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Validation of the Use of the Rapid Speech Transmission Index (Rasti) In Elementary School Classrooms

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VALIDATION OF THE USE OF THE RAPID SPEECH TRANSMISSION INDEX (RASTI) IN ELEMENTARY SCHOOL CLASSROOMS

by

Aparna Rao

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Aparna Rao

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in Elementary School Classrooms

by

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The aim of this study was to assess the validity of an objective method of speech intelligibility, the Rapid Speech Transmission Index (RASTI), in elementary school classrooms. The RASTI can be obtained more quickly than subjective measures of speech intelligibility and has been shown to be highly valid with adult listeners in auditoriums. In this study RASTI values were correlated with scores on a subjective test of speech intelligibility, the Word Intelligibility by Picture Identification (WIPI) test, for 45 students in two elementary classrooms (grades 1 through 3 and grade 5). Results indicated that the RASTI value is a poor predictor of subjective speech intelligibility (WIPI) scores for these students. There was no significant difference between the correlations obtained in the two classrooms or between the correlations obtained with the average and largest of the three RASTI values and the WIPI scores. Further study needs to be done to determine the applicability of the RASTI to classroom environments.

(55 pages)

INTRODUCTION

It is recognized that the listening environment in a classroom is of critical importance in the learning process. Research has shown that in a classroom 75% of the time is spent on speaking and listening and only 25% is spent on reading and writing (Berg, 1987). Inappropriate acoustic design of a classroom will be a barrier to academic achievement because the information transmitted by the teacher will not be maximally intelligible everywhere in the room. The acoustical factors which modify the sound and affect speech intelligibility have been identified as background noise, reverberation, and distance between the speaker and listener (Berg, 1987).

The factors of noise, reverberation, and distance from the speaker do not occur in isolation. Many researchers have attempted to quantify the combined effects of these acoustical factors on speech intelligibility in rooms (Peutz, 1971; Steeneken & Houtgast, 1980). Traditionally, acoustical engineers have developed and used various procedures to measure speech intelligibility in auditoriums. These methods may be broadly classified into two divisions, those being subjective and objective measures. The subjective measures have used direct word or sentence recognition tests in which listeners have been asked to identify what is said in various acoustical environments. Subjective measures of speech intelligibility have the advantage of face validity in that they measure what actually occurs in a specific environment. However, they are time consuming to measure and difficult to obtain. For this reason, there has been a tendency to develop the use of objective measures. The objective measures have been derived from calculation schemes developed for intelligibility measures across telephone lines. Basically these objective measures have calculated intelligibility scores from the physical parameters of the room, including the signal-to-noise ratio, the reverberation time, and the distance between the speaker and listener. These calculations resulted in the development of indices and measures such as the Articulation Index (Kryter, 1962), the Articulation Loss of Consonants (Peutz, 1971), the Speech Transmission Index (Steeneken & Houtgast, 1980), and the Rapid Speech Transmission Index (Houtgast & Steeneken, 1984).

Both subjective and objective measures have been used extensively in the designing of the acoustical properties of auditoriums in the last decade. However, relatively little attention has been paid to these measurements in classrooms. Very few studies have been published in which authors have used subjective or objective techniques to measure speech intelligibility in classrooms.

In 1978 Finitzo-Hieber and Tillman used a subjective measure of speech intelligibility in which they presented a word recognition task at different combinations of signal-to-noise ratios and reverberation times. Houtgast (1981) compared the results from a subjective measure (Articulation Loss of Consonants) and an objective measure (Speech Transmission Index) to determine the effect of ambient noise on speech intelligibility in classrooms. More recently, Leavitt and Flexer (1991) have measured the degradation of a speech-like signal in a classroom using the Rapid Speech Transmission Index.

Based on the importance of the acoustical environment of classrooms for learning and on the lack of information as to how noise, reverberation, and distance interact to affect speech intelligibility in the classroom, it is essential that more information be obtained regarding the measurement of classroom speech intelligibility. Because of the difficulty in the use of subjective measures, it would be advantageous to use objective measures to measure speech intelligibility. Thus far, however, only the 1981 study by Houtgast has attempted to correlate subjective measures of speech intelligibility with the objective measures made in a classroom. The present study will attempt to address this lack of information by determining the relationship between an objective measure, the Rapid Speech Transmission Index, and a direct subjective measure of speech intelligibility for elementary school children in a classroom.

REVIEW OF THE LITERATURE

The acoustical conditions of a room in which verbal communication takes place are of paramount importance. As pointed out in the previous section, they are even more important in a classroom because in typical classrooms most learning takes place through the auditory channel (Berg, 1987). Various methods have been developed to measure the clarity of speech based on specific acoustical conditions. These methods have focused on the combined effects of noise, reverberation, and distance of the speaker from the listener. The effects of all acoustic factors must be considered simultaneously because disregarding any one factor will lead to an unrealistic estimate of the effect of the others (Houtgast, 1981). In a room where listening occurs, reverberant sound and noise are mixed with speech, and the listener has to decode speech in the presence of this background noise.

One factor which affects speech intelligibility in a classroom is background noise. Noise is defined as any undesired disturbance that interferes with what the listener wants to hear (Burns, 1973; Kryter, 1970). If noise is mixed with speech, some components of speech are masked by the noise, and these components become inaudible. The intensity difference in decibels between the speech signal and the background noise in an environment is termed the signal-to-noise ratio (S/N), and the intelligibility of the signal in a classroom is directly proportional to the signal-to-noise ratio. It has been recommended that the signal-to-noise ratio in a classroom be between

+6 dB and +10 dB for children with normal hearing (Finitzo-Hieber & Tillman, 1978).

Reverberation, another factor which influences speech intelligibility, is the result of a continual process of sound reflection leading to the prolongation of the sound. Reverberation is measured in terms of the time which is required for the mean-square sound pressure level to decrease 60 dB after the sound impulse stops (Ross, 1972). Reverberation in a classroom directly influences the quality of the listening environment by introducing additional energy to the energy of the direct sound. Rooms with abnormally long reverberation times will seem to echo, thus decreasing the intelligibility of the primary speech source. Based on the work by Finitzo-Hieber and Tillman (1978), it has been recommended that the reverberation time in a classroom be approximately 0.5 seconds for children with normal hearing.

A third factor influencing the intelligibility of speech in a classroom is the distance of the listener from the speaker. This distance determines the total sound energy, consisting of a mixture of direct sound and reflections, which reaches the listener. The sound pressure level of the direct sound is highest at the source and decreases 6 dB with every doubling of distance from the speaker or source (Berg, 1987). At a point called the critical distance, the levels of the direct and reflected sounds are equal. Peutz (1971) found that speech discrimination decreases as the distance from the sound source increases until the critical distance is reached. Beyond this point, the intelligibility of the speech remains constant.

A number of methods have been developed to measure speech intelligibility in rooms. These methods have been categorized as either subjective or objective measures. Subjective measures are the most direct methods of assessing the acoustical conditions of a room. They involve using trained talkers (speakers) and listeners to obtain a speech intelligibility score based on test materials such as sentences or words (Steeneken & Houtgast, 1980). Despite the obvious advantage of the directness of subjective measures, they have some serious drawbacks. They require a number of trained talkers and listeners and are therefore expensive to carry out. A great deal of time and effort is needed to conduct these tests too. Additionally, they cannot be used when designing a room, but are useful only in measuring the speech intelligibility of an existing room. Because of these disadvantages, efforts have been directed toward devising objective measures of speech intelligibility.

Objective measures involve the calculation of speech intelligibility in a room based on specified physical and acoustical parameters. They are typically obtained quickly and easily, and they can be used either at the design stage or in actual situations. Studies have shown that these objective measures correlate well with the subjective measurements of intelligibility (Houtgast, Steeneken & Plomp, 1980; Houtgast & Steeneken, 1984; Peutz, 1971). Most of the objective approaches for estimating speech intelligibility have been used in large rooms, such as auditoriums, but their usefulness in smaller classrooms is obvious.

One of the studies in which a subjective measurement technique was used was conducted by Finitzo-Hieber and Tillman in 1978. They studied the monosyllabic word recognition ability of two groups of children in rooms with varying acoustical conditions. Each group consisted of 12 children; one group had normal hearing and the other group had moderate hearing losses bilaterally. The children were instructed to repeat words presented through a loudspeaker placed 12 feet in front of the youngsters. Test conditions included three reverberation times, ranging from 0.4 to 1.2 seconds, in combination with four signal-to-noise ratios, ranging from 0 to +12 dB. Results were expressed in terms of the percentage of correctly repeated words. This approach is direct and unambiguous and gives a representation of the speech intelligibility in various acoustical conditions.

In order to develop a more practical and economical procedure to measure intelligibility in auditoriums, Nordlund, Kihlman, and Lindbald conducted a study in 1968. A loudspeaker with acoustical characteristics similar to the human voice was placed in the speaker's position and was used to present nonsense monosyllables. Stereophonic recordings of the nonsense syllables were made in different listener positions through an artificial head with a microphone placed in each ear. These recordings were later reproduced through earphones to a group of 12 subjects with normal hearing. This method enabled each subject to listen in various simulated positions. The variability caused by many different listeners was therefore minimized, and only the acoustical characteristics of the room influenced the results. In order to validate this procedure, scores obtained through the artificial head were compared to scores obtained with direct listening by a group of 30 students. The results were found to show satisfactory congruence, and the researchers concluded the stereophonic recordings were a satisfactory and efficient way to measure speech intelligibility in auditoriums.

Researchers have used various strategies in their attempts to develop effective measures of speech intelligibility. One of these techniques has made use of the principles used in obtaining the subjective measure of speech intelligibility (Peutz, 1971). Others' techniques have evolved their measures from calculation schemata developed for intelligibility measurements across telephone lines (Houtgast & Steeneken, 1973; Kryter, 1962).

Peutz (1971) based his objective measure of speech intelligibility on the measurement of the articulation loss for consonants. The percentage of consonants in word lists which were misunderstood was used to determine the speech intelligibility in rooms. Peutz found that this measure was dependent on reverberation time, signal-to-noise ratio, and distance to the sound source. A formula to calculate the percentage of the articulation loss for consonants (% AL_{cons}) was developed based on these variables. This formula correlated well with Peutz's subjective measure of the articulation loss for consonants. The % AL_{cons} formula for determining speech intelligibility is easy to use and also has the advantage of face validity since it correlates well with the subjective measurements of intelligibility.

The other objective measures of speech intelligibility have been developed from direct calculations of physical parameters of transmission channels, most typically those of telephone lines. These calculations have been applied to determine the speech transmission quality of various rooms, generally auditoriums. French and Steinberg (1947) published a method of predicting the speech intelligibility of a transmission channel from its physical parameters. Their method, the Articulation Index (AI), divides the speech spectrum into 20 frequency bands, each of which is thought to make an equal and independent contribution to the overall speech recognition performance. The signal-to-noise ratio in a given band is used to determine whether the band contributes fully, partially, or not at all toward overall speech recognition performance.

This method was reconsidered by Kryter (1962) who greatly increased its usability by introducing a calculation scheme to determine the Articulation Index. It was found that the Articulation Index was appropriate and accounted for distortions in the frequency domain, such as interfering noise. It did not, however, prove accurate when distortions in the time domain, such as reverberation and echoes, were involved.

In order to account for distortions in the frequency domain as well as those in the time domain, Steeneken and Houtgast (1980) developed the Speech Transmission Index (STI) which represents an extension of the Articulation Index. Initially, they based their work on the concept of the Modulation Transfer Function (MTF), which quantifies the transmission path by a decrease in modulation depth as a function of modulation frequency

(Houtgast & Steeneken, 1973). The Modulation Transfer Function is derived from an acoustical analysis of a test signal at the listener's position, and it includes the influence of reverberation, echoes, and interfering noise. In the same study, Steeneken and Houtgast computed the weighted Modulation Transfer Function, which is a weighted sum of individual contributions in different frequency regions, and compared it to the subjective intelligibility measurements made using Phonetically Balanced (PB) words in Dutch for 68 conditions. They found the accuracy of the weighted Modulation Transfer Function to be within 4% of the subjective PB-word score.

A refinement of the Modulation Transfer Function by Steeneken and Houtgast (1980) led to the development of the Speech Transmission Index. The Modulation Transfer Function provides a calculation scheme to determine a single index to express the speech intelligibility in rooms. This is known as the Speech Transmission Index. It was compared to the subjective intelligibility measures obtained by trained subjects listening to meaningless consonant-vowel-consonant (CVC) words embedded in a short carrier phrase. Results of the study showed that the difference between the actual intelligibility scores and those predicted by the speech transmission index was less than 5.6%.

Houtgast, Steeneken, and Plomp (1980) conducted another study to describe a calculation scheme for the Speech Transmission Index which incorporated other variables that influence speech intelligibility in rooms. These other variables included the volume of the room, the reverberation of the room, the ambient noise level, the talker's vocal output, and the talker-to-listener distance. The researchers derived the Speech Transmission Index mathematically from the design specifications of auditoriums and found that the index was related to experimental data and various rules in auditorium acoustics.

Houtgast (1981) conducted a study in which he obtained data on speech intelligibility in various classrooms by means of the subjective measurement of the percentage of articulation loss of consonants (% AL_{cons}) method. He then correlated these measurements with the values obtained by calculating the Speech Transmission Index. Ten teachers administered the test to 202 students without providing visual cues. The conclusions indicated that the percentage of articulation loss for consonants (% AL_{cons}) correlated highly with the Speech Transmission Index calculations made for each of the classrooms.

The concept of Speech Transmission Index has undergone further modifications leading to the development of the modified Speech Transmission Index (mSTI) (Humes, Dirks, Bell, Ahlstrom, & Kincaid, 1986) and the sound field version of the Speech Transmission Index (STI_x) (Humes, Boney, & Loven, 1987). The mSTI has incorporated the advantageous features of the Articulation Index and the Speech Transmission Index. The STI_x includes the effects of the directivity of the speech source and listener, since these variables affect speech recognition performance in sound fields.

Another important modification of the Speech Transmission Index has been the evolution of a simplified version called the Rapid Speech Transmission Index (RASTI) as a screening method for assessing speech intelligibility in auditoriums (Houtgast & Steeneken, 1984). The Rapid Speech Transmission Index varies between 0 and 1 and serves as a measure of speech intelligibility. It is based on the measurement of the reduction in signal modulation that occurs between the speaker's and listener's positions. This measure accounts for effects of both background noise and reverberation. The merits of this method were evaluated by the International Electrotechnical Commission in 1984. RASTI measurements and articulation tests were conducted in 11 countries in 14 auditoriums with various degrees of noise and reverberation. It was found that the RASTI measurements were in agreement with the average behavior of seven articulation tests. This measurement therefore seems to hold promise as a simplified way to assess speech intelligibility in rooms.

Studies have indicated that both subjective and objective measures of speech intelligibility have been successful in assessing acoustical conditions in rooms. The materials used for subjective intelligibility measures have typically been monosyllabic words with both meaningful, phonetically-balanced words and consonant-vowel-consonant nonsense words being used. It has been recommended that a carrier phrase be used in the presentation of these words, as the absence of a carrier phrase reduces the relative importance of reverberation (Houtgast & Steeneken, 1984). In most of the studies in which subjective measures have been used, researchers have used young adults as subjects and only three studies (Blair, 1977; Finitzo-Hieber & Tillman, 1978; Houtgast, 1981) have used children in classrooms as their subjects.

The objective measures have used indices to account for as many acoustical conditions in a room as possible. These indices have been validated by means of subjective scores obtained on various subjective tests. A screening version called the Rapid Speech Transmission Index (RASTI) was developed to make it possible to obtain a speech intelligibility score more quickly, and this method was found to be valid (Houtgast & Steeneken, 1984). Electronic equipment to help in the derivation of the RASTI and the Speech Transmission Index (STI) has been developed (Houtgast & Steeneken, 1984). Apparatus for the measurement of the RASTI and STI is now commercially available from both Bruel & Kjaer and Techron Instruments. These instruments have been standardized to comply with the International Electrotechnical Commission's recommendations in the "Report on the RASTI Method for the Objective Rating of Speech Intelligibility in Auditoria" (1984).

Despite the fact that there are now equipment and methodology to obtain objective measures of speech intelligibility quickly and easily, very little emphasis has been placed on using this technology in classrooms where acoustical conditions are of critical importance. Only in the study by Houtgast (1981) has a researcher compared objective measures of speech intelligibility in classrooms with subjective measures obtained by children in the classrooms. More information of this nature was needed to assess the use of objective measurements of speech intelligibility in classrooms. Therefore the present study was aimed at correlating the RASTI score, an objective measure of speech intelligibility, and the Word Intelligibility by Picture Identification (WIPI) test administered as a group test to elementary school children. The tests of speech intelligibility used were different from those used by Houtgast (1981) in his study.

PURPOSE AND OBJECTIVES

The objective measures of speech intelligibility have been validated by means of subjective measurements using talkers and listeners. All the objective measures of speech intelligibility have been used in auditoriums in the past, and it is only recently that this technology has been applied to classrooms to enhance the listening environment. This application to classrooms is important as it is critical to know the speech intelligibility in rooms where learning takes place through the auditory channel.

The RASTI measure, one of the objective measures, has been used in some research (Leavitt & Flexer, 1991) to determine the speech intelligibility of classrooms. While this measure has been shown to correlate highly with subjective tests of speech intelligibility with adult subjects (Houtgast & Steeneken, 1984), there has been no research to validate its use with children in classroom environments. Additionally, there is no information on the efficiency of the use of the average or the largest of a set of RASTI scores obtained at a position. Only the largest value has been considered in the past (Leavitt & Flexer, 1991).

The purpose of this study was to correlate RASTI scores with subjective word discrimination scores obtained from children in a classroom. This study also sought to determine if the average or the largest of three RASTI values obtained at a given position correlated best with the subjective word scores.

The objectives of this study were as follows:

1. To determine if the RASTI values are a valid predictor of speech intelligibility for elementary school children with normal hearing.

2. To determine if there are differences in the predictive ability of the RASTI in a lower elementary classroom (grades 1, 2, & 3) and grade 5 classroom.

3. To determine if the average or the largest of the three RASTI values obtained at a given position correlates best with the subjective word score obtained on elementary school children.

The research questions that this study answered were as follows:

1. Will there be a correlation between the RASTI values and the word discrimination scores for all elementary school children with normal hearing?

2. Will there be a correlation between the RASTI values and the word discrimination scores for all the lower elementary children with normal hearing?

3. Will there be a correlation between the RASTI values and the word discrimination scores for all the fifth grade children with normal hearing?

4. Is the correlation obtained in the lower elementary grade significantly different from the correlation obtained in grade 5?

5. Does the average or the largest of the three RASTI values correlate better with the subjective scores obtained on elementary school children?

PROCEDURES

Population and Sample

The target population for this study was elementary school children with normal hearing sensitivity. The accessible population was children enrolled at Edith Bowen Laboratory School. The sample included all children with normal hearing in two classrooms of the school. One classroom was grade 5 and the second classroom contained children of grades 1, 2, and 3. Children from one classroom of grade 1 could not be included in the study, as originally planned, because this school had formed "learning communities" for the younger elementary children. Each "learning community" contained an equal number of children from grades 1, 2, and 3. The children in the "learning community" were between 7 years and 9 years of age and included 11 males and 12 females. The children in grade 5 were between 10 years and 11 years of age and included 12 males and 10 females. All the children were Caucasians with the exception of three children who belonged to different ethnic populations.

As the intelligibility in most elementary school classrooms is similar, it was not necessary to test all classrooms in the school. However, because there is maturation of attention and auditory skills during the elementary school years, it was decided to include students of a lower elementary grade and an upper elementary grade in the sample. Because the RASTI value reflects speech intelligibility for listeners with normal hearing, only students with normal hearing sensitivity were included in the sample.

Specific Procedures

The study was conducted with prior permission from the principal, classroom teachers, and parents. A letter explaining the test procedures and requesting permission for the children to participate in the study (see Appendix A) was sent home with each child before the testing. None of the parents refused participation of their child in the study.

A pure tone hearing screening for all children in the study was conducted within two days prior to the classroom measurements of speech intelligibility. The American Speech-Language-Hearing Association's Guidelines for Identification Audiometry (ASHA, 1985) were followed. A rescreen was conducted after the initial screening, and those children who failed the rescreen were referred for further management (see Appendix B). The data obtained from students who passed the rescreen was included in the analyses. The students who failed the screening participated in the classroom measurements so as not to call attention to their failure, but their data was excluded from the analyses.

It was necessary to have two measures of speech intelligibility at each student's position. The subjective measure of speech intelligibility was made first as it was hoped that the children would pay maximum attention in the beginning of the session. The word discrimination test which was administered was the Word Intelligibility by Picture Identification (WIPI) test by Ross and Lerman (1970).

The WIPI is a test that requires the child to select the correct response from six choices. This test uses a vocabulary level corresponding to an age of 4 years, 6 months, so it was felt that it was appropriate for both groups of students.

A recording of the WIPI test was made from the compact disc version of the "Speech Audiometry Materials" produced by the Hearing and Speech Sciences Laboratory at Brigham Young University (Harris, 1991). The list recorded by the male talker was replayed to the students in each classroom with the presentation level being 70 dB SPL at one meter. This level was set to match the level of the RASTI signal presented 10 dB above the reference level of the instrument. This level is also very close to the intensity of the average long-term spectrum of speech at that distance (69 dB SPL at one meter; Beranek, 1949). The loudspeaker was set at the same height as the researcher's mouth. The tape was stopped as necessary to provide time for the students to respond.

A pilot study was conducted with the subjective speech intelligibility test to determine the accuracy of administration of the word discrimination test. Ten children belonging to a lower elementary grade participated in the pilot study. Results indicated that the procedures followed to administer the word discrimination test were appropriate.

The WIPI was administered to each class simultaneously. Before the administration of the test, all students were assigned identification numbers that were recorded on answer sheets. The students' responses were a "mark the picture task" for the lower elementary graders and a "mark the word" task for the fifth graders. The testing session was monitored by the teacher and the researcher to ensure that the procedure was followed.

The RASTI measurement, the objective measure of speech intelligibility, was made at each of the student's positions. The measurement was coded with the same identification number assigned for the subjective measure. The transmitter unit was set in the teacher's position, and the receiver microphone was placed at the ear level of each child using a headband (see Appendix C). The presentation level was set to "ref+ 10 dB" (the reference level on the RASTI being 55 dB SPL at the 0.5 kHz octave and 59 dB SPL at the 2 kHz octave). Three measurements were made at each position. The average of the three values and the largest of the three values were recorded.

Both the word discrimination test and the RASTI measurements were conducted on the same day in the lower elementary classroom. This could not be done in the grade 5 classroom due to time constraints. The measures were conducted on two successive days with care taken to make sure that the students were in the same position for both the measurements. When the RASTI measurement was made, the researcher was "blind" to the score of each student on the first measure in both classrooms.

Data and Instrumentation

The Bruel & Kjaer RASTI equipment, model number 3361, which consisted of the transmitter type 4225 and receiver type 4419, was used as a screening instrument for the objective measure of speech intelligibility. Care was taken to verify that the instrument was functioning according to the manufacturer's specifications before making the measurements. A stereo cassette deck (Technics M234X) with an Eico amplifier was used to present the words through an Altec loudspeaker for the discrimination test. The level of the speech was measured with a Larson-Davis 800B sound level meter before the presentation of the test in each room.

Each of the student's response sheets for the word discrimination task was marked with an identification number corresponding to the child's position in the classroom. The response sheets were checked for accuracy by the researcher, and a percentage correct score was calculated. Because there was no subjectivity involved in scoring of the test sheets, there was no need for inter-observer agreement for this measure. The RASTI value measured at each child's position had the same identification number as the response sheet.

Analysis

A correlation coefficient between RASTI values and the word discrimination scores was calculated to determine if the RASTI values are a valid predictor of speech intelligibility for elementary school children with normal hearing. A correlation coefficient was also calculated for each grade separately. The statistical significance of the difference between the correlation coefficients for the lower elementary classroom and grade 5 was calculated to assess the differences in the predictive ability of the RASTI in the lower elementary classroom and grade 5. The average and the largest RASTI values were to be considered for each of these calculations.

The proportion of the variability that scores on the two variables have in common (r^2) and the proportion of variability not explained by the relationship ($1-r^2$) were also calculated. These results are reported and the implications are discussed in the next section.

RESULTS AND DISCUSSION

The total number of children whose data was analyzed was 45. The classroom which contained children from grades 1, 2, and 3 had 28 students. One child did not pass the hearing screening, and four students were absent on the day the measurements were made. There were therefore 23 lower elementary students included in the study. There were originally 27 children in the grade 5 classroom. Three of them did not pass the hearing screening, and two children were absent on the day the measurements were made, leaving a total of 22 children in grade 5 who participated in the study. In both classrooms the children were within 20 feet of the loudspeaker and the RASTI transmitter during all testing. See Appendix D for a pictorial layout of the two classrooms and Appendix E for the WIPI test scores and RASTI values obtained on three trials in the two classrooms. The noise levels in both classrooms were close to 65 dBA and were found to agree with previous findings of noise levels in quiet classrooms filled with students (Berg, 1987). The reverberation time at the center of both classrooms was approximately 0.5 seconds when the subjects were not present.

When the RASTI data was analyzed, it was found that the mean RASTI value for all positions was 0.71 when using the average of the three RASTI measurements and 0.76 when using the largest of the three measurements. The range of values, mean data, and standard deviations for all RASTI measurements in all positions are reported in Table 1. The data for each of the three measurements for each position in both classrooms revealed minimum values ranging from 0.59 to 0.62 and maximum values ranging from 0.86 to 0.88. For each measurement the mean value for all positions was between 0.70 and 0.73 and the standard deviation was either 0.05 or 0.06. For the average RASTI value, the values ranged from a minimum of 0.64 to a maximum of 0.87 The mean was 0.71 with a standard deviation of 0.04. The largest RASTI value ranged from 0.68 to 0.88 with a mean of 0.76 and a standard deviation of 0.04.

Table 1

Minimum, Maximum, and Mean RASTI Values With Standard Deviations Obtained in Two Elementary School Classrooms

	Minimum Value	Maximum Value	Mean	Standard Deviations
RASTI-1	0.62	0.86	0.71	0.05
RASTI-2	0.59	0.88	0.73	0.05
RASTI-3	0.59	0.87	0.70	0.06
RASTI-Average	0.64	0.87	0.71	0.04
RASTI-Largest	0.68	0.88	0.76	0.04

Since the mean RASTI values obtained using the average of the three measurements and those obtained using the largest value were similar, it was decided to use only the largest RASTI value for subsequent analysis. This is in agreement with the procedures used by previous researchers (Leavitt & Flexer, 1991).

Objective One

The first objective was to determine if RASTI values are a valid predictor of speech intelligibility for elementary school children with normal hearing. The largest RASTI values ranged from 0.68 to 0.88 with a mean of 0.76 and a standard deviation of 0.04. The WIPI scores ranged from 84% to 100% with a mean of 96.88% and a standard deviation of 3.99%. In order to determine the relationship between the subjective WIPI scores and the objective RASTI values, a correlation coefficient was computed. The correlation coefficient was 0.06, revealing that there was a very poor relationship between the largest RASTI values and the WIPI scores of elementary school children in the study.

There are several factors which possibly contribute to the lack of relationship found between the WIPI scores and the RASTI values. The word discrimination test yielded very high scores with a mean of 96.88% for all students. This indicated that the test was too easy for the subjects, thus creating a ceiling effect which made it impossible to determine differences in performance among the children. The ease of the word recognition test using the WIPI test is likely due to the closed-set response paradigm, the level of presentation, the use of a carrier phrase for presentation of the words, and/ or the use of meaningful words.

The WIPI test required students to guess which of six words was presented; therefore it is possible that the scores were inflated because of guessing. The test was also administered at a level suitable for comfortable listening so the children did not have to strain to listen to the test words. Lastly, the test words were presented with a carrier phrase and were meaningful, thus increasing their intelligibility.

Another factor which likely decreased the relationship between the WIPI scores and the RASTI values was the lack of variability in the RASTI values. The positions in which the RASTI measurements were obtained were within 20 feet of the RASTI transmitter and were only about 3 feet apart. As the positions were very close to each other, there was very little variability in the RASTI values.

Objectives Two and Three

The second and third objectives were to find the relationship between the RASTI values and the WIPI scores for each classroom separately. Table 2 shows the range of values, means, and standard deviations for the RASTI values and the WIPI scores in each of the classrooms.

In the lower elementary classroom, the largest RASTI values ranged from 0.68 to 0.88 with a mean of 0.76 and a standard deviation of 0.05. The WIPI scores ranged from 84% to 100% with a mean of 94.26% and a standard deviation of 3.97%. A correlation coefficient of 0.11 was obtained between the RASTI values and the WIPI scores for the lower elementary children. This again indicated a poor, but positive relationship between the two variables. The proportion of variability that the two scores have in common (r^2) was found to be only 1.21%. This indicated that a large degree of the variability in the measurements remained unexplained.

Table 2

Minimum, Maximum, and Mean Scores With Standard Deviations Obtained in Each of the Classrooms

	Minimum Value	Maximum Value	Mean	Standard Deviation
RASTI-Largest (grade 1, 2, 3)	0.68	0.88	0.76	0.05
WIPI scores (grade 1, 2, 3)	84%	100%	94.26%	3.97%
RASTI-Largest (grade 5)	0.68	0.86	0.76	0.03
WIPI scores (grade 5)	96%	100%	99.64%	1.18%

The largest RASTI values ranged from 0.68 to 0.86 with a mean of 0.76 and a standard deviation of 0.03 in the grade 5 classroom. The WIPI scores ranged from 96% to 100% with a mean of 99.64% and a standard deviation of 1.18% . A correlation coefficient of -0.05 was obtained between the RASTI values and the WIPI scores in the grade 5 classroom. This implied essentially no relationship between the RASTI values and the WIPI scores. The proportion of variability explained by the scores on each of the two variables in this case was found to be only 0.23%.

As stated earlier, the reasons for the poor relationships may be the subjective word discrimination test used and the administration procedure of the word test. The distances at which the RASTI values were obtained may have also contributed to the lack of relationship.

Objective Four

In order to determine if there was a difference in the ability of the RASTI values to predict the subjective word discrimination scores between the two groups of children, the correlation coefficients in the two classrooms were compared using a chi-square analysis (Cochran & Cox, 1957). A chi-square value of 0.16 was obtained with a degree of freedom of 1 and this value was not significant.

This result suggested that there is no significant difference between the correlations obtained in the lower elementary classroom and the grade 5 classroom. This is due to the poor correlations obtained in both classrooms because the RASTI values were similar in both classrooms and a majority of students in both the classrooms scored near 100% on the WIPI test.

Objective Five

The fifth objective was to determine whether the average or the largest of the three RASTI values best predicted the WIPI scores. The largest of the RASTI values has been used in the past to predict the subjective speech intelligibility at a given position. It was believed that the average of three values might better represent the RASTI values obtained at a given position. Therefore an analysis was done to determine which of the two values best predicted the WIPI scores. Table 3 shows the correlation of these two RASTI values with the WIPI scores in each classroom separately and for all students.

Table 3

Correlations Between RASTI Values and WIPI Scores for Each Classroom Separately and for All Students Combined

	WIPI Scores		
	Grades 1, 2, 3	Grade 5	Overall
RASTI-Average	0.02	0.27	-0.01
RASTI-Largest	0.11	-0.05	0.06

Chi-square values were calculated to determine the statistical significance of the difference between the correlation coefficients obtained with the average and the largest RASTI values and the WIPI scores for each group. Chi-square values of 0.09, 0.09, and 1.00 were obtained for the whole group, for the lower elementary grade, and for grade 5, respectively. These chi-square values were obtained with a degree of freedom of 1, and none were found to be significant. As it was found that the differences between correlations obtained with the average RASTI values and the largest RASTI values were not statistically significant, it was determined that the largest RASTI value could be used for the analysis of the data.

These results also suggested that neither the largest nor the average of three RASTI values could be used to predict WIPI scores in classrooms for elementary children. Additionally a correlation coefficient of 0.85 was obtained between the average and the largest of the three RASTI values. This is in agreement with prior research, indicating that the RASTI values obtained in a particular location are indeed reliable.

CONCLUSIONS AND RECOMMENDATIONS

The study aimed at determining the value of the RASTI as a predictor of speech intelligibility in classrooms. The results indicated a very poor relationship between the RASTI values and the subjective word discrimination test (WIPI) scores obtained for children with normal hearing in two classrooms in an elementary school.

The largest RASTI value was compared to the average RASTI value to determine if one was more predictive of the word discrimination test scores which were measured. It was found that there was essentially no difference between the two values for either classroom or for the total group.

The reasons for the poor relationships between the subjective and objective measures of speech intelligibility may be due to the lack of variability in scores obtained on both the WIPI test (subjective) and the RASTI values (objective). The reasons for the lack of variability seen on the WIPI test and the RASTI values have been discussed in the previous section.

Another factor which may account for the results of this study is the interpretation of the RASTI values and the WIPI scores. The range of RASTI values from 0.75 to 1.00 is considered to be in the excellent range, while the range of scores on the WIPI test considered to be excellent is from 92% to 100%. Therefore, most of the RASTI values and WIPI scores were in the excellent range. If one were to use the descriptive categories for both RASTI values and WIPI scores, there would be excellent correlation between the scores obtained using either method. However, at the present time there seems to be no convenient way to correlate these subjective values.

Before the RASTI can be used to predict the subjective intelligibility scores in a classroom, further research needs to be done to establish the relationship of the RASTI and a subjective speech intelligibility test in classrooms. Based on results obtained in this study, it is recommended that :

1. This study be replicated with adult listeners in classrooms with more difficult words and an open-set response paradigm to confirm the validity of the RASTI in small rooms.

2. The subjective word intelligibility test used with children be made more difficult by using nonsense syllables or an open-set response task.

3. Sentence tests be used if possible since they approximate speech in everyday listening situations better than single words or nonsense syllables.

4. The tests be administered using live voice to simulate an actual classroom listening situation. If this is not possible, the level of presentation used for the presentation of the subjective measure should be similar to the level of the voice of the teacher of that grade. Additionally, the use of a signal-to-noise ratio representative of classes at that grade level should be considered.

5. Children in the other elementary grades be included in future study.

6. The variability of both the RASTI and the subjective speech intelligibility scores be increased by scattering the listeners in different locations around the classroom.

7. A method to interpret the RASTI values and the word discrimination scores in

descriptive categories be investigated.

8. These same tests be tried with varying signal-to-noise ratios and reverberation times in the classrooms to determine if the relationship between these two measures is affected by different listening environments.

Previous studies have shown a good relationship between subjective word intelligibility scores of young adults and RASTI values in auditoriums (Houtgast & Steeneken, 1984; IEC, 1984). These previous results contrast sharply with the findings of this study, where poor relationships were found between RASTI values and the WIPI test scores using elementary children in classrooms. Only by systematically measuring the relationship between the subjective and objective measures of speech intelligibility can the use of RASTI in classrooms be validated. Further research is necessary to determine if the RASTI measure can be validly used as a predictor of speech intelligibility in classrooms.

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Appendixes

Appendix A: Letter of Explanation and Permission for Participation in the Study

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322-6700
Edith Bowen Laboratory School
telephone (801) 750-3085

November 26, 1991

Dear Parents:

As a part of our role as a laboratory school, we assist USU faculty and graduate students with research projects. Before approving a research project we review the procedures to assure that: 1) students will **not** be harmed; 2) confidentiality of each student will be protected; and, 3) procedures will **not** interfere unduly with classroom learning time.

One project we have approved is being conducted by Aparna Rao, a graduate student in the Communicative Disorders program working under the direction of Dr. James C. Blair. The study involves evaluating the intelligibility of speech at various positions in the classroom.

The study has three phases — a hearing screening and two tests of speech intelligibility. First, students will be given an individual hearing screening that takes about 10 minutes to perform. Parents will be given the results of this hearing screening. Next, two tests of speech intelligibility will be done at each student's desk. For the first test, children will listen to a recorded words and mark an answer. This will be a group test taking about 20 minutes. The second test will involve placing a microphone on a headband at the ear-level of each child and making a measurement of sound intensity. This test will take about 2 minutes per child and will be performed during quiet reading time.

Two classrooms were selected to participate in the study — Ms. Rhees' Learning Community and Ms. Dobson's fifth grade class. This letter is to inform you that the study will be conducted during the first two weeks of December, 1991. If you do not want your child to participate, please call me at 750-3085 by Tuesday, December 3, 1991.

Sincerely,

Thomas Shuster
Research and Development Coordinator

Appendix B: Letters Explaining Results of the Hearing Screening and Recommendations for Follow up

UTAH STATE UNIVERSITY • LOGAN, UTAH 84322-1000

DEPARTMENT OF COMMUNICATIVE DISORDERS
Speech-Language-Hearing Center
(801) 750-1375

December 16, 1991

Dear Parent:

Your child ____________ has failed the hearing screening conducted on ____________ and the rescreening conducted on ____________ in the Edith Bowen Laboratory School.

If this is not a known hearing loss, it may be that the hearing loss is temporary and may resolve itself. However, it is recommended that you seek medical consultation or an audiological evaluation to determine the nature of the hearing loss. If you are interested in an audiological evaluation, you may schedule an appointment at the USU Speech-Language-Hearing Center by calling 750-1375 after January 6, 1992. Please indicate that you were referred from the Edith Bowen Research Project, and you will not be charged for the testing. If you have questions about the screening, please call Peggy Von Almen at 750-1375 prior to December 20, 1991.

Thank you for permitting your child to participate in the study.

Sincerely,

Aparna Rao

Aparna Rao
Graduate Student

Peggy Von Almen

Peggy Von Almen, Ed.S, CCC-A
Audiology Supervisor

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UTAH STATE UNIVERSITY · LOGAN, UTAH 84322-1000
DEPARTMENT OF COMMUNICATIVE DISORDERS
Speech-Language-Hearing Center
(801) 750-1375

December 16, 1991

Dear Parent:

Your child ____________ was absent for the hearing screening. If you have any concerns, regarding his/her hearing you may call the USU Speech-Language-Hearing Center at 750-1375 for a screening which will be done after January 6, 1992. Please indicate that you were part of this research study so that you will not be charged.

Thank you for permitting your child to participate in the study.

Sincerely,

Aparna Rao
Aparna Rao
Graduate Student

Peggy Von Almen
Peggy Von Almen, Ed.S., CCC-A
Audiology Supervisor

kr

UTAH STATE UNIVERSITY • LOGAN, UTAH 84322-1000
DEPARTMENT OF COMMUNICATIVE DISORDERS
Speech-Language-Hearing Center
(801) 750-1375

December 16, 1991

Dear Parent:

Your child ____________ has passed the hearing screening conducted on ____________ in the Edith Bowen Laboratory School. Thank you for permitting your child to participate in the study.

Sincerely,

Aparna Rao

Aparna Rao
Graduate Student

Peggy Von Almen

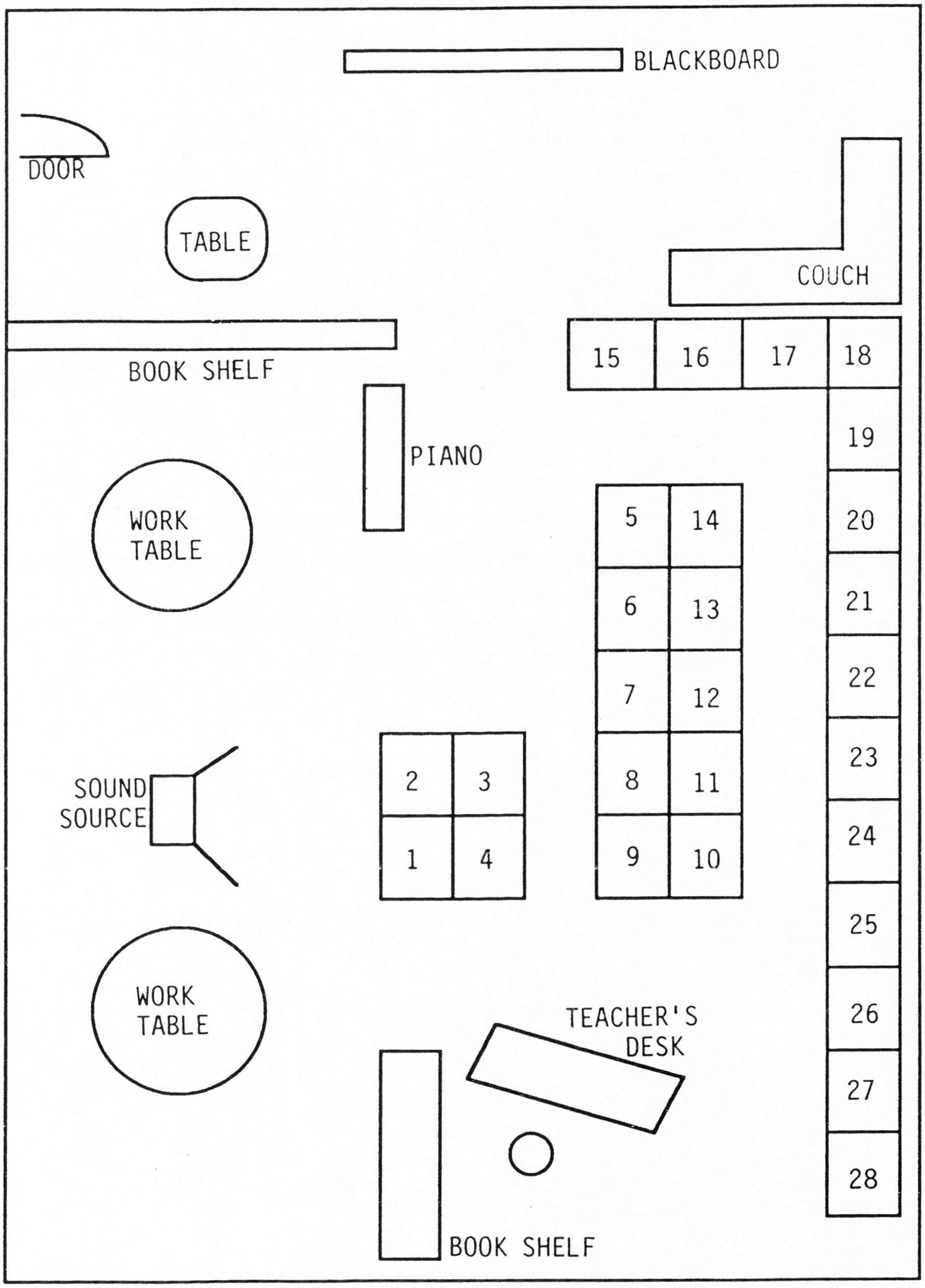
Peggy Von Almen, EdS, CCC-A
Audiology Supervisor

kr

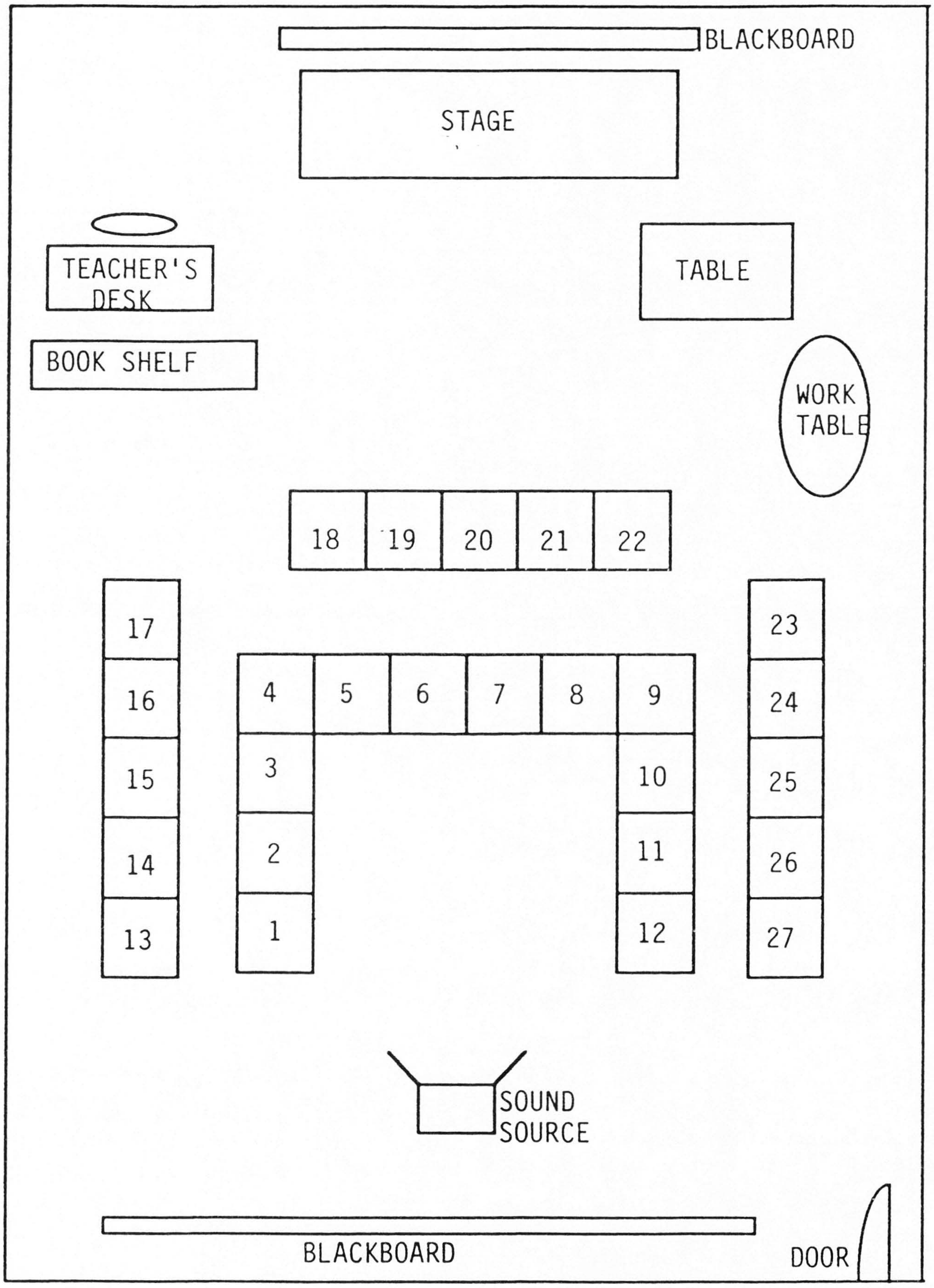
Appendix C: Picture of the RASTI Receiver Microphone Placed on a Child

Appendix D: Layout of the Classrooms Used in the Study

Classroom of Grades 1, 2, 3



Grade 5 Classroom



Appendix E: WIPI Test Scores and RASTI Values Obtained on Three Trials in Grades 1, 2, 3 and Grade 5

Grades 1, 2, 3

Subject Numbers	WIPI Scores	RASTI Trial 1	RASTI Trial 2	RASTI Trial 3
1	92%	0.86	0.88	0.87
2	96%	0.81	0.84	0.86
3	100%	0.86	0.78	0.80
4	100%	0.72	0.70	0.68
5	96%	0.73	0.71	0.75
6	88%	0.71	0.68	0.75
7	96%	0.68	0.72	0.66
8	Absent			
9	96%	0.72	0.75	0.61
10	92%	0.79	0.75	0.77
11	100%	0.70	0.75	0.79
12	Absent			
13	88%	0.74	0.71	0.72
14	Did not pass hearing screening			
15	96%	0.67	0.68	0.60
16	96%	0.71	0.60	0.66
17	96%	0.69	0.66	0.72

Subject Numbers	WIPI Scores	RASTI Trial 1	RASTI Trial 2	RASTI Trial 3
18	96%	0.67	0.71	0.70
19	92%	0.63	0.76	0.62
20	96%	0.74	0.59	0.61
21	92%	0.69	0.68	0.74
22	Absent			
23	92%	0.71	0.76	0.71
24	96%	0.71	0.75	0.65
25	Absent			
26	96%	0.72	0.81	0.59
27	84%	0.72	0.69	0.67
28	92%	0.77	0.78	0.71

Grade 5

Subject Numbers	WIPI Scores	RASTI Trial 1	RASTI Trial 2	RASTI Trial 3
1	Absent			
2	100%	0.78	0.79	0.71
3	100%	0.79	0.74	0.72
4	Did not pass hearing screening			
5	96%	0.77	0.68	0.64
6	100%	0.71	0.79	0.76
7	100%	0.68	0.75	0.76
8	100%	0.75	0.74	0.77
9	Absent			
10	96%	0.64	0.76	0.64
11	100%	0.65	0.74	0.74
12	100%	0.71	0.68	0.77
13	Did not pass hearing screening			
14	100%	0.74	0.70	0.65
15	100%	0.74	0.79	0.76
16	100%	0.68	0.67	0.63
17	Absent			
18	100%	0.67	0.71	0.64
19	100%	0.62	0.76	0.67
20	100%	0.66	0.72	0.76

Subject Numbers	WIPI Scores	RASTI Trial 1	RASTI Trial 2	RASTI Trial 3
21	100%	0.65	0.76	0.67
22	100%	0.72	0.75	0.76
23	100%	0.66	0.76	0.76
24	100%	0.73	0.85	0.66
25	100%	0.67	0.69	0.74
26	100%	0.74	0.65	0.67
27	100%	0.71	0.73	0.64