Sternum - tracing of the movement of the chest wall taken at the lower sternum level. The movements are smooth and regular. There is a rapid inspiration followed by the slow phrasing movement. There are 5 phrases for the 90 syllable paragraph.

Epigastrium- tracing of the movement of the abdominal wall taken at the mid-epigastric level; the movements are smooth and regular, similar to those in the tracing above.

Tracing II. Kymogram for a deaf subject before training.

L. Sternum- tracing of the movement of the chest wall taken at the lower sternum level. The movements are very irregular with breathing movements of varying lengths. There are 21 phrases for the 90 syllable paragraph.

Epigastrium- tracing of the movements of the abdominal wall taken at the mid-epigastric level. The movements are very irregular. Note the changes in the general level of the tracing.

Tracing III. Kymogram for a deaf subject after training.

L. Sternum- tracing of the movement of the chest wall taken at the lower sternum level for both quiet and speech breathing. The speech breathing movements with the exception of the first four phrases are more regular than those before training. There are 7 or 8 phrases for the 90 syllable paragraph.

Epigastrium-tracing shows the movement of the abdominal wall at the mid-epigastric level for quiet and speech breathing. Phrases 1 to 4 show short gasps for breath appearing on a larger phrasing movement. Phrases 5,6, and 7 indicate that the breathing mechanism has become adjusted. The movements are regular and of greater amplitude than those of the sternum above.

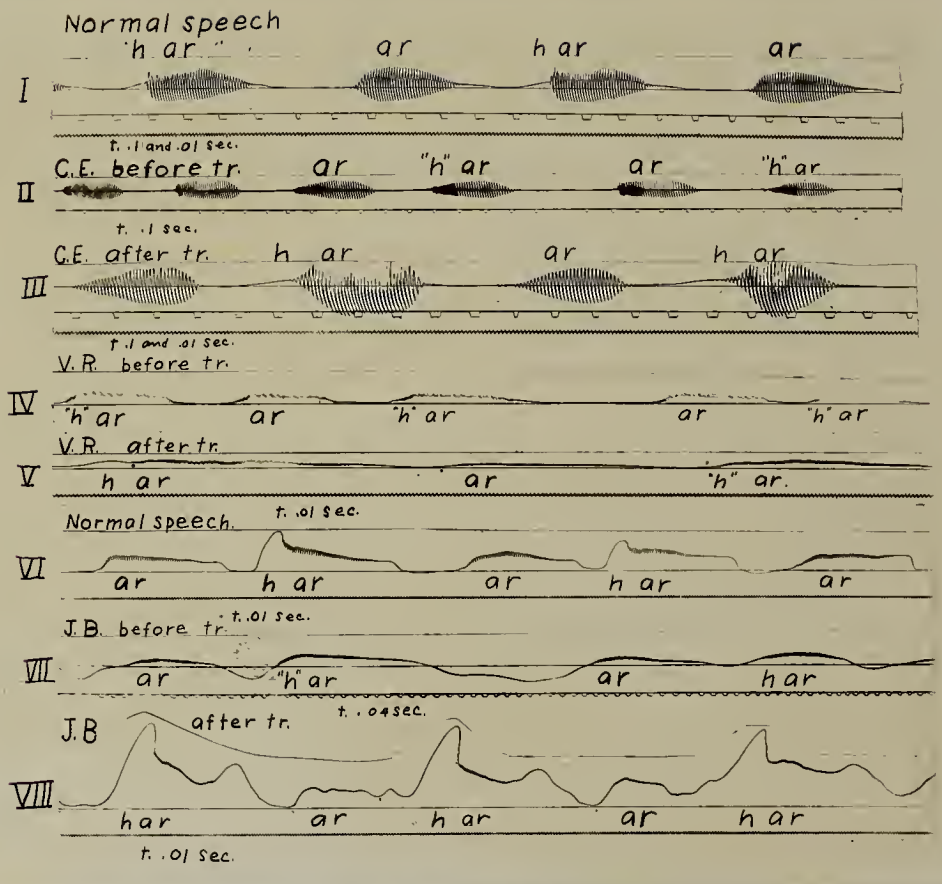
Normal speech
"h ar"
ar
h ar
ar
I
t. .1 and .01 sec.
C.E. before tr.
ar
"h" ar
ar
"h" ar
II
t. .1 sec.
C.E. after tr.
h ar
ar
h ar
III
t .1 and .01 sec.
V.R. before tr.
IV
"h" ar
ar
"h" ar
ar
"h" ar
V.R. after tr.
V
h ar
ar
"h" ar.
Normal speech.
t. .01 sec.
VI
ar
h ar
ar
h ar
ar
J.B. before tr.
t. .01 sec.
VII
ar
"h" ar
ar
har
J.B
after tr.
t. .04 sec.
VIII
har
ar
h ar
ar
h ar
t. .01 sec.

Figure 2

Figure 2.

COMPOSITE KYMOGRAM SHOWING THE SYLLABLES AR AND HAR SPOKEN BY A NORMAL SPEAKER AND THREE DEAF SUBJECTS BEFORE AND AFTER TRAINING.

Tracings I. and VI. Air pressure just outside the mouth for a normal speaker using the voice tambour in Tracing I and the pneumodeik in Tracing VI. The voice tambour responds to voices with low frequencies. The pneumodeik is more sensitive to delicate pressure changes and responds to higher frequencies. The flow of breath rises from the baseline for the aspirate h before the vowel in the syllable har. The vibrations begin at the baseline for the syllable ar.

Tracing II. Air pressure just outside the mouth for a deaf subject before training made with the voice tambour. There is no flow of breath for the aspirate h in the syllable har.

Tracing III. Air pressure just outside the mouth for the same subject after training. There is a clear distinction between the syllables ar and har. This is very much like the tracing from the normal subject, tracing I.

Tracing IV. Air pressure just outside the mouth for a deaf subject before training, made with a pneumodeik. There is no flow of breath for the aspirate h in the syllable har. There is no differentiation between the two syllables. The voice is of a very high pitch.

Tracing V. Air pressure just outside the mouth for the same subject after training. There is no flow of breath for the aspirate h in the syllable har. The tracing shows the flow of breath for one syllable har, in the first syllable.

Tracing VII. Air pressure just outside the mouth for a deaf subject before training. There is no flow of breath for the aspirate h in the syllable har. There is no differentiation between the two syllables. Breath is taken between each syllable.

Tracing VIII. Air pressure just outside the mouth for the same subject after training. Dot shows where voice begins for the syllable ar. There is a clear distinction between the two syllables. It is very much like the tracing from the normal subject, Tracing VI. All of the syllables are given without taking a breath between syllables.

Table 1

Distinction between ar and har expressed in percent; the figures indicate the ability of each subject to control the glottal adjustment for the two types of vocal attack.

Experimental Group

	Initial tests		Final tests	
	ar	har	ar	har
G.E.	100%	00%	100%	86%
G.B.	23%	79%	93%	54%
J.E.	100%	8%	100%	100%
V.R.	100%	00%	100%	20%
E.W.	82%	58%	100%	96%
J.A.	28%	80%	90%	78%
Average	72%	38%	97%	72%

Table 2

Showing data from the individual breathing tests for each subject in the experimental group, before and after training.

	Initial tests				Final tests			
Subject	No. phrases	Amount breath	Time	Speech Score	No. phrases	Amount breath	Time	Speech Score
C.E.	15	166	39		6	95	35	
	17	187	38		8	97	35	
	13	143	41		6	116	34	
	22	185	43		8	107	36	
	13	131	39					
Average	16	162	40	11	7	104	35	68
G.B.	12	79	36		12	65	33	
	9	67	33		13	64	34	
	12	91	37		12	65	30	
	12	84	36		12	59	33	
	10	86	36		12	52	32	
	11	74	37					
Average	11	80	36	8	12	61	32	38
J.B.	16	157	35		11	94	34	
	15	151	35		13	102	36	
	16	167	35		13	100	37	
	16	155	36		13	110	36	
Average	16	156	36	17	13	102	36	41
V.R.	23	137	54		17	129	50	
	19	135	49		15	117	43	
					15	106	44	
					16	95	48	
Average	21	136	51	7	16	112	46	27
E.W.	27	284	42		8	89	40	
	25	249	43		13	150	48	
	22	254	41		13	146	46	
					20	170	47	
					16	176	43	
					8	107	40	
Average	25	262	42	5	13	139	44	32
J.A.	23	178	42		8	89	33	
	25	210	38		9	83	31	
	27	235	39		11	117	31	
	26	213	38		10	82	27	
					8	85	31	
Average	25	209	39	7	9	91	31	59
	Average score for 20 normal subjects							
Average	6.3	69.0	25.0					130
S.D.	1.2	15.0	1.1					

Table 3.

Showing data from the breathing tests for each subject in the control group, before and after training.

	Initial tests				Final tests			
Subject	No. phrases	Amount Breath	Time	Speech Score	No. Phrases	Amount breath	Time	Speech Scores
V.G.	13	86	48		12	87	50	
	14	94	47		11	66	51	
	13	101	47		15	79	50	
	10	80	45		15	80	51	
Average	12	88	47	27	13	78	51	31
Y.B.	22.5	157	40		16	169	38	
	22	127	41		16	169	35	
	22	151	37		16	136	35	
	21.5	155	39		15	142	35	
Average	22	148	39	15	16	152	36	22
W.S.	10	154	37		14	172	39	
	12	192	37		13	199	41	
	11	203	40		12	173	39	
	10	183	36		10	149	40	
Average	11	184	38	16	12	173	40	16
O.B.	17	134	34		20	158	45	
	13	111	35		17	115	43	
	13	144	34		24	142	45	
	13	121	34		21	116	44	
Average	14	131	34	4	21	133	44	9
O.P.	27	249	57		25	231	64	
	29	264	58		23	223	67	
	26	260	61		21	221	63	
					21	213	61	
Average	27	258	57	6	23	222	64	11
E.O.	23	197	45		28	148	42	
	21	149	40		20	126	38	
	21	152	41		19	127	36	
	23	173	42		22	131	37	
Average	22	156	40	17	22	134	38	21
M.W.	20	159	48		14	124	40	
	18	164	49		16	131	43	
	15	173	43		16	137	44	
					16	148	41	
Average	18	165	47	19	16	135	42	31

Table 4.

Showing the individual and average gain during the training period in speech intelligibility for both the experimental and control groups.

Experimental Group.

	C.E.	G.B.	J.B.	V.R.	E.W.	J.A.	Average
Initial Test	40	11	53	29	41	46	37
Final Test	67	44	70	68	77	64	65
Gain	27	33	17	39	36	18	28

Control Group.

	V.S.	Y.B.	W.S.	C.B.	O.P.	E.O.	M.W.	Average
Initial Test	45	63	39	9	47	73	71	49
Final Test	52	67	42	35	74	81	87	62
Gain	7	4	3	26	27	8	16	13

Table 5.

Showing average scores of the intelligibility tests for both groups of subjects before and after training. The scores for both types of auditors and a final average are given.

Experimental Group

Subject	Initial Test Look and Listen Av.	Listen Av.	Gen. Av.	Final Test Look and Listen Av.	Listen Av.	Gen. Av.
C.E.	50	30	40	82	52	67
G.B.	16	5	11	56	31	44
J.B.	47	59	53	79	62	70
V.R.	34	26	29	68	68	68
E.W.	47	35	41	78	75	77
J.A.	49	44	46	73	55	64
Gen. Average	41	33	37	73	57	65

Control Group

Subject	Initial Test Look and Listen Av.	Listen Av.	Gen. Av.	Final Test Look and Listen Av.	Listen Av.	Gen. Av.
V.G.	49	39	45	58	47	52
Y.B.	66	60	63	75	59	67
W.S.	58	20	39	42	41	42
O.B.	8	10	9	42	29	35
O.P.	44	50	47	83	66	74
E.O.	75	70	73	84	78	81
M.W.	76	66	71	88	86	87
Gen. Average	54	45	49	67	58	62

Table 6.

Showing the individual and average gain during the training period in combined speech score for both the experimental and control groups.

Experimental Group

	C.E.	G.B.	J.B.	V.R.	E.W.	J.A.	Average
Initial Test	11	8	17	7	5	7	9
Final Test	68	38	41	27	32	59	44
Gain	57	30	24	20	27	52	35

Control Group

	V.G.	Y.B.	W.S.	O.B.	O.P.	E.O.	M.W.	Average
Initial Test	27	15	16	4	6	17	19	15
Final Test	31	22	16	9	11	21	31	20
Gain	4	7	00	5	5	4	12	5

Approved by

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