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HOW THE LISTENER'S EXPERIENCE INFLUENCES THE RATING OF THE INTELLIGIBILITY OF HEARING-IMPAIRED CHILDREN'S SPEECH

Independent Study

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Speech intelligibility has proven to be one of the most difficult areas to assess in terms of a complete educational evaluation of a hearing-impaired child. A valid and objective rating scale has not yet been determined; rather a subjective judgment made on the part of a listener has been the basis for rating the intelligibility of hearing-impaired children's speech (Jensema, et al., 1978; Monsen, 1978; Brannon, 1966; Hudgins and Numbers, 1942; Smith, 1973; Hudgins, 1949).

The importance of improving evaluative techniques of speech intelligibility becomes unmistakable when the current literature is surveyed. The majority of results suggest that overall levels of speech intelligibility are quite low -- around 20% in most studies (Brannon, 1966; Markides, 1970; Smith, 1973). Monsen (1978) suggests that evaluation of a hearing-impaired child's speech production abilities might be of greater value to educators than the child's speech reception abilities. In order to develop more effective training procedures it is necessary to know the effect on intelligibility of the numerous deviations from normal speech patterns that are typical of hearing-impaired speech. A child's speech must also be assessed for the purpose of noting his progress and improvement, evaluating and comparing teaching methods and, in many instances, to make recommendations for the educational future of the child -- whether he remains in a special school environment or is placed into a regular school setting.

The definition of intelligible speech and the factors that influence its production are important to consider when determining how to rate a child's speech. It would seem logical to say that the child's intelligibility depends upon his ability to transmit the language code; a task which includes knowledge and proficiency with language* -- the expression of ideas through words.

*(lexical, morphological, syntactic and semanic rules).

The more weighted aspect of intelligibility is the way in which the child produces sounds, words and phrases in connected discourse - his speech. Speech refers to the child's articulation, voice quality and rhythm or durational patterns. Both language and speech contribute to the child's overall intelligibility. Brannon (1966) describes intelligibility as "the percentage of items spoken that are understood by a group of listeners." This definition of intelligibility suggests that not only must the articulatory skills of the child be analyzed, but also the complete cycle of communication involving the thought and language of the speaker and the perception and reception of the message by the listener. Most of the studies involving the rating of speech intelligibility by a group of listeners agree that the procedures for evaluation involve several fundamental factors (Hudgins, 1949; Thomas, 1963; Brannon, 1966; Monsen, 1978). These factors can be said to include:

I. Characteristics of the Speaker, such as articulation, voice quality, rhythm or durational patterns and the speaker's use of language.

II. Sensory Cues given to the Listener. Does the listener receive acoustic and visual cues combined or just the acoustic signal? Does the listener know what the speaker is talking about?

III. Types of Material to be communicated.

IV. Characteristics of the Listener, namely experience.

A description of the characteristics of the speaker involves the particular aspects of hearing-impaired speech which deviate from that of normal speakers. It has been reported that all areas of hearing-impaired speech (segmental and suprasegmental) are deficient: articulation of phonemes, rhythm, voice quality and the use of language (Hudgins and Numbers, 1942; Markides, 1970; Calvert, 1962; Smith, 1973). These abnormalities can only be attributed to the profound effects of a hearing loss on the development of normal speech and language. Jensema, Karchmer and Trybus (1978) reported that the correleation coefficient between intelligibility ratings and the degree of hearing loss is -.68, which emphasizes the fact that intelligibility declines as the severity of the loss increases. Other research has indeed supported this idea, but it is erroneous to assume that a profoundly deaf child is incapable of developing intelligible speech and language. The frequency and quality of speech input, the degree to which the child uses his residual hearing, the maintenance and usage of a good hearing aid, the type of intelligibility test used to obtain the score and the methods of teaching all contribute to a child's ability and intelligibility score. Smith (1973) reported that intelligibility was highly correlated (-.65) with hearing level but that the variable most clearly correlated with intelligibility was the measure of phoneme recognition.

Hudgins and Numbers (1942) found that articulatory and rhythmic errors were the primary causes for lack of intelligibility. They reported two distinct groups of error categories: the inaccuracy or the failure of the articulatory processes and a lack of coordination between articulatory processes and breathing muscles. Consonant errors included failure to distinguish between voiced and voiceless consonants, substitution, excessive nasality, the distortion of consonant blends and clusters and the omission of appropriate stop and release consonants in words and in co-articulated speech. Vowel production was characterized by substitutions, diphthongization, neutralization and nasalization.

Although consonant errors have been judged to be more common than vowel errors (Hudgins and Numbers, 1942), there exists the possibility that a hearing-impaired child's distortion of vowel formant and mean voice-onset-time information (Monsen, 1978) may influence the production (and perception) of intelligible consonants. Hudgins described problems of breath control, nasalized vocal quality and abnormal temporal and intonational patterns. Calvert (1962) and Monsen (1978) reported that deaf speakers distort the duration of phonemes and Parkhurst and Levitt (1978), in a study of prosodic errors, found that three factors correlated highly with reduction in intelligibility: unexpected adventitious sounds, very long prolongation of individual sounds and unexpected changes in pitch. This variety and number of articulatory and rhythmic errors certainly affect the listener's ability to comprehend what is being said. However, other evidence suggests that comprehension involves additional sensory cues above those that can be given in the auditory signal alone.

Thomas (1961) evaluated the transmission of information from the deaf speaker to the listener of normal hearing. He proposed that a hearing loss is imposed on the listener and that this loss is a discrimination type loss. If this is indeed the case, other information must be provided to the listener in order to compensate for the hearing loss. Hudgins and Numbers (1942) and Thomas (1961) reported that cues derived from lipreading add considerably to the intelligibility scores of hearing-impaired speakers. Miller and Nicely (1955) asked normally-hearing listeners to discriminate syllables under varying conditions of noise and frequency distortion. They found that the place of articulation was the most difficult feature to hear correctly but also the easiest of the features to see on the speaker's lips. The other features (manner of articulation, voicing vs. non-voicing, durational and nasality cues) are hard to see but easy to hear. Lipreading then, would be a valuable skill for listeners who are handicapped by the discrimination type loss imposed on the listener by a hearing-impaired speaker. Visability of the speaker can therefore greatly improve the intelligibility score of a hearing-impaired speaker (Thomas, 1961).

Although many studies have shown that speech recognition is based on the acoustic features of the speech wave (Petersen and Barney, 1952; Monsen, 1978), it may also be said that rarely can an acoustic feature completely identify a speech sound by itself in all phonetic contexts. Speech recognition is accomplished by combining acoustic, linguistic, semantic and circumstantial cues. When we listen under the most favorable conditions, the cues available are far in excess of what is actually needed for recognition. General context, our expectations of what will be said, knowledge of the speaker and knowledge of the rules of grammer all explain why, under normal conditions, we can understand speech easily. It is therefore important to examine the types of material used as a factor influencing a listener's judgement of what is being said.

The nature of the material, the phonetic complexity, the size of the units, the amount of redundancy and contextual clues all must be considered when judging intelligibility. In general, the intelligibility of a word is a direct function of the number of syllables in the word; monosyllabic words are more intelligible than nonsense syllables and spondaic words are more intelligible than monosyllabic words. The contextual cues, or word probability, is increased by words in a sentence -- and related to the amount of redundant information in the sentence (Hirsh, Reynolds and Joseph, 1954; Thomas, 1961). Therefore, the most simple sentences, containing phonetically balanced words, can be said to give the critical information and some redundancy, rendering the material very intelligible. Sentence length and word frequency should all be taken into account when creating intelligible sentence material (Monsen, 1978).

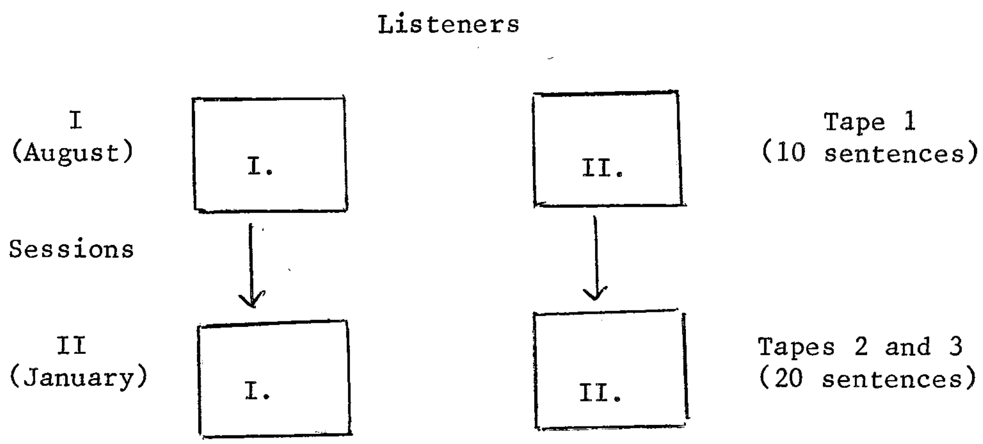
The final factor to be considered in rating intelligibility is the listener. How does a listener's ability, as a result of exposure, experience or auditory training, enable him to decode the speech of the hearing-impaired speaker and what is the rate at which this ability increases over time? Several studies support the idea that experienced listeners can understand more than naive listeners. Thomas (1961) concluded that experience seems to allow a listener to derive more information from the hearing-impaired speech signal -- both through the auditory and visual channels. Hudgins (1949) gave his panel of listeners training to familairize them with both the mechanics of listening and with the voices and speech of hearing-impaired children. He found that each of the listeners made the greatest improvement during the first three training sessions, but from that point on, the average improvement was minimal. Monsen (1978) reported that for four listening tapes the experienced listeners understood about 9% more than the naive listeners. After the first listening session, the experienced listeners understood about 14% more than did the naive group; but after having listened to three out of four tapes, the naive group understood only 5% less than the experienced group. Monsen interpreted these results as follows: "...while experience in hearing the hearing-impaired speak is a considerable advantage in understanding what is said, it is an advantage that is rather quickly and easily acquired."

The purpose of this study is to give further emphasis to the importance of listener experience as a factor to be considered when developing a more valid and objective measurement of intelligibility.

Method

This study consisted of having two groups of listeners -- experienced and naive -- listen to recorded sentences spoken by hearing-impaired children. The ability of both groups to improve in understanding hearing-impaired speech over time was measured and compared. The emphasis then, was to look at the effects of exposure to hearing-impaired speech on this ability to understand using the same listeners at two different points in time (See Figure 1: Study Design).

FIGURE I: Study Design



Speakers and Material

The speakers and material for this paper were taken from the data and audio-recordings collected in April, 1976 for R. Monsen's study, "Toward Measuring How Well Hearing-Impaired Children Speak," (1978). The selection of ten speakers, hearing-impaired students from Central Institute for the Deaf, out of the thirty-seven children in Monsen's study, was made in order to provide a good range of intelligibility to the listeners. Intelligibility scores were obtained for each child by averaging the listener's responses for each speaker. A percentage intelligibility score was then calculated for each speaker. The children's age, sex, mean hearing level in the better ear and the intelligibility scores are given in Table 1.

The test material, thirty simple sentences, was designed to contain only common monosyllabic words and spondees in order that all of the subjects would be able to produce at least partially intelligible speech (see Table 2). The sentences were rearranged into three groups for this study so that the average mean score of difficulty of each set of ten sentences was within a comparable range (Table 2). The was done so that the degree of difficulty of the material would not change over time thereby affecting the listener scores.

Monsen recorded each child saying all thirty sentences in an audiometric testing booth on a Nagra tape recorder. The master tapes from these recordings were then edited for this study using the Random-Access Programmable Recorder of Complex Sounds (RAP). Based on the sentence rank order of difficulty (see Scoring) and the child's intelligibility score, a pairing of child and sentence was made for each of three sets of ten sentences (Table 2). For example, the child who was rated as most intelligible with a score of 98%, was assigned the most difficult sentences in each set (6.54, 5.04, 5.46). The child with the lowest intelligibility score of 44.2% was given the easiest sentences in each set (9.54, 9.80. 9.54). The sentences, having been stored on a RAP disk, were

TABLE 1. SPEAKER INFORMATION

(Monsen, 1978, page 201)

Rank No.	Age	Sex	Mean (Better Ear) Hearing Levels (in dB re: ANSI-1969) at 0.5,1,2 kHz	0.5,1,2,4 kHz	Speech Intelligibility Scores (in percent)
1	12-7	F	65	68	98.0
2	12-10	M	70	78	94.3
3	12-10	M	97	104	88.5
4	11-8	F	92	89	86.5
5	12-0	F	92	97	81.0
6	12-7	F	103	103	79.3
7	14-6	M	100	106	71.7
8	15-7	M	107	105	70.1
9	15-9	M	123	123	54.8
10	14-7	F	102	103	44.2

TABLE 2. SENTENCE MATERIAL: Difficulty Score, Child Who Spoke Each Sentence.

Tape 1	Sentence Score	Child Rank No.
The playground is clean.	6.54	1
I like icecream.	9.34	10
Can you tell us?	8.58	9
I need a toothbrush.	8.56	8
Let me read this.	7.43	5
Will you go there?	7.11	2
The icebox is full.	7.42	4
Will he see it?	7.16	3
Please help me do it.	8.39	7
We bought a new car.	7.97	6
Mean sentence score-	7.87	
Tape 2		
The football is brown.	8.81	8
I want a hotdog.	8.29	6
Can I come in?	9.80	10
He has a workshop.	5.20	2
I don't want any.	8.83	9
Will he like them?	6.71	4
The workshop is small.	6.42	3
Do you know how?	8.35	7
I know how to dance.	7.45	5
We all like sports.	5.04	1
Mean sentence score-	7.49	
Tape 3		
The icecream was good.	9.54	10
He plays baseball.	7.76	7
Can you show me?	9.18	9
We have an airplane.	8.16	8
I don't think so.	5.46	1
Did you find it?	6.12	3
The toothbrush is red.	5.97	2
Can they hear it?	6.84	4
We eat lunch at noon.	7.18	5
Our baseball is lost.	7.41	6
Mean sentence score-	7.36	

then transferred onto three master tapes which were used for listening purposes. Each tape contained ten sentences, each spoken by a different child. A 500 Hz tone, approximately one second in duration, preceded each sentence presentation in order to prepare the listener. Each sentence was repeated with a brief pause between presentations so the listener had two chances to hear the material. A 15 second delay followed the second presentation so that the listeners could record their responses. The tapes were played on a Nagra tape recorder, with a Panasonic speaker attached, in a sound-proof listening room.

Listeners

There were nine naive listeners chosen from the first year class of graduate students in Deaf Education and Audiology at Central Institute for the Deaf. The experienced listeners were ten second year graduate students, also from C.I.D., who had spent at least one year in almost daily contact with hearing-impaired children.

Instructions to Listeners

The listeners were given a response sheet on which they were instructed to write down what they thought was being said. They were asked to guess if they could not understand but not to use any phonetic symbols to interpret a word or sound.

Scoring

The scoring was based on the method used by Monsen (1978) where each sentence was given a value of ten points. The relative value for each word within the sentence was based on the frequency of it's usage in the English language. The listener's score for each sentence was computed and averaged together.

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Results

(see Table 3)

The results tabulated from the first tape show a range of 50% to 79%, with a mean score of 60.5%, for the naive listeners. The experienced listeners' scores ranged from 62% to 94.5% with a mean score of 76.5%. The difference between the average scores was 16%.

The scores from the second listening session for the naive listeners ranged from 67% to 90.75%, with a mean score of 80.5%. Experienced listener scores ranged from 75.25% to 89% with a mean score of 82.8%. The comparison here showed only a 2.3% difference between the two groups. The overall degree of improvement for group I (naive) was 20% and for group II (experienced) the change was 6.3%.

Discussion and Conclusions

An important question for educators of the hearing-impaired is: how can a child's intelligibility be evaluated in a more valid and consistant manner. If one considers the factors which influence a child's intelligibility, how can a classroom teacher's judgment be regarded as an objective measure? Perhaps a standard rating form would improve reliability; but how can progress be recorded if the teacher rating the child is changed from year to year? And to what degree does a trained, familiar ear influence the objectivity of such a measurement? Is it a more reliable and valid test to ask and expect a completely naive listener to be able to understand, much less judge, the speech of a hearing-impaired child?

TABLE 3. LISTENER INFORMATION

Group I: Naive Listeners

Listener No.	Session I score (in percent)	Session II score (in percent)
1	79	81.75
2	70.5	72.5
3	68.5	90.75
4	61	85.5
5	57.5	87.75
6	55	84.75
7	52	73.5
8	51	67
9	50	81.25
AVERAGE SCORE-	60.5	80.5

Group II: Experienced Listeners

Listener No.	Session I score (in percent)	Session II score (in percent)
1	94.5	80.5
2	84.5	82
3	80.5	75.25
4	77.5	88.25
5	77.5	89
6	76	85
7	76	86.25
8	71	79.25
9	65.5	80.75
10	62	81.75
AVERAGE SCORE-	76.5	82.8

Both Groups

Degree of Improvement: (session I to II)
- Group I: 20%
- Group II: 6.3%

% difference between groups:
- Session I: 16%
- Session II: 2.3%

This study attempted to focus on the listener experience aspect of intelligibility rating for the purpose of considering the possible effect on intelligibility scores. The results showed that naive listeners become better at listening to and understanding the speech of hearing-impaired children with experience and exposure over a brief five month period. The results could have been more effective if there had been an additional listening session along with a third group of more experienced listeners (teachers) with which to compare the present scores. However, the results support the findings of other intelligibility studies, primarily those of Thomas (1961) and Monsen (1978). The listener's experience, among other factors, can affect the rating of intelligibility of a child's speech. It does seem that with a fairly small amount of training, a listener can improve his ability to understand. For this reason, perhaps a valid test of a child's intelligibility (or progress there of) would be to have one listener with a trained ear (such as the child's teacher) and another listener, unfamiliar with the speech of the particular child, but familiar in general with the speech of hearing-impaired children. This combination could listen to an audio-recording of the child's speech -- preferably a spontaneous sample. If the two listeners agreed upon a criterion-referenced scale of rating, then perhaps they would be able to more objectively consider a child's overall intelligibility. The teacher, when listening to the audio-tape, might be able to observe errors that she had previously missed because of visual cues. The second experienced listener might be able to advise the teacher as to corrective methods for the child's speech errors. However, in order to have a valid test of the child's progress, these same two listeners would need to consistently rate the child's speech -- year after year.

If educators can develop a valid, consistant method of evaluating overall intelligibility, then such a tool would certainly lead to improved methods of instruction and better speech production. This information would also add to our knowledge of what "speech intelligibility" really is; is it a measure of how well a listener can "tune in to" a deviant speech pattern or can it help to determine what specific aspect of a child's speech renders him unintelligible? Since speech is such a complicated pattern of acoustic signals, children who are most unintelligible usually distort the normal speech pattern in many ways. Listeners can improve in their ability to understand but only up to a certain point. For this reason, an intelligibility score should be able to predict how well a child will be able to communicate. Considering all the factors known to influence speech intelligibility, the most critical seems to be the child's ability to make himself understood and his attitude about persisting in doing so. At this point, the most positive step educators can take is to build up a child's catalogue of error probability, or ability to self-correct, so that he may be understood by more than those familiar with hearing-impaired speech.

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