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LOYOLA UNIVERSITY CHICAGO

AN INVESTIGATION OF THE EFFECTS OF SELECTED AUDITORY VARIABLES IN THIRD AND EIGHTH GRADE CLASSROOMS

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE GRADUATE SCHOOL OF
LOYOLA UNIVERSITY OF CHICAGO
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

BY LOREN DAVID MAY

CHICAGO, ILLINOIS

JANUARY, 1993

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As I reflect over the time devoted to this dissertation I am reminded of the many people who contributed to its completion.

The professional growth which I have enjoyed can be attributed to the members of my dissertation committee, who throughout this project, and during all of my work at Loyola, have been most supportive: Dr. Allan Ornstein, director, Dr. Barney Berlin, Dr. Jack Kavanagh and Dr. Kenneth Kaufman. A special thank-you is directed to Dr. Kaufman, whose unfailing encouragement, help, and continued friendship throughout this project was greatly appreciated.

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talents to complete this manuscript and my parents whose encouragement and love never wavered.

Most importantly, I wish to thank my wife, Kathy, whose support and love allowed me to complete this dissertation.

Dedicated to:

Ashley Anne

VITA

The author, Loren David May, was born May 12, 1948 in Kendallville, Indiana. Mr. May received both his Bachelor of Science in education (1970) and his Master of Education Degree (1973) from Miami University. He completed the certification requirements for administration and supervision at Cleveland State University in 1974.

In 1975, following five years of teaching at both the junior high and elementary levels, Mr. May became an administrator in Bensenville, Illinois. During the past seventeen years Mr. May has served as the building principal at Chippewa and Johnson Elementary Schools and Blackhawk Junior High School.

Professionally, Mr. May holds memberships in the International Reading Association, the Association for Supervision and Curriculum Development and the National Staff Development Council.

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CHAPTER I

INTRODUCTION

Ralph Tyler (1984) has advanced the concept that "the more we understand about the factors influencing academic learning, the more complete learning system we have in mind to identify factors that may not be functioning and factors that can be strengthened in order to improve our instructional efforts" (p. 29). Appropriately, during the past decade, educational research has focused on the variables that are alterable and have an effect on the academic achievement of students. This investigation seeks to expand and gain further understanding of two classroom environmental variables previously identified as causing auditory interference in the classroom, as well as one variable believed to enhance the classroom auditory environment.

The first, a physiological variable, is "minimal hearing loss" (MHL). The second, an environmental variable, is "separation distance" between the speaker (teacher) and listener (student). A third and related variable, also environmental, is "noise abatement" (soundproofing) of the

classroom and its effectiveness in mitigating undesirable exterior noise which interferes with speech intelligibility.

It is hypothesized that each variable, hearing loss, separation distance and noise abatement, singularly or in some combination, has an effect on the academic achievement of students. Before developing the background of the problem for these three variables, a theoretical framework, (Figure 1), developed by Denes and Pinson (1973) and utilized in a previous and related study by Kaufman (1985) is presented.

The paradigm describes the different forms in which a spoken message is conceived, initiated or spoken, and transmitted from the mind of the speaker (teacher) to the mind of the listener (student). Thus, the paradigm allows for five different levels of classification: (a) the linguistic level for the speaker, (b) the physiological level for the speaker, (c) the acoustic level for both speaker and listener, (d) the physiological level for the listener, and (e) the linguistic level for the listener.

The paradigm allows for either discrete events or continuous phenomena to be examined. This paradigm is labeled as "The Speech Chain" and is used as the theoretical model to study the effects of MHL as well as the micromediating influences of separation distance and noise abatement. Minimal hearing loss and separation distance were analyzed at the listener's (student's) physiological

level while noise abatement was considered at the acoustical level. The listener's (student's) linguistic level was used to evaluate the effectiveness of treatment.

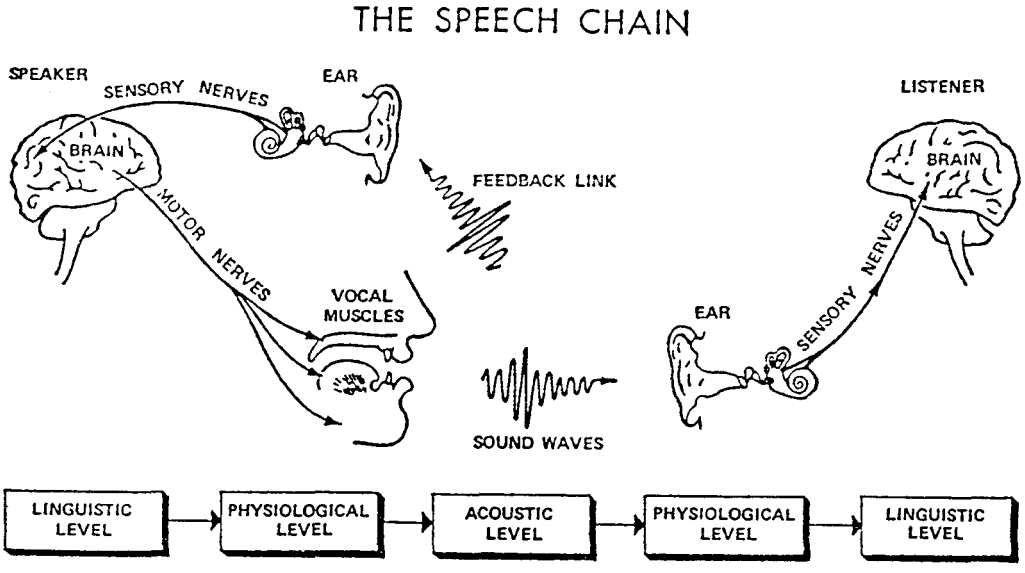


Figure 1: Speech Chain

Source: Figure 1 reproduced from "The Speech Chain", by Peter S. Denes and Elliot N. Dinson, Copyright 1973 by Bell Telephone Laboratories Incorporated. Reproduced by permission of Doubleday and Company, Inc. April 27, 1992

Background of the Problem

A study by O'Falom and Young (1982) concluded that "a school by nature produces noise and by necessity requires quiet" (p. 286). Kaufman (1985) expands this point in noting, "schools must abate and control sounds from within while some schools, particularly those located near large metropolitan airports, must additionally attend to sounds intruding from the exterior" (p. 4). Regardless of its source, however, sound is known to have an impact on students. As Simon (1985) has noted, classrooms are auditory-verbal environments where information is presented through speech with the underlying assumption that students can, in fact, hear the teacher. Therefore, an understanding of the interaction between unwanted noise, hearing acuity and speaker-to-listener separation distance is needed in managing an efficient and effective auditory environment for learners.

Utilizing the speech chain model noted earlier, (Figure 1), this study (a) expands previous voice amplification research in the Bensenville School District into additional and higher grade levels (i.e., grade three and grade eight) and includes an outcome variable other than reading, (b) examines the effect of separation distance on students exhibiting the presence or absence of minimal hearing loss, and (c) considers the effect of noise abatement on student achievement in a selected subject area.

Bensenville, Illinois, a western Chicago suburban community of 17,767 (1990 Census Data, STF 1), is located adjacent to O'Hare International Airport. According to the noise contours developed by the Federal Aviation Administration (FAA) and the City of Chicago, which are reported in the "Chicago O'Hare International Airport 150 Noise Compatibility Planning Study" (1988), two of the sites used in this study, an elementary school, grades K-6, and a junior high school, grades 7-8, are both located in 65-70 LDN (level of noise day and night) noise contours. The third site in the study, an elementary school, K-6, is located in a 70 to 75 LDN noise contour. However, this site has been soundproofed in accordance with FAA guidelines, which has set the classroom standard for acceptable noise level at 45 decibels. The fourth site, also an elementary school, K-6, is located within 400 yards of the 70 LDN noise contour that encompasses both site 1 and site 2.

Kaufman's (1985) research into MHL identified in the first- and second grades a high proportion of students exhibiting minimal hearing loss, sixty-six percent. In addition, he found that in reading, both first- and second-grade subjects benefitted from treatment (voice amplification), but the greater gains were found in the second-grade group.

The present study seeks to extend the initial local research and follows Tyler's (1983) observation that

"efforts to improve the effectiveness of schools cannot be intelligently directed without understanding the dynamics of particular schools" (p. 462), and "improving the functioning of a specific school requires that relevant data be gathered about that school" (p. 464).

Minimal Hearing Loss Problem

Minimal hearing loss (MHL), i.e., hearing that is below the 25 decibel/hearing loss (dB/HL) fence which is used by the State of Illinois (1974) as the cutoff to identify hearing loss, has gradually been acknowledged as an educational handicap. Early work in minimal hearing loss was reported by Quigley (1970), Hughes (1980), and Sarff (1981). More recent research on minimal hearing loss has been undertaken by Jania (1985), Kaufman (1985), Bullerdieck (1986) and Friel-Patti (1990).

A number of these researchers have noted that the standards employed by the State of Illinois relevant to hearing acuity overlook many children, who because of poor hearing do not achieve to their potential in school. They propose that hearing loss be classified on a continuous rather than on a categorical basis.

Many of the identified MHL students can hear in favorable conditions, i.e., face-to-face conversation, but cannot hear effectively in less favorable conditions. Finitzo (1988) reports that these less favorable conditions

can stem from activities such as: (a) "the movement of children, teachers, or desks on hard surface floors, (b) noisy or malfunctioning equipment, and (c) multiple teaching activities that occur simultaneously in the same classroom" (p. 223).

The earlier noted research also stressed the need for early identification and intervention for students identified as having minimal hearing loss. In addition, some of the more recent investigations have identified a greater prevalence of minimal hearing loss in the population than was previously thought (MARRS, 1983; and Kaufman, 1985). It has also been postulated that some minimal hearing loss may be age-dependent and that its most serious effect is interference with linguistic task performance in young children (Sarff, 1981; and Kaufman, 1985).

Separation Distance Problem

Research in the field of classroom noise has identified three major areas that affect speech intelligibility in the classroom: (a) speech-to-noise ratio, (b) reverberation time, and (c) speaker-to-listener distance, commonly referred to as separation distance. These variables have been examined separately and/or in combination in a number of studies, Finitzo (1988), Loven and Collins (1988) and Hygge, Ronnberg, Larsby and Arlinger (1992).

Specifically, separation distance examines the distance between the speaker (teacher) and the listener (student), and its effect on understanding speech communication by the listener. Work by Sarff (1981) and Kaufman (1985) attempted to control for separation distance through the utilization of a voice amplification system, thus reducing separation distance as a factor interfering with speech intelligibility for students identified as having MHL. Thus, without amplification, if a student (listener) is located near a teacher (speaker) the effect of separation distance upon the listener's ability to understand speech is negligible. Whereas, at greater distances from the source, the MHL and/or exterior noise eventually masks speech intelligibility and obstructs speech communication. Therefore, separation distance represents a specific variable in the speech chain within classrooms that may be isolated and examined. This study provides for an analysis of the separation distance question.

Noise Abatement Problem

Noise abatement, as related to the classroom environment, is a method by which certain construction procedures are used to insulate a classroom or school to keep unwanted sound from entering. As noted earlier, Bensenville Elementary School District #2 schools are located in a noisy environment with one school site in the

70-75 LDN noise exposure contour, two school sites in the 65-70 LDN noise exposure contour, and a final site in the 60-65 LDN noise contour as reported in the "Chicago O'Hare International Airport Part 150 Noise Compatibility Planning Study" (1988).

Research by Houtgast (1980), the U.S. Department of Transportation - Federal Aviation Administration (DOT-FAA) (1977), and the U.S. Environmental Protection Agency (EPA) (1978), concluded that 45 dB should be selected as the threshold level for speech interference effects in school buildings. Thus, interior noise which exceeds the 45 dB threshold begins to interfere with speech communication. To remedy speech communication interference, the federal government in the "Airport and Airway Development Act of 1977" (P.L. 94-353), the "Report to Congress" (1977) and Public Law 97-248 (December, 1982) provided funds for the noise abatement of schools.

One of the District #2 schools included in the present study has been soundproofed and brought into compliance with the 45 dB federal limit. The questions of interest addressed in the soundproofing portion of this study focus on whether noise abatement has effectively eliminated noise interference for MHL and non-MHL students, and whether voice amplification and/or the separation distance variables need to be considered once noise abatement procedures have been retrofitted to a school building.

Statement of the Problem

Students who attend Bensenville Elementary District #2 schools are exposed continuously to a high level of noise that varies between 60 LDN and 75 LDN. The most noticeable consequence of this noise is its effect on speech communication in the classroom. At the time of the present research, one school building in the district had been noise abated (soundproofed) to reduce the speech intelligibility interference resulting from excessive noise.

Previous local research has indicated that a high proportion of first- and second-grade students experience some degree of minimal hearing loss and that teacher voice-signal-amplification technology assisted students in academic growth in the area of reading.

Therefore, the present research, which utilizes grades three and eight and employs mathematics as the dependent variable, extends and expands previous minimal hearing loss research. The present research also explores related constructs, i.e., separation distance, and noise abatement in relation to speech intelligibility interference.

Significance of the Study

The negative impact of minimal hearing loss on student achievement in language development and reading at the lower and intermediate grades has been well documented (Kaufman, 1985; Bullerdiech, 1986; and Friel-Patti and Finitzo, 1990).

However, research related to the significance of minimal hearing loss on other school subjects is not as conclusive. This study will examine minimal hearing loss and student achievement in mathematical computation and mathematical reasoning at the third- and eighth-grade levels. The inclusion of these two grade levels will allow for information to be gathered related to the possible age-dependent effect of minimal hearing loss. The study will also consider separation distance as a factor in examining the effects of minimal hearing loss. Finally, the effect of noise abatement (soundproofing) on student achievement in a noisy environment will be explored. The latter two variables, separation distance and noise abatement, have not been fully studied in a naturalistic setting.

Thus, the theoretical implications of the study rest on its potential to expand an empirically derived research base covering minimal hearing loss and student achievement. The study also represents a continuing attempt by the local school district to identify methods and procedures which positively influence students' academic performance in the classroom.

Limitations of the Study

The following are limitations of this study:

- The effects of amplification treatment, separation distance, and a noise-abated environment were limited to ninety-five days.
- The study was undertaken in a naturalistic setting, therefore assignment of individuals on a randomized basis to classes and/or schools was not an option.
- Data on 283 students in grades three and eight, located at four different sites, was collected (i.e., hearing acuity, pre- and posttest mathematics scores in computation and reasoning, aptitude, etc.). However, because of transfers and/or absences only 234 subjects could be utilized.
- Project Marrs procedures, which identified hearing acuity deficits, are based on the weaker of the subjects' two ears. Clinical audiologists identify hearing acuity deficits based on the better of the subjects' two ears.
- This investigation did not address the causes of MHL nor did it attempt to establish a recommendation for a low-fence interval.

- This investigation made no attempt to identify or assess any procedures or strategies that students may have adopted in an attempt to compensate for living/learning in a noisy environment.

Definition of Terms

The following terms are defined as they apply to this study.

Acoustics: The physical characteristics of a room which determine how well sounds can be heard. Acoustical factors which influence speech intelligibility in a classroom are: 1) ambient noise, 2) reverberation (Finitzo-Hieber, 1981) and 3) distance (Crum, 1974).

Academic Achievement: Academic achievement is defined in terms of test performance in mathematics (which includes scores for computation and reasoning). The standardized test utilized was developed by the Scholastic Testing Service, (1986).

Ambient Noise: Interior or exterior sounds that are too weak to interfere with speech or normal listening activities in the classroom.

American National Standards Institute (ANSI): The standards set by the ANSI specify the sound pressure levels that correspond to the normal threshold for both pure tone

and speech stimuli. This study uses the most recent standards.

Decibel (dB): A decibel is a measure of intensity or loudness of sound. The decimal equivalent of a particular intensity ratio is ten times the logarithm to the base of ten of that ratio (e.g., forty dB is ten times as intense as thirty, and 100 times as intense as twenty dB). However, to the human ear the ratio is perceived as 2:1 rather than as 10:1.

Fence: A point used by researchers to denote a demarcation point on a scale for the purpose of dichotomous classification.

Hertz: The international unit of frequency that represents the number of vibrations (cycles) per second. Frequencies are expressed in Hertz (Hz). The human ear responds to frequencies between 20 and 20,000 Hz.

LDN Contour: The official U.S. FAA acronym for level of noise, day and night. The LDN contour is a map with rings circling outward from an airport. Each contour ring is a number which depicts generalized areas within which varying levels of aircraft noise are likely to exist. The LDN is an A-weighted sound level over a 24-hour period including a 10-dB penalty for the nighttime hours between 10:00 P.M. and 7:00 A.M.

Linguistic Task Performance: The reception of oral communication (voice signal) from the speaker (teacher) to the listener (student). The student processes and acts on the oral communication received from the speaker (teacher) in a whole-group instructional setting.

MARRS: The acronym is an abbreviation for Mainstream Amplification Resource Room Study. Project MARRS was developed and implemented in 1977 in three southern Illinois public schools, in grades four, five, and six. Project MARRS provided procedures for the identification and treatment of students with minimal hearing acuity deficits.

Minimal Hearing Loss (MHL): The criteria for defining minimal hearing loss vary. For this study the following upper and lower fences were applied across six frequencies, i.e., five hundred Hz, one thousand Hz, two thousand Hz, four thousand Hz, six thousand Hz, and eight thousand Hz.

Upper Fence: A subject was considered to be beyond the upper fence if s/he: (a) failed to hear any one tone signal at 35 dB in either ear or (b) failed to hear any two tone signals at 25 dB in the same ear.

Lower Fence: A subject was considered to be below the lower fence if s/he heard all tones at the 15 dB in either ear.

Subjects beyond the upper fence were classified as having hearing loss (as differentiated from minimal hearing

loss) and were excluded from the experimental design. Subjects registering thresholds below the upper fence and above the lower fence were classified as MHL cases. Subjects below the lower fence were classified as non-MHL and are included in the posteriori analysis between MHL and non-MHL subjects.

Noise Abatement (Soundproofing): The physical process of reducing or eliminating sound from outside of a structure that is coming through and into the structure.

Otitis Media: Inflamed condition of the ear. Specifically, it is the inflammation of the middle ear or tympanum. It usually occurs as a result of infection spreading up the Eustachian Tubes from the nose, throat or one of the sinuses. Otitis Media may occur as a complication of a cold or tonsillitis.

Reverberation Time: Refers to the presence of sound due to repeated reflections within a given space and is described quantitatively as reverberation time i.e., the time (in seconds) required for sound energy to decrease 60 dB, following termination of the signal.

Speech Chain: A paradigm for describing the process which occurs as a spoken message progresses from the mind of the speaker to the mind of the listener.

Separation Distance: The linear distance between the speaker (teacher) and listener (student) as measured in feet.

Signal-to-Noise Ratio (S/N): The paradigm utilized to evaluate the acoustical acceptability of an environment. This is done by analyzing the difference in decibels between the speech signal and the background noise in a given space. For example a S/N ratio of +3 means that the spoken communication in a particular area is 3 dB greater than the ambient noise in the same area.

Teacher Voice Signal Amplification Treatment: Technology for increasing the intensity and distribution of a teacher's voice signal throughout a classroom environment. The teacher wears a cordless unidirectional microphone which allows freedom of movement and permits oral instruction from any area of the classroom while maintaining a constant voice level.

U.S. DOT-FAA: United States Department of Transportation, Federal Aviation Administration.

Research Problem

The research problem was developed from previous facts, concepts, and theories related to speech communication interference in the classroom setting. Speech communication interference due to minimal hearing loss has been identified by researchers as an overlooked and understudied classroom variable. It is an attribute variable that represents a type of speech communication interference. Within the Bensenville Elementary School District, noise is a pervasive problem with four of the five schools located in the 65-LDN to 75-LDN noise contours of the Chicago O'Hare International Airport. Speech communication interference from jet aircraft is a well documented problem in schools (U.S. DOT-FAA, 1977).

Teacher voice-signal-amplification units were utilized for treatment subjects (experimental) while control subjects did not receive teacher voice-signal-amplification. The research question continuing to be tested is whether the voice-signal-amplification will reduce separation distance and eliminate or reduce noise interference. Therefore, the minimal hearing loss variable is closely aligned to another independent variable, separation distance. Separation distance will also be addressed based upon a model (Figure 2) dealing with noise and space relationships between the speaker and the listener. This paradigm describes the speaker (teacher) to listener (student) separation distance

for reliable communication as a function of the interfering noise level in a school classroom.

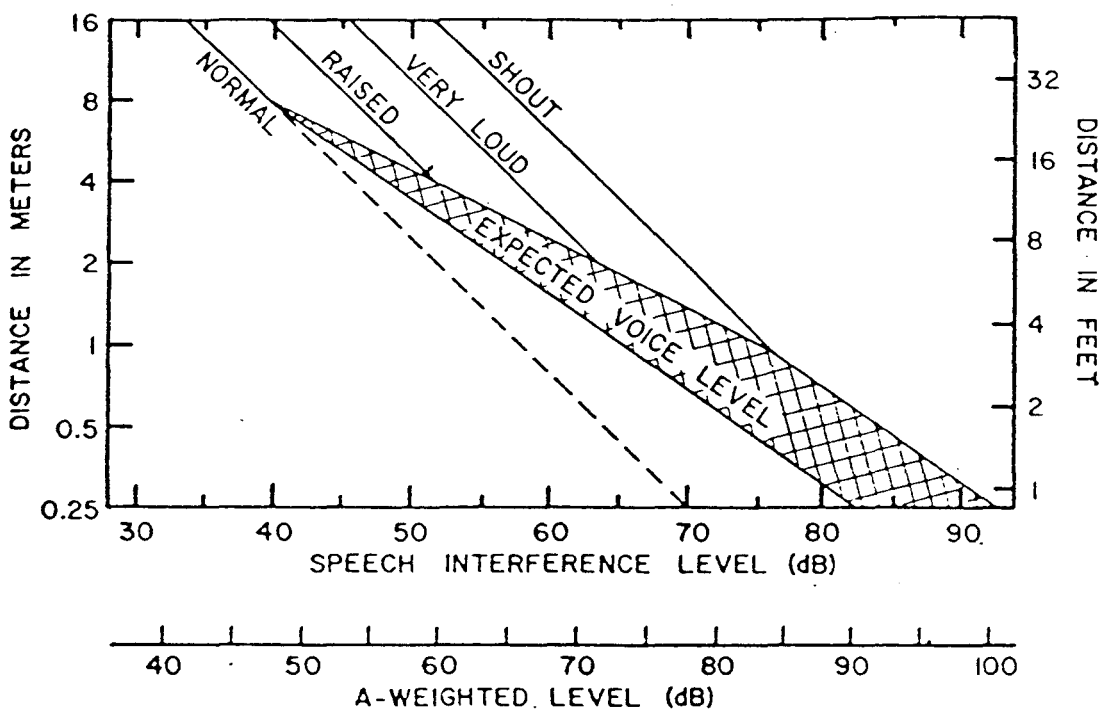


Figure 2: Rating Noise With Respect to Speech Interference - ANSI Standard S 3.14-1977. Reprinted by permission of the Acoustical Society of America, New York, N.Y. July 14, 1992.

The speech intelligibility model was utilized to examine the suspected alterable variable, separation distance. Each classroom in the research setting was divided into three areas for the purpose of examining the separation distance variable. The first area was six feet from the front of the classroom to the front of the teacher's desk, thus developing a "teaching area." From this established zone a second zone that extended from 6 to 12 feet from the front of the classroom was identified and labeled zone A. A final zone which extended from 12 feet to the back of the classroom was then established and labeled zone B. The major research question being tested was the effect of classroom separation distance between speaker and listener on student achievement. A correlating research question examined the possible age-dependent characteristics of students who exhibit MHL.

Finally, this study examined the role of noise abatement and its effect on mitigating speech communication interference in the classroom. Noise abatement was examined in amplified (experimental) and non-amplified (control) classrooms. Noise abatement was also examined in conjunction with the earlier noted separation distance paradigm.

To assess the effect of teacher voice-signal-amplification treatment on minimal hearing loss and its relationship to speech communication interference,

comparison with the minimal hearing loss variable was undertaken. In doing so, the minimal hearing loss factor was represented by two levels, i.e., presence or absence.

In assessing separation distance, the presence or absence of minimal hearing loss was accounted for as well as each subject's location in either zone A or B within each classroom.

To assess the effect of the noise abatement variable, students who attend the noise-abated school environment were analyzed using the following: the presence or absence of MHL, their inclusion into either an experimental or control classroom, and their assigned zone for separation distance. Given this information, students were then compared with similar students in non-abated environments.

The preliminary design shown in Table 1 includes a visual representation of each of the major independent variables examined. The first component of the design assisted in answering questions related to teacher voice-signal-amplification and speech communication interference due to minimal hearing loss. The second component addressed the research questions which focused on teacher voice-signal-amplification and separation distance in speech communication interference. The third component examined the relationships between teacher voice-signal-amplification and noise abatement. Finally, the effects of interaction between and among the variables were examined.

Table 1

Preliminary Design Layout

		Speech Communication Interference from M.H.L. Factor	
		Level 1 MHL≥15 & <30 dBHL loss	Level 2 non-MHL<15dBHL loss
Teacher Voice Signal Amplification Treatment Factor	Level I treatment		
	Level 2 control		

		Separation Distance and Speech Communication Interference	
		Level 1 Separation Dist. Zone A	Level 2 Separation Dist. Zone B
Teacher Voice Signal Amplification Treatment Factor	Level 1 treatment		
	Level 2 control		

		Soundproofing and Speech Communication Interference	
		Level 1 Soundproofed Environment	Level 2 Non-soundproofed Environment
Teacher Voice Signal Amplification Treatment Factor	Level 1 treatment		
	Level 2 control		

Another independent variable examined was grade level, which was added to the design to assess the relationship between grade level and treatment. The independent variable, subject aptitude, was evaluated in a post hoc stratification to account for subject variability.

The dependent variable used to compare performance between experimental and control subjects was linguistic task performance. This is consistent with the speech chain model (Denes & Pinson, 1973) as well as with Kaufman's

research (1985) which first utilized the paradigm in an experimental research setting to study speech communication interference.

In the present study, spoken communication by the teacher was in a whole-group direct instructional setting for approximately forty to sixty minutes each day. Instruction focused on both mathematical computation and mathematical reasoning. A testing instrument aligned with classroom instruction/content was used to measure linguistic task performance.

Subjects

The subjects utilized for this study included third- and eighth-grade students. Organizationally, the third grade included eight self-contained classrooms (N=160) while the eighth grade had four departmentalized mathematics classes (N=83). Four of the third-grade intact classes and two of the eighth-grade intact classes were randomly selected to serve as the experimental groups while the remaining classes (four third- and two eighth grades) served as control groups.

Method

Audiometry screening was conducted on all students to identify those exhibiting minimal hearing loss. Teacher voice signal amplification treatment was administered to all

experimental subjects for ninety-five days. Pretest data on mathematics performance and aptitude were collected on all subjects. During the study all third- and eighth-grade mathematics classes received instruction that was based on the district's adopted curriculum for mathematics. Posttest treatment data were collected on all subjects. A test-retest format was utilized. Posttest data were used to compare growth between experimental and control subjects in linguistic task performance. A commercially prepared test, "Educational Development Series Achievement Test" (Scholastic Testing Service, 1986), was utilized.

Questions of Interest

Questions of interest for each of the variables, minimal hearing loss, separation distance and noise abatement were advanced. They are:

Minimal Hearing Loss

Research questions related to minimal hearing loss are:

1. How prevalent is MHL in grades three and eight in the present school population?
2. Does MHL have an effect on student achievement in the upper grades?
3. Does the achievement of identified MHL students improve when exposed to voice amplification?
4. Do students with different ability levels respond differently to voice amplification?

5. Do non-MHL students benefit from voice amplification?

Separation Distance

Research questions regarding separation distance:

1. Does separation distance affect achievement for students identified as having MHL?
2. Does decreased separation distance improve performance for younger children more than for older children?
3. Does the aptitude of students offset the effect of separation distance?
4. Does amplification of the teacher's voice affect student performance at different separation distances?
5. Which zone(s) seem to optimize linguistic task performance for students?

Noise Abatement

Research questions related to noise abatement are:

1. Is the effect of soundproofing more beneficial for students with MHL than for students without MHL?
2. Does teacher-voice-signal amplification have a positive effect for students with MHL in soundproofed and non-soundproofed environments?

3. Does soundproofing affect or mitigate the variable of separation distance?

A more detailed presentation of the research design and methods are presented in Chapter III.

CHAPTER II

REVIEW OF LITERATURE

The major focus of this inquiry is to gain a further understanding of the effects of minimal hearing loss, separation distance, and noise abatement on student achievement. To provide the necessary background, a review of studies related to the above-noted variables (minimal hearing loss, separation distance, and noise abatement) is presented.

Minimal Hearing Loss

Winn (1988) and Healy (1990) both conceptualize listening as an active mental process that serves understanding and memory. It is the first language skill to develop and serves as a precursor to the customarily followed sequence of speaking, reading, and writing. The ability to listen influences, for better or worse, the ability to learn. The association between learning and listening affects awareness, the development of vocabulary, and, ultimately, reasoning. It is only when one can accurately perceive what has been transmitted and

communicated that one can function and fully actualize one's potential.

Gumpery (1981), in writing about classroom conversations, has stated that "to the extent that learning is a function of the ability to sustain interaction, the child's ability to control and utilize this convention is an important determinant of educational success" (p. 11).

Language in the classroom is connected with the development of oral language skills through the exchange of information between student and teacher, peer interaction, and text language (Butler, 1984; Nelson, 1984). Hence the physiological process of "hearing" relates very closely, and in fact is a forerunner, to a child's general intellectual development as well as to academic success in the classroom.

Berg (1986) notes that, "to listen effectively is crucial to school learning because students spend 45% of school time listening and 30% speaking, but only 16% reading and 9% writing" (p. 3).

Although it is well documented that severe hearing loss impacts upon the linguistic development of children, literature on the relationship of hearing acuity and academic achievement has indicated that even a mild hearing loss has a detrimental effect on both linguistic development and learning (Bess, 1985; Kluwin and Moores, 1989; Arnold and Mason, 1992). Downs (1988), in examining research

related to conductive hearing loss, concludes that the mild hearing losses (<25 dB), "may be a great deal more educationally handicapping than has been thought."

Ling (1986) has descriptively represented even slight hearing loss as an invisible acoustic filter. The significant effect of this filter is its detrimental impact on verbal language development. The secondary negative effect of this invisible acoustic filter is its impact on the higher level linguistic skills of reading and writing (Wray, Hazlett and Flexer, 1988). If one does not hear clearly, one does not develop clear verbal language, including verbal language concepts. If one has deficient verbal language, one is also likely to have poor reading skills which may then limit other academic options.

Goetzinger (1964) designed a study which compared students who exhibited small hearing losses (in the 20/70 dB levels) for the frequencies of 500-1000-2000 Hz in the better ear. The study concluded that students with hearing losses that could be described as minimal do not function as well as normal students, i.e., those without hearing loss. In addition to lower scores in auditory discrimination, the minimal hearing loss students were noted by teachers to be more introverted, have poorer work habits, have greater emotional variability and be shyer than the students classified as having normal hearing.

Quigley (1970) conducted a study of 173 subjects in the second- through tenth grades who were identified as having hearing acuity deficits but were receiving no treatment. Exploring additional audiometry procedures, Quigley identified almost 32% of the above noted 173 students as having hearing acuity deficits of 15 dB to 26 dB. Consequently, he recommended a change in the classifications related to hearing loss so that students with a slight hearing loss would be eligible for services. Quigley considered even minimal hearing loss to be a degree of educational handicap.

Ling (1972) compared achievement test results on two matched groups of school children. One group had hearing losses ranging from 15 to 45 dB. The control group evidenced no hearing loss. The groups were matched for age, intelligence, and environmental factors. The MHL group evidenced retardation of 15 months in reading skills, 16 months in mechanical arithmetic and 19 months in problem arithmetic. The degree of retardation was positively correlated with the severity of the loss, but even the children with the mildest losses showed significant academic handicaps.

The State of Illinois Child Hearing Test Act (1972) states that medical evaluation and audiological review should occur as a result of threshold screening testing. The criteria for the test are contained in the Illinois

Public Health Audiogram for speech frequencies (500 Hz-1000 Hz-2000 Hz); a cut-off score of 30 dB has been stipulated. Failure at this level will generate a medical referral.

Wall, Naples, Bukrer and Capodanno (1985) conducted a national survey of public schools' hearing conservation programs and reported no standard set guidelines were in use. Although most schools provided identification procedures, the procedures were not comprehensive in scope nor were they standardized.

Others, such as Northern and Downs (1991) have proposed a definition of minimal hearing loss which addresses the following issues: age, medical components, and hearing levels. The proposal states:

1. hearing acuity level of >15 dB
2. indications of serious otitis media in a child under 18 months more than half the time for a period of six months
3. fluctuating hearing levels from 0 to over 15 dB more than half the time for one year.

While the exact definition of minimal hearing loss is still not available, Chernak and Peters-McCarthy (1991) stress the need for an acceptable resolution to the issue. They call for state and national goals for a hearing program which aims at prevention and reduction of the prevalence of

minimal hearing loss, as well as exact identification of all levels of hearing loss.

Pimentel (1988) points out that, unlike adults who have acquired their hearing loss later in life (after developing language and speech), children with any degree of hearing loss must learn utilizing an impaired system.

Data which speaks indirectly to the issue of MHL comes from studies of language development in children with mild to moderate hearing losses (Liberman and Mattingly, 1985; Hasenstab, 1987; Freyman and Nerbonne, 1989; and Dreschler and Leeuw, 1990). The overall analysis of these studies support the generalization that children with even mild hearing losses do not perform as well on tests of language as do children who have normal hearing.

As a result of the accumulated research on minimal hearing loss, several researchers have advanced remedies to mediate the problem of MHL. Project MARRS, (1978, 1983) and Kaufman (1985), have attempted to improve speech intelligibility for students with hearing impairment or minimal hearing loss through voice amplification.

Project MARRS (1978) using a sample of 601 fourth-, fifth- and sixth-grade students, identified 197 who failed the audiometry screening and exhibited academic deficits at least one-half year below their grade placement in reading, language, and mathematics. The criteria established to identify hearing acuity deficits not identified by the State

of Illinois testing consisted of air conduction thresholds of 10 dB to 40 dB and a pure tone average of less than 25 dB in the better ear. Subjects were randomly assigned to treatment (amplification) and non-treatment control groups. Both groups utilized similar curriculum and were pre- and posttested in reading, mathematics, and language. Results of the improved performance were reported for treatment groups in reading and language but not in mathematics.

Boyd (1974) also found a less significant relationship between hearing loss and mathematical computation (a non-verbal task). Northern and Downs (1991) reviewed several studies of deaf students which indicated that these students in some instances score higher in mathematical computation than their normal hearing peers. The researchers postulated however, that the assessment of mathematics achievement is often mixed with reading tasks which relate to verbal tasks, hence the lack of consistent relationships between hearing acuity and mathematics.

Kluwin and Moores (1989) postulated that the quality of the experience was the most critical factor for a student with mild to moderate hearing loss in determining their level of achievement in the area of mathematics. They defined quality as a supportive teacher, regular and extensive review of the material, time devoted to direct instruction, positively expressed affect, and a demand that the student work to the task.

Both a nonverbal (mathematics computation) and verbal (mathematics reasoning) effect analysis has been incorporated into the research design of this investigation as outlined in Chapter III. The inclusion of both analyses (nonverbal and verbal) is an attempt to clarify the problem of mathematical assessment discussed earlier.

Relevant information related to language acquisition and hearing acuity has been advanced by Skinner (1978). The speech sounds of general American English vowels (voiced), consonants (voiced and unvoiced) and combination sounds (voiced and unvoiced) range from 55 dB to 65 dB in normal conversation. As one listens to speech with interference from noise that is extraneous to the conversation, however, sounds and words are dependent on the listener's ability to hear small differences in qualities, intensity patterns and energy concentrations. She concluded:

> For a child with even a mild hearing loss, the ability to "hear" various intensities varies which makes reception of oral communication more difficult for them (p. 643).
>
> Children with conductive hearing loss are more susceptible to hearing loss fluctuation. Thus acoustic cues do not sound similar from day to day. One day the child will hear the cue and it will be comfortably loud, while the next day the same cue may well be inaudible (p. 644).

Downs (1988) states that:

> It is exceedingly more important for a first grader to hear all of the speech sounds in a new word than it is for an experienced listener to hear them. Voiceless stop consonants and the voiceless fricative consonants are in some cases 30 dB less intense than the vowels and other consonants. Voiceless stop consonants include the /p/ as in pay, /t/ as in to, and /k/ as in key; and the unvoiced fricatives include the /f/ as in for, /s/ as in see, /th/ as in thin, and /sh/ as in she. For the child who is still learning language, a mild conductive hearing loss may place an unbearable strain on coping abilities (p. 188).

In effect, students who are identified as having MHL can often understand only what is being said under the most favorable conditions (persons speaking loudly or face-to-face), but will not understand in less favorable conditions (in a classroom).

Downs further demonstrates this concept by noting that if a person presses the tabs in the front of their ears into the ear canals, occluding the ear canals completely, the results are the same as a 25 dB HL average hearing loss. The listener has to strain a great deal in order to catch what people are saying, yet this kind of hearing loss passes traditional school screening tests, where only 1,000, 2,000

and 4,000 Hz are screened at 25 dB HL. Further, she notes that this type of hearing loss is common for many children on a regular basis due to infections or colds.

Friel-Patti (1990) concludes that long before children begin to speak they are able to make fine phonetic discriminations to distinguish the speech sounds of the language around them. During early language acquisition, the child learns the sound system as well as how to form such things as plurals and past tense. This requires hearing the difference between words such as plays and place or help and helped. An inconsistent auditory signal resulting from fluctuating hearing loss may make the stream of speech difficult to segment and may impede the child's ability to form such linguistic categories.

In a study, Burgener (1980) examined soundfield amplification on the test taking performance of children with MHL as well as those with normal hearing. Burgener tested 131 second- and third-grade students, verbally administering reading and spelling tests. The results of the study found that soundfield amplification significantly improved the test taking performance on the verbally administered spelling test for all students regardless of hearing loss, while the reading test results were insignificant. Burgener's "identification procedure" which incorporated a 10 dB level across all frequencies (250 Hz through 8000 Hz) has been challenged by Kaufman (1985),

since pure tone signals presented to even a normal ear at 250 Hz could be inaudible below 25 dB. This error may have led to the finding of no significance in reading. However, both Burgener and Kaufman have suggested further investigation into the age-dependent effect, i.e., the suspected inverse relationship between MHL and a child's age. Such analysis has been incorporated into the present research design as explained in Chapter III.

In a related study Suter (1980), working for the U.S. Department of Labor, Occupational Safety and Health Administration, examined the extent to which subjects, whose hearing levels were better than 26 dB, differed from one another when listening conditions were degraded by background noise. Subjects were divided into three groups of 16 each. Each group was stratified by hearing levels. Subjects were tested for intelligibility acuity in three different speech-to-noise ratios ranging from 0 dB to 26 dB. The results indicated:

> 1. Differences among groups increase as speech-to-noise ratios decrease.
> 2. The higher frequencies of 1000 Hz, 2000 Hz and 4000 Hz should be included in acuity screening.
> 3. The low-fence hearing acuity is between 15 dB and 30 dB and could, pending further research, be approximately 22 dB (p. 203-209).

Subsequent work by Sarff (1981) has resulted in the recommendation to establish a low-fence cutoff of ≥15 dB. Subjects having hearing acuity thresholds of ≥15 dB would be classified as having an educationally significant hearing loss.

Hughes (1980) studied a group of children previously identified as learning disabled. The original group, consisting of 81 students, with an average hearing loss threshold of 15 dB in one ear, were identified as MHL. Multiple regression found significant (.05) relationships for reading and arithmetic in relation to the students identified as MHL and learning disabled. The findings by Hughes were, however, tempered by the fact that his sample was not randomly selected but was based on parent permission to participate, thus raising doubt about external validity.

Jania (1985) studied a total of 189 fifth-graders, 51 (or 26%) of whom qualified as having MHL (i.e., a threshold of 20 dB in one ear). Using the Stanford Achievement Test (15 subtests) and the Otis-Lennon Intelligence Test, it was found that students identified as having MHL scored significantly less (.05) than their peers without MHL. These subtests included reading comprehension, word study skills, mathematical computation, spelling, language, social studies, science, total reading, total mathematics, and total battery.

A study by Kaufman (1985) examined the aggregate number of students affected by MHL and the effect of teacher voice-signal-amplification interaction on reading for first- and second-grade students. First- and second-grade students (n=339) in three separate schools were utilized in the study.

Intact classrooms were randomly assigned to either treatment groups (teacher voice-signal-amplification) or to control groups. Both experimental and control subjects were administered pre- and posttests using the Stanford Reading Test. Both groups were taught using the district prescribed reading program which emphasized whole group direct instructional methodology.

Major findings drawn from the MHL portion of the study revealed that 66% of the experimental population manifested minimal hearing acuity deficits, utilizing 15 dB as the low-fence cutoff. Speech communication interference was reduced but not eliminated by teacher voice-signal-amplification intervention for linguistic task performance, represented by specific subskills, such as auditory discrimination, phonetic analysis, and auditory vocabulary.

Further analysis revealed that high aptitude subjects benefitted more from the treatment than did low aptitude subjects. It was also found that second-grade subjects evidenced more subskill growth than did first-grade subjects. Kaufman postulated that the latter finding

occurred due to the greater separation distance prevailing in the experimental setting between speaker and listener at the second-grade level, thus allowing amplification intervention more opportunity to reduce separation distance. The researcher recommended that separation distance be included as an independent variable in future studies examining speech communication interference.

In a related study Bullerdiech (1986) researched the effects of hearing acuity, middle ear pressure, and grade level on the reading achievement of elementary students. The results of her work indicated that minimal hearing loss greater than 15 dB but less than 50 dB has a significant negative effect on the reading achievement of elementary students in grades one through five. Further, Bullerdiech concluded that the effect of minimal hearing loss is accumulative, i.e., student achievement in grades four and five is more depressed than student achievement in grades one and two.

Bess (1986) concluded that it is no longer appropriate to assume that preferential seating will solve the problems of the child with minimal hearing loss. Additional solutions must be utilized such as FM wireless systems for the good ear or amplifying the entire classroom to improve the signal-to-noise (S/N) ratio.

Elliott and Hammer (1988) found in a related study examining longitudinal changes in auditory discrimination,

that those students with poor pure-tone sensitivity even within the "normal" range (≤20 dB), tended to perform more poorly on tests of language function. The researchers have postulated that if one cannot hear a word properly, one cannot learn to say it properly or learn its correct usage.

Friel-Patti and Finitzo (1990) reported significant correlations between hearing over a particular time period and the number of days children exhibited effusion (otitis media) over the same time period.

The study categorized children as better-hearing, i.e., those whose average hearing loss was ≤ 20 dB HL, and as worse-hearing, i.e., those whose average hearing loss was > 20 dB HL. Receptive language was significantly higher for children in the better-hearing group at 12 and 24 months; expressive scores were significantly higher for the better-hearing group at 18 and 24 months. Thus, by two years of age, both receptive and expressive language performances were higher for children with better-hearing due to fewer days of effusion.

Friel-Patti (1990) has noted that, "although a causal relationship between auditory and phonetic perception and reading ability cannot be established from the correlation studies performed thus far, the weight of evidence supports the view that auditory and phonetic perceptual deficits may cause reading difficulties" (p. 15).

Weiss (1986) notes that several studies point to the fact that conversational demands placed on the child in the classroom may be setting-specific. Thus a student, to succeed in an academic setting, must be able to hear and interact with conversation initiated by teachers and other students.

White (1986) also stresses that as background noise intensifies, students with hearing deficits experience increased difficulty in hearing. She further points out that many students with MHL experience daily variations in their ability to hear as well as their need for increased intensity.

Hasenstab (1987) concurs that efficient language learning is compromised because inconsistent auditory data may be categorized by the child as different input stimuli during shifts in hearing thresholds.

Thus, classrooms are an obvious example of rooms where a very high level of acoustical quality is required. Conventionally, a teacher talks to a group of students who are expected to hear everything that the teachers says (Bradley, 1986).

In summary, the emerging research on mild or minimal hearing loss has identified a relationship between hearing acuity and linguistic task performance. In addition, the aspect of age-dependency, the degree of conductive hearing

loss and the fluctuating nature of hearing acuity play a role in the effect minimal hearing loss has on children.

Public agencies such as the Illinois Public Health Department and the U.S. Department of Labor (OSHA) have substantiated a need for further work in accumulating data on minimal hearing acuity, while a number of authorities have identified a higher than suspected prevalence of minimal hearing acuity deficits among children.

Separation Distance

French-St. George (1986) notes that, "the speech perception process in normal conversation is controlled by interaction between a listener's knowledge base and incoming auditory signals" (p. 113).

Hirsh (1987), states that listeners in general can attend to a single auditory signal even if it is accompanied by many others. However, when the level of other signals of "noise" becomes too high, recognition of a specific signal or of speech becomes impossible. Minimal hearing loss, therefore, is the inverse of "noise" in that the absence of normal hearing acuity affects recognition of a single auditory signal or of speech, thus severely limiting recognition for the listener, just as "noise" limits the recognition of speech for the normal ear. Suter (1987) contends that just as noise masking reduces the inherent redundancy in speech, hearing impairment reduces it further.

Depending upon the degree of hearing loss and the level of noise, messages may be correctly perceived, partly or completely misunderstood, or missed entirely.

Finitzo (1988) in discussing classrooms that have an affirmative acoustical impact on students with mild to moderate hearing loss, outlines four factors which are essential to creating a positive auditory environment:

1. Signal-to-voice (S/N) ratios that are no less than +20 dB with very low continuous background noise levels.
2. Provisions for high isolation against outside intrusion of noise.
3. Maintenance of teacher-student separation distances of six feet or less to minimize the detrimental effects of reverberation and maximize the visual cues for the child.
4. Providing the student with both auditory and visual cues to maximize the information from the spoken message (p. 232).

Pimentel (1988) notes factors which will affect the quality of the auditory signal include: the distance between the teacher and student when the teacher is speaking, the background noise in the environment, and the clarity of the speaker's voice.

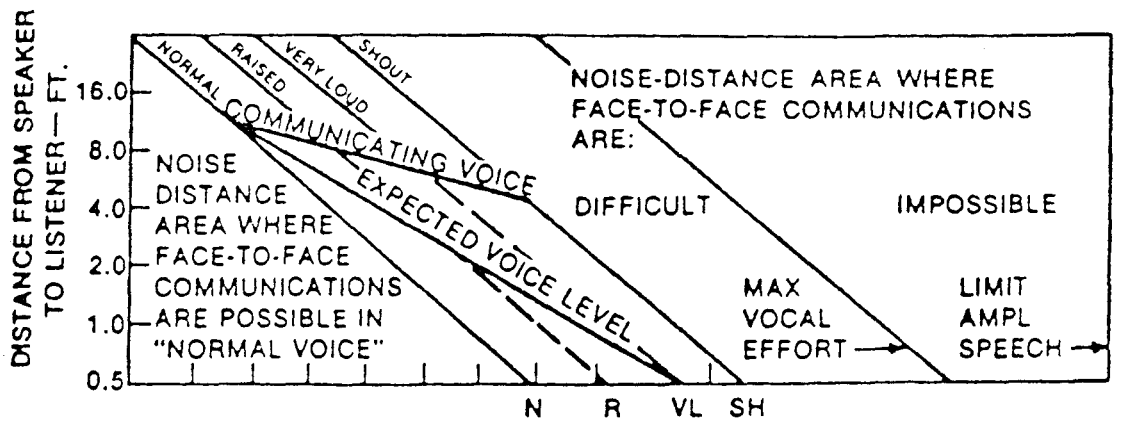
Pearsons, Bennett and Sidell (1977) studied 20 classrooms in two different school systems for speech intelligibility. At each site, three microphone locations were utilized, one of which was on the teacher.

Considerable variation of speech levels were measured in the classrooms with the speech levels at school 2 at all microphone locations being higher on the average by 5 dB than those found in school 1. Higher background levels (over 3 dB) were also noted for school 2 over school 1. An analysis of the speech-to-background noise ratio for all microphones utilized by teachers revealed that at both schools the same ratio was maintained by teachers in that their average speech level was 15 dB higher than the background noise for school 1 and 16 dB for school 2. However, students in school 1, experiencing less ambient or background noise than students in school 2, scored 14% higher on tests that measured the words that listeners could hear correctly and understand.

Figure 3 represents a theoretical paradigm published by the FAA (1984). The theoretical paradigm as well as similar versions are utilized to specify speaker-to-listener separation distance for acceptable conversation.

A refinement of the original paradigm (Figure 2) was introduced by Houtgast at the Third International Congress on Noise as a Public Health Problem, Freiburg, West Germany, September 25-29, 1978 (Houtgast, 1980). The refinement

added indoor reverberation as a part of the calculations, thus changing the model from an outdoor noise predictor to an indoor noise predictor. By applying the model, Houtgast sought to identify what indoor noise level could be tolerated in terms of speech intelligibility. Houtgast's findings led him to develop the criterion of 45 dBA for tolerable indoor classroom noise (1980, p. 183).



PSIL	40	50	60	70	80	90	100	110	125
SIL	37	47	57	67	77	87	97	107	122
dB(A)	47	57	67	77	87	97	107	117	132
PNdB	60	70	80	90	100	110	120	130	145
dB(C)	54	64	74	84	94	104	114	124	139

Figure 3: Relationship Between Speaker-Listener Separation, Ambient Sound Level and Ability to Communicate.

Source: U.S. Department of Transportation and Federal Aviation Administration, Final Environment Impact Statement: Chicago O'Hare International Airport, Chicago, Illinois, 2 vols. May, 1984, vol. 1, p. 449. Reproduced with permission from Jerry Mark, FAA; June 2, 1992.

His criterion synchronizes with the findings of the U.S. DOT-FAA (1977) and U.S. EPA (1978), which establishes 45 dB as the threshold level for the onset of speech interference effects in schools.

Kaufman (1985) summarizes research in this area by noting that, "authorities seem to agree that 45 dBA is the threshold level above which ambient noise begins to interfere with speech communication, contingent upon separation distance and speaker voice level" (p. 53).

Crum (1974) investigated the combined effects of reverberation, noise, and separation distance from the sound source on the speech intelligibility of young adult listeners with normal hearing. His research demonstrated that speech intelligibility can be dramatically reduced by the compounding effects of reverberation, noise, and separation distance.

Specifically, Crum selected twelve normal hearing subjects from the student population at Northwestern University. Each subject's hearing sensitivity was assessed by using an audiometer calibrated to ANSI,S3.6-1969 standards and utilizing a sound treated test room. Air conductive thresholds were obtained at octave frequencies from 250-4000 Hz. All subjects evidenced hearing thresholds equal to or less than 10 dB.

A list of monosyllables was selected as the stimulus material and each subject's understanding of speech

intelligibility was evaluated in one non-reverberant (anechoic) and three reverberant listening environments with the dimensions of 20x25x12, approximately the size of a small- to medium-sized classroom.

Subjects were evaluated at one of three speaker-to-listener distances during each test condition, 6, 12 and 24 feet respectively from the source of sound. Crum noted:

> Earlier research had not systematically investigated the effects of distance upon communicative efficiency in small rooms; yet, even a basic understanding of sound distribution patterns suggests that distance should influence the understanding of speech. Depending upon his location in such an environment, a listener could receive speech either directly or by indirect sound transmission (p. 52-3).

Crum selected the 6-, 12- and 24-foot distances to simulate spacial relationships which occur frequently in a classroom. For example zero through six feet would represent small group activities, e.g., the classroom teacher would meet together with a small group of students in a specific space in the classroom for the purpose of directing instruction related to a selected topic. The 12- and 24-foot areas were more representative of a student's

location during whole-class teacher-directed lessons or during general classroom discussion.

Results of the study indicated that speech intelligibility, in reverberant conditions, decreased as distance increased from 6 to 12 feet but that an additional increase from 12 to 24 feet resulted in no further reduction in understanding. Hence 12 feet from the source of sound (speaker) was the maximum distance that one would be able to be without experiencing notable changes in speech intelligibility. Crum's results are significant when one considers that he was utilizing an ideal population in terms of hearing (subjects were adults whose hearing was $\leq$ 10 dB) and that his experimental parameters were acoustically treated areas that were only representative in size of some educational classrooms.

Orloske and Leddo (1981) also considered the influence of separation distance on the hearing acuity of school age children and concluded that the optimal distance to hear most classroom communication adequately was eight feet from the source of sound. They noted that at distances of less than eight feet between the teacher and student, the teacher tends to speak more softly; at distances between the teacher and student greater than eight feet, the teacher's voice is not strong enough so that students can always hear clearly.

In a related study Hygge, Ronnberg, Larsley and Arlingar (1992) matched 24 mildly hearing-impaired subjects with 24 normal hearing subjects in hearing environments normally encountered in a classroom: a) random background noise, b) background speech and c) foreground speech. The normal hearing subjects performed better than the subjects possessing hearing loss in all areas except random background noise. It was postulated by the researchers that the hearing-impaired subjects were unable to adequately sort out the conflicting sounds and thus could not adequately compensate for their deficit.

Loven and Collins (1988) found that a student's ability to hear specific signal recognition was impacted by the strength of the signal, i.e., the teacher's voice, the presence of reverberation, filtering and masking. Further, the interactive effects of these signal modifications served to increase the relative strength of the effect of the parameter compared to its strength in isolation.

Consequently, the difference in a young child's listening performance when compared to an adult listener's performance is due to language recognition skills that are not yet well formed and therefore require acoustically consistent and simple environments if correct recognition is to occur. Miller (1974) discusses speech and its understanding by noting:

> A talker generates a complicated series of sound waves. This series is called the speech stream. It is not possible to assign a particular acoustic pattern to each of the "sounds" of the English language in a one-to-one fashion. Rather, the "speech stream" carries the cues for the "sounds" of English and the listener decodes the "speech stream" by a complicated, synthetic process that not only relies on the acoustic cues carried by the "speech stream" but also relies on the listener's knowledge of the language and the facts of the situation (p. 740).

Wilson and Zizz (1990) attempted to standardize speech for use in speech audiometric procedures. The data from the experiment indicated that to obtain equal detection and equal recognition performances on two versions of an auditory test (N.U. No. 6) the female speaker version had to be presented in sound pressure levels that were 5 dB higher (detection) to 15 dB higher (recognition) than the sound pressure levels required by the male speaker version. The researchers noted that this type of adjustment could be accomplished through either voice-signal amplification or reduction in separation distance between the speaker and the listener.

Thus, the importance of "hearing" correctly all of the information discussed or imparted in the classroom is critical, especially for younger students.

Glass (1985) notes that in many rooms of modest size, the understanding of speech is poor, not because of lack of power but because of the lack of clarity which is influenced by reverberation and distance.

Berg (1986) has indicated that in "noisy" classrooms even normal hearing children may not listen effectively. This is especially true if teachers do not talk loudly enough or face their students while talking. For classroom teachers to be heard, their speech must reach their students loudly enough and without interference. Therefore, to compensate for either noise and/or separation distance, teachers must raise their voices.

In summary, evidence seems to support the inference that separation distance is related to speech intelligibility in children possessing minimal hearing loss. If the presence of speech can be detected, but only indistinctly or with difficulty, the speech is just above what is often referred to as the threshold of detectibility. In addition, an important effect of background noise on speech communication is that the distance over which the speech can be understood is greatly reduced. It can also be concluded that the more intense the speech in relation to the noise or the shorter the separation distance, the greater the percentage of messages correctly understood by the listener. Another micromediating influence of separation distance is age. Younger children do not possess

the knowledge of language that adults do. Thus, children are also less able to understand speech in the presence of ambient noise.

Noise Abatement

While the earlier discussion addressed speech communication interference at the listener's (student's) physiological level on the speech chain paradigm, the following analysis addresses the acoustical level. Again, communication may be altered and mediated at more than one point on the speech chain.

During the past few years increasing emphasis has been placed upon the need to provide an acoustically appropriate classroom environment that allows students to effectively hear what is being spoken by the teacher. Originally, noise abatement focused only on noise generated by exterior sources, but currently the need has been advanced for better acoustical conditions for students who exhibit physiological deficits. This component of the investigation will address the abatement variable.

Ikenberry (1974) noted that little attention had been given to the problem of noise compatibility for many schools and their surroundings, yet increased ground and air traffic have brought highways, runways and existing schools closer together. Finitzo (1988) notes that when the location of an existing school is not optional, certain steps can be taken to decrease the outdoor noise. Schools, such as those

involved in this study, which operate in excessive noise areas suffer from loss of classroom time when the teacher cannot be heard by the students. The U.S. EPA (1978) has explicitly stated that speech interference is an adverse effect of noise exposure, while Clark and Herbert (1991) also concluded that activity interference is adversely impacted by noise.

Further evidence connecting aircraft noise with interference of speech communication in affected schools comes from a federal government study of sixty schools and hospitals near six major U.S. airports (U.S. DOT-FAA, 1977). All buildings in the survey were located within 65 dB LDN noise contours. Through the use of noise monitoring technology, threshold levels for speech communication interference were identified.

A summary of school-specific findings were:

1. Speech in schools is a noise sensitive activity. The threshold for speech interference is lower than that of either health degradation or attitudinal reaction.
2. A level of 45 dBA has been selected as the threshold for speech interference in school classrooms.

3. Frequent short-term disruption of speech communication can interfere with the efficient flow of verbal instruction.
4. Due to their inexperience with language, children should have lower background noise levels if they are expected to achieve the same degree of speech comprehension as an adult (p. 21-22).

The above-noted federal research was promulgated in Public Law 97-248 (1982) which provided funds for the soundproofing of schools impacted by aircraft noise.

Finitzo (1988) stresses that for a normal hearing adult, the effects of a noisy classroom may not be immediately apparent. But for a teacher who is transmitting information all day long, the experience may be fatiguing. Moreover, a young child who is trying to learn unfamiliar concepts may find the room stressful, while a hearing impaired youngster may understand almost none of the information presented.

The above body of knowledge, along with that presented in the section of this study entitled Separation Distance, indicates that if a listener is located close to the speaker, noise and/or MHL will have a negligible effect upon the listener's ability to understand speech. At greater distances from the source, however, the direct sound field decreases in intensity and the reverberant sound field plus

ambient noise eventually predominates. Therefore, it seems vital to provide the most advantageous listening environment for the student in the classroom.

Cohen, Evans, Krantz and Stokols (1980) and Cohen, Evans, Krantz, Stokols and Kelly (1981) have reported results of two sequentially related studies that investigated the psychological, motivational and cognitive effects of aircraft noise on third- and fourth-grade students in Los Angeles. The four elementary schools (experimental) that house these students, located in the main air corridor of the Los Angeles International Airport, recorded peak sound level readings of 95 dBA with more than 300 overflights daily. Three control (quiet) schools were matched with the four experimental (noisy) schools for age, socio-economic status, and noise. A total of 262 subjects (142 experimental and 120 control) were involved in the study. Children who exhibited hearing loss were excluded so as not to confound the findings. A second study, utilizing the same subjects, retested students on the same measures previously used to develop longitudinal data and assess whether children adapt to noise over time. Also examined was the effect of noise abatement intervention introduced in a number of noise impacted classrooms.

The findings of the second study indicated that a cross-sectional comparison of noise abated and non-abated experimental classrooms revealed a cluster of variables

unaffected by abatement. These variables were: children's perceptions of noise; noise interference; health factors; and auditory discrimination. However, two variables did provide some support for the ameliorative effect of abatement. The first was children's ability to solve a moderately difficult test puzzle (helplessness task) and the second was mathematics achievement. Mathematics performance was higher for children in abated than in non-abated classrooms. Further, it was found by the researchers that children in abated classrooms reported fewer problems hearing their teachers than did students in non-abated rooms. It should be noted that control (quiet) classroom children were not included in this analysis because of the conceptual problem of evaluating change scores when initial scores were significantly different. The analysis of the effectiveness of noise abatement in this longitudinal study indicates that, although initial abatement results were positive, there is need for further examination of the problem.

Ireland, Wray and Flexer (1988) state that hearing is pivotal to academic achievement and until the problem of auditory reception is addressed, the pervasive effects from any level of hearing loss will persist and escalate. Therefore, anything that can be done to maximize hearing will have a positive impact on a child's academic performance.

Thus, ambient noise, from whatever source, has the effect of raising the threshold of audibility of a sound, a phenomenon known as masking. Brase (1989) argues that the purpose of reducing a classroom's ambient noise level is to improve one's ability to hear in the space, by raising the signal/noise ratio. The importance of low ambient noise cannot be overstated, for a noisy background will negate other acoustical measures attempted. In a study discussed earlier, Crum (1974) noted that, "In a classroom with ambient noise from external sources, the noise would be less disruptive to communication if the room was acoustically treated to reduce reverberation" (p. 120).

The noise level in a room therefore determines the lowest sound pressure level audible to a listener. The effect of noise is to raise the listener's threshold of audibility with a resultant loss of intelligibility of speech at low intensity levels. Unless the speech is raised sufficiently or the ambient noise reduced (abated), speech intelligibility is reduced by the masking effect of the noise. The same phenomenon also occurs with students exhibiting MHL. The lack of normal hearing masks the sounds the student needs to hear, and thus speech intelligibility is affected.

Noise abatement or soundproofing has been attempted on a limited basis to minimize the effects of ambient noise. Berg (1987) states that, "reducing noise within classrooms

is of particular importance. Outside to inside noise reduction, called sound transession loss (STL), will be created if inside partition surfaces are acoustically treated" (p. 109).

The present study seeks to better understand the effects of noise abatement on improving both the acoustical and physiological environment within schools.

CHAPTER III

DESIGN AND METHODOLOGY

The objective of this study is threefold: (a) to continue the accumulation of data related to minimal hearing loss, including the effect of teacher voice amplification on students with minimal hearing loss (MHL); (b) to examine the effect of speaker to listener separation distance on student performance; and (c) to explore the effect of noise abatement (soundproofing) in an identified high noise environment (75 LDN) on both MHL and non-MHL subjects.

Setting

The research setting is a K-8 elementary school district with a student population of 1,789 and five schools, four of which were utilized in this study. The following is a description of the schools from which the samples were drawn:

Site 1: a K-6 attendance center with a total population of 326 students. It is located in the 70-75 LDN noise contour according to the noise exposure map (Chicago, 1988). This building was soundproofed in 1986 in accordance with FAA guidelines so as to comply with the 45 dB interior

noise level requirement established by the U.S. EPA as the threshold noise level that is necessary to avoid speech intelligibility interference in classrooms.

Site 2: a departmentalized seventh- and eighth-grade junior high school with 393 students. It is situated in the 65-70 LDN noise contour (Chicago, 1988).

Site 3: a K-6 elementary attendance center with a population of 329 students. The school is located in the 60-65 LDN noise contour (Chicago, 1988).

Site 4: a K-3 attendance center with a population of 441. It is located in the 65-70 LDN noise contour (Chicago, 1988).

Sample

The units of observation were the entire third-grade population in the district, eight intact classrooms from three schools, (n=160), as well as half of the eighth-grade mathematics classes, four (n=83). The four eighth-grade classes were selected randomly. A limiting factor of the sample size was the presence of only six sound amplification units. Of the six, one was assigned to site 1 to be placed in one of the two classrooms, with the same procedure being applied to site 3. Site 4 received two units for the four third- grade classes while site 2 received two units for its four classes. The amplification units were then randomly

assigned to the classes in each building for treatment purposes (six intact classes: four third grades, two eighth grades). The amplification equipment was installed in the six intact classrooms on January 12, 1987, and operated for the remainder of the school year (95 days).

Based on archival records, subjects at site 4 had repeatedly shown lower performance gains in achievement and aptitude than those of sites 1 and 3. Students at site 2 are a representative proportion of students from the three sites utilized in the study. Achievement and aptitude differences could not be controlled experimentally since assignment options for either individuals or intact classes to school sites were not available to the researcher.

Data Collection and Analysis

Aptitude Assessment: The concomitant variable, student aptitude, was obtained from the scores reported for students on the Cognitive Skills section of the "Educational Development Series Achievement Test" (Scholastic Testing Services, 1986). This score is similar to a deviation I.Q. score and reflects the student's performance relative to the performance of others the same age. The test was administered to each intact classroom by the classroom teacher at grade three and by the mathematics teacher in grade eight. Uniform testing procedures were coordinated by this researcher. The results were machine scored by the Scholastic Testing Service. Test reliability provided by

Scholastic Testing indicates an internal consistency relationship correlation of .95 at third grade and .96 at eighth grade (Scholastic Testing Service Inc., 1985, p. 7-13/7-15).

A separate reliability test was not administered since there was no reason to suspect any population variance because all subjects were functioning in a regular classroom, spoke English and had been subjected to previous standardized testing. In addition, the test norms utilized included all ethnic backgrounds represented in the sample population, and therefore a significant difference in the test reliability was not expected.

Linguistic Task Performance

Pre- and posttest data on mathematical computation and mathematical reasoning were collected on all subjects as a measure of linguistic task performance.

In consultation with district administrators, classroom teachers, and publishers' consultants, a commercially published test was selected, i.e., "Educational Development Series Achievement Test" (Scholastic Testing Service, 1986). The subtest components utilized included (a) cognitive aptitude, (discussed earlier in this chapter), (b) mathematics computation and (c) mathematics reasoning. A test-retest procedure was utilized for gathering pre- and posttest data.

Test reliability information provided by the publisher indicates an internal consistency reliability correlation of .79 for mathematics computation and .89 for mathematics reasoning for third grade. For eighth grade the respective correlations are: mathematics computation .89 and mathematics reasoning .88 (Scholastic Testing Service, Inc., 1986).

Uniform test administration was developed by this researcher and reviewed with teachers in each building during a grade-level meeting. Both the pretest and posttest were administered by the classroom teacher. There is no known reason to suspect systematic test administration variability. Both pretests and posttests were scored by the test publisher, Scholastic Testing Service.

All data collected in this investigation were coded by this researcher on general coded forms and processed utilizing on-line facilities of the Loyola University Academic Computing Service.

Minimal Hearing Loss

Minimal Hearing Loss identification procedures follow those outlined by Kaufman (1985). A standard school-type audiometer, Maico Model MA-19, ANSI 1969, was utilized to define each subject's hearing acuity. To conduct hearing tests, procedures are specified by the State of Illinois, Department of Public Health (1974). In addition, to ensure uniformity of testing, a portable soundproof testing booth

was used. The unit is labeled as Controlled Acoustical Environment by Industrial Acoustic Company, Inc., New York. The unit conforms with 1969 ANSI standards.

Using the audiometer and soundproof booth, all students were administered an individual pure tone air conduction hearing test by a certified audiologist. The procedure utilized a tone given at 10 dB to each subject. The tone was given at the frequencies 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz, 6,000 Hz and 8,000 Hz in both ears. If the subjects responded to the signal appropriately they were passed and identified as not having MHL. If a subject did not pass the test, a threshold test was administered. This involved a complete audiogram which utilized all frequencies at each intensity level, 0 dB through 35 dB, at intervals of 5 dB. The subjects' responses were recorded on data collection forms. Subjects failing the State of Illinois criteria were referred for further evaluation in accordance with Department of Health procedures.

Table 2 provides four hypothetical cases of the recording of data used for this portion of the investigation. In the example, case #1 represents an MHL subject, case #2 and #3 represent normal hearing subjects, while case #4 represents a subject who failed the screening criteria and was referred for further medical evaluation.

Table 2
Pure Tone Air Conduction Audiometry Data
Recording Scheme

	Right Ear						Left Ear					
	500	1000	2000	4000	6000	8000	500	1000	2000	4000	6000	8000
C1	0	0	5	20	10	10	5	0	5	10	15	25
C2	5	5	0	10	10	10	5	0	5	10	10	5
C3	10	0	0	5	5	10	10	5	0	5	5	10
C4	5	10	15	15	25	25	15	5	10	15	35	45

As previously noted, the work by Sarff (1981) and Kaufman (1985) established the MHL criteria for the lower fence as 15 dB in either ear while the upper fence is 25 dB, also in either ear.

Separation Distance

The separation distance paradigm was extrapolated from previous research by Crum (1974) which was reviewed in Chapter II. Crum established separation distances of 6 feet, 12 feet, and 24 feet respectively. The shortest distance (six feet) represents teacher/student separation distance in small group situations while the 12- and 24-foot spans relate to the separation distance the student would experience during whole-class instructional groupings. Results of Crum's study indicated that speech intelligibility, in reverberant conditions, decreased as distance increased from 6 to 12 feet but that an additional increase from 12 to 24 feet resulted in no further reduction in understanding. Hence 12 feet from the source of sound (speaker)

was the maximum distance that one would be able to be without experiencing notable changes in speech intelligibility.

This researcher assessed each classroom included in the present study based on the above information and then measured and plotted zones within each classroom.

In all classrooms an equal interval for the teachers' station--a distance from the blackboard (the wall of the room) to a point six feet from the blackboard--was created. In this zone, teachers used the blackboard, overhead projector, and directed mathematical learning experiences utilizing whole group instruction. Beyond the teaching zone, a second zone beginning at the six foot mark and extending to another mark six feet from the first mark (12 feet total from the blackboard) was created. Students seated in this zone, A, were identified and remained in zone A for mathematics instruction during the duration of the experiment. From the 12-foot mark to the end of the classroom, a zone, which varied in length due to various classroom configurations was developed and labeled zone B. Students were identified and assigned to zone B for the duration of the study.

Noise Abatement

Site I was acoustically soundproofed during the summer of 1986 in accordance with FAA standards. Interior noise levels were not to exceed 45 dB. The architectural firm of Donahue and Associates certified compliance with the soundproofing requirements at the completion of the project in the fall of

1986. Thus, Site I served as the site for the soundproof variable examined in this study.

Questions of Interest

The purpose of this investigation has been previously outlined. In summary, the threefold purpose was to: (a) continue the accumulation of data related to minimal hearing loss, including the effect of teacher voice-signal-amplification on students with minimal hearing loss in subject matter other than reading: (b) examine the effect of separation distance, the distance between the speaker (teacher) and the listener (student) on student performance; and (c) examine the outcome of noise abatement in an identified high-noise environment (75 LN) on both MHL and non-MHL identified students. From the purpose of the study, specific questions of interest were developed for each category. They are:

Minimal Hearing Loss

Research questions related to minimal hearing loss are:

1. How prevalent is MHL in grades three and eight in the present school population?
2. Does MHL have an effect on student achievement in the upper grades?
3. Does the achievement of identified MHL students improve when exposed to voice amplification?

4. Do students with different ability levels respond differently to voice amplification?
5. Do non-MHL students benefit from voice amplification?

Separation Distance

Research questions regarding separation distance:

1. Does separation distance affect achievement for students identified as having MHL?
2. Does decreased separation distance improve performance for younger children more than for older children?
3. Does the aptitude of students offset the effect of separation distance?
4. Does amplification of the teacher's voice affect student performance at different separation distances?
5. Which zone(s) seem to optimize linguistic task performance for students?

Noise Abatement

Research questions related to noise abatement are:

1. Is the effect of soundproofing more beneficial for students with MHL than for students without MHL?
2. Does teacher voice signal amplification have a positive effect for students with MHL in soundproofed and non-soundproofed environments?
3. Does soundproofing affect or mitigate the variable of separation distance?

Assumptions

The following assumptions are advanced for this study:

1. There are both discreet and continuous phenomena that are involved in speech communication.
2. Hearing acuity in the population sample represents measurable discreet events.
3. The speech chain as presented in Figure 1 is an appropriate theoretical model for this investigation.
4. It is appropriate to examine one or more factors involved in a research effort while limiting the study to fewer than all possible factors available to the researcher.

Data Analysis

To analyze all research questions, this researcher used the mainframe computer at the Academic Computing Service Center, Loyola University, Chicago. The following quantitative tests and statistics were used to analyze the research data, check for comparisons, determine significance, and provide information to facilitate the research:

1. frequency tabulations
2. two-way analysis of variance
3. four-way analysis of variance
4. correlation analysis

A 2x2x2 factorial analysis of covariance with aptitude as the covariant was used with the data related to MHL. For the

separation distance and noise abatement questions of interest a 2x2x2x2 factorial analysis was utilized. These designs allowed several research questions to be tested simultaneously and a determination made if interaction between two or more variables was significant.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The threefold purpose of this study is as follows: (a) to gain a further understanding of the effect of minimal hearing loss on third- and eighth-grade students' performance in subject matter other than reading; (b) to examine the effect of speaker-to-listener separation distance on student performance; and (c) to explore the effect of noise abatement (soundproofing) in an identified high noise environment (75 LDN) on both MHL and non-MHL subjects. All three variables were examined in comparison to the dependent variable, students' linguistic task performance.

This chapter is divided into four subsections. A descriptive analysis of the sample is provided in the first section. The second section analyzes the research questions related to minimal hearing loss. The third section focuses on the research questions involving separation distance. The fourth section examines the research questions related to noise abatement.

Descriptive Analysis

Table 3 displays the number of subjects at each grade level involved in the study as well as their distribution at each site by frequency and percentage.

Table 3

Frequency Distribution of Subjects by Grade and Site

Grade	Frequency	Percent
3	160	65.8%
8	83	34.2%

Site	Frequency	Percent
1 (grade 3)	49	20.2%
2 (grade 8)	83	34.2%
3 (grade 3)	37	15.2%
4 (grade 3)	74	30.5%

The descriptive data related to the variables MHL (acuity), separation distance (zone) and noise abatement (soundproofing) are illustrated in Tables 4-8.

An examination of Table 4 reveals that approximately one-fourth or 25% of all subjects experienced some degree of MHL.

Table 4

Frequency Distribution of Subjects by Acuity

Acuity	Frequency	Percentage
MHL	59	24.3%
Normal	184	75.7%

Table 5 analyzes acuity by percentages for grade and site.

Table 5

Acuity Distribtuion by Grade, Site and Percentage

	Grade 3	%	Grade 8	%
MHL	38	23.75%	21	25.30%
Normal	122	76.25%	62	74.70%

	Site (%) 1		Site (%) 2		Site (%) 3		Site (%) 4	
MHL	9	18.37	21	25.30	9	24.32	20	27.03
Nor.	40	81.63	62	74.70	28	75.68	54	72.97

In examining the data contained in Table 5 the percentage of students exhibiting MHL in grades three and eight are remarkably similar (23.75% to 25.3%). Also the percentage of students exhibiting some degree of MHL at all sites constitutes a fairly narrow range of 18.37% to 27.03%.

Table 6 displays the frequency distribution of subjects in the two zones utilized for analysis of separation distance.

Table 6

Frequency Distribtuion of Subjects by Zones

Zone	Frequency	Percentage
A	109	44.9%
B	134	55.1%

Table 7 displays the zone data by utilizing percentages for subjects at each grade and site.

Table 7

Zones Distribtuion by Grade, Site and Percentage

Zone	Grade 3	%	Grade 8	%
A	25	51%	34	40.96%
B	24	49%	22	59.04%

Zone	Site 1	(%)	Site 2	(%)	Site 3	(%)	Site 4	(%)
A	25	51%	34	41%	15	41%	35	47%
B	24	49%	49	59%	22	59%	39	53%

Table 7 reveals that at the third grade the distribution of students between zones A and B was almost even, i.e., 51% in zone A to 49% in zone B. At the eighth grade the distribution was more contrasted, with zone A representing approximately 41% of the students, while zone B

housed 59% of the students. A similar range of approximately ± 10 percentage points from the expected mean was evident when analyzing the distribution by zone and site.

Table 8 displays the distribution of subjects by soundproofing which was limited to site 1, a K-6 attendance center. The site housed two third grades, with a total of 49 students.

Table 8

Frequency Distribution by Subjects and Noise Abatement at the Third-Grade Level

Soundproofing	Frequency	Percentage
Yes	49	31%
No	111	69%

The analysis for noise abatement incorporated six other third-grade classes housed in Sites 3 and 4 which had not undergone noise abatement procedures.

Minimal Hearing Loss Analysis

The focus of this portion of the study was to continue the accumulation of data related to minimal hearing loss, including the effect of teacher voice-signal-amplification on students with minimal hearing loss in subject matter other than reading.

To that end, questions of interest were formulated that would address the MHL variable. The questions of interest for MHL were:

1. How prevalent is MHL in grades three and eight in the present school populations?

2. Does MHL have an effect on student achievement in the upper grades?
3. Does the achievement of identified MHL students improve when exposed to voice amplification?
4. Do students with different ability levels respond differently to voice amplification?
5. Do non-MHL students benefit from voice amplification?

The linguistic task performance (dependent variable) which was used to measure the questions of interest for the MHL variable were scores obtained by each subject on mathematics computation and mathematics reasoning tests. The test instruments and procedures were discussed previously in Chapter III.

The results of the linguistic task performance in relation to minimal hearing loss in computation for both third- and eighth grades are reported in Tables 9-12.

Table 9 displays the third-grade mean computation scores.

Table 9

Third-Grade Test Means by Acuity for Computation

Group	N	Mean Computation
Control	84	7.643
Experimental	76	7.697
Site	**N**	**Mean Computation**
3	37	9.000
1	49	6.571
4	74	7.730

Group	X	Site	N	Mean Computation
Control		3	17	9.647
Control		1	24	5.625
Control		4	43	7.977
Experimental		3	20	8.450
Experimental		1	25	7.480
Experimental		4	31	7.387

Acuity	N	Mean Computation
MHL	38	8.079
Normal	122	7.541

Group	X	Acuity	N	Mean Computation
Control		MHL	17	7.588
Control		Normal	67	7.657
Exper.		MHL	21	8.476
Exper.		Normal	55	7.400

Site	X	Acuity	N	Mean Computation
3		MHL	9	9.333
3		Normal	28	8.893
1		MHL	9	8.111
1		Normal	40	6.225
4		MHL	20	7.500
4		Normal	54	7.815

Group	X	Site	X	Acuity	N	Mean Computation
Control		3		MHL	2	9.000
Control		3		Normal	15	9.733
Control		1		MHL	3	4.333
Control		1		Normal	21	5.810
Control		4		MHL	12	8.167
Control		4		Normal	31	7.903
Exper.		3		MHL	7	9.429
Exper.		3		Normal	13	7.923
Exper.		1		MHL	6	10.000
Exper.		1		Normal	19	6.684
Exper.		4		MHL	8	6.500
Exper.		4		Normal	23	7.696

Although no significant differences between means were noted, some differences between means are apparent. However, the direction of the differences is not consistent. Also, some of the n's in selected cells, especially in the second and third order interactions, are small, and therefore assumptions of the model regarding normal distribution may not have been met.

Table 10 reflects the third-grade computation scores utilizing the ANOVA procedure.

Table 10

Analysis of Variance Table for Computation Scores

Third Grade

Source	DF	Type I SS	F. Value	Pr>F
Group	1	0.119	0.00	0.949
Site	2	124.761	2.16	0.112
Group X site	2	61.535	1.06	0.3476
Acuity	1	5.113	0.18	0.6747
Group X Acuity	1	10.231	0.35	0.5528
Site X Acuity	2	13.755	0.24	0.7886
Group X Site X Acuity	2	47.104	0.81	0.4448
Error	148	4278.827		
Total	159	4541.444		

In analyzing the above data there is no second order interaction present, no first order interaction present nor any main effects which are significant.

Table 11 reflects the mean scores for acuity by computation at the eighth-grade level.

Table 11

Eighth-Grade Test Means by Acuity for Computation

Group	N	Mean Computation
Control	40	-0.950
Experimental	43	0.558

Acuity	N	Mean Computation
MHL	21	-0.095
Normal	62	-0.194

Group X	Acuity	N	Mean Computation
Control	MHL	11	-0.545
Control	Normal	29	-1.103
Exper.	MHL	10	0.400
Exper.	Normal	33	0.606

The means for acuity by computation at the eighth-grade level exhibited no significant differences for group, acuity or group by acuity.

Table 12 represents the ANOVA for acuity by computation

at the eighth grade. (Note: only the factors, group, acuity and group by acuity will be analyzed and discussed in this section.)

Table 12

Analysis of Variance Table for Computation Scores

Eighth Grade

Source	DF	Type I SS	F Value	PR>F
Group	1	47.134	1.84	0.179
Acuity	1	0.526	0.02	0.886
Group X Acuity	1	2.283	0.09	0.766
Zone	1	0.734	0.03	0.866
Group X Zone	1	2.709	0.11	0.746
Acuity X Zone	1	54.736	2.14	0.148
Group X Acuity X Zone	1	7.856	0.31	0.581
Error	75	1917.660		
Total	82	2033.639		

The ANOVA reflects the earlier comparison of the mean scores in that no first order interaction or main effect was significant for eighth grade in the linguistic task performance, computation.

The second Linguistic Task Performance analysis is Mathematics Reasoning by Acuity. This analysis is presented in Tables 13-16. Table 13 will examine the mean scores for third-grade reasoning.

Table 13

Third-Grade Test Means by Acuity for Reasoning

Group	N	Mean Reasoning
Control	84	4.464
Experimental	76	4.526

Site	N	Mean Reasoning
3	37	5.946
1	49	5.020
4	74	3.419

Group X	Site	N	Mean Reasoning
Control	3	17	6.529
Control	1	24	5.208
Control	4	43	3.233

Experimental	3	20	5.450
Experimental	1	25	4.840
Experimental	4	31	3.677

Acuity	N	Mean Reasoning
MHL	38	4.711
Normal	122	4.426

Group	X	Acuity	N	Mean Reasoning
Control		MHL	17	4.882
Control		Normal	67	4.358
Experimental		MHL	21	4.571
Experimental		Normal	55	4.509

Site	X	Acuity	N	Mean Reasoning
3		MHL	9	6.444
3		Normal	28	5.786
1		MHL	9	5.111
1		Normal	40	5.000
4		MHL	20	3.750
4		Normal	54	3.296

Group	X	Site	X	Acuity	N	Mean Reasoning
Control		3		MHL	2	8.000
Control		3		Normal	15	6.333
Control		1		MHL	3	5.000
Control		1		Normal	21	5.238
Control		4		MHL	12	4.333
Control		4		Normal	31	2.806
Exper.		3		MHL	7	6.000
Exper.		3		Normal	13	5.154
Exper.		1		MHL	6	5.167
Exper.		1		Normal	19	4.737
Exper.		4		MHL	8	2.875
Exper.		4		Normal	23	3.957

In examining the mean scores from Table 13, a significant difference is noted between sites 3 and 4 and 1 and 4 at the 0.05 level of significance. Archival records maintained within the district indicate that subjects at site 4 had repeatedly demonstrated lower performance on measures of both aptitude and achievement compared with subjects at sites 1 and 3. This finding of significance is also reflected in the ANOVA analysis, Table 14, which summarizes the data related to mathematical reasoning and acuity for third grade.

Table 14

Analysis of Variance Table for Reasoning Scores

Third Grade

Source	DF	Type I SS	F-Value	PR>f
Group	1	0.154	0.01	0.9198
Site	2	177.999	5.90	0.0034
Group X Site	2	14.890	0.49	0.615
Acuity	1	7.922	0.53	0.4698
Group X Acuity	1	10.586	0.70	0.4035
Site X Acuity	2	5.064	0.17	0.8457
Group X Site X Acuity	2	12.691	0.42	0.6574
Error	148	2232.690		
Total	159	2461.994		

As noted, the data reflects there is no second order interaction, no first order interaction and only the main effect, site, indicates that a significant difference ($F=5.90$, $P<.01$) is present.

Table 15, reflects mathematics reasoning by acuity at the eighth-grade level. It displays the mean scores for group, acuity and group by acuity.

Table 15

Eighth-Grade Test Means by Acuity for Reasoning

Group	N	Mean Reasoning
Control	40	1.250
Experimental	43	1.000

Acuity	N	Mean Reasoning
MHL	21	1.571
Normal	62	0.968

Group X	Acuity	N	Mean Reasoning
Control	MHL	11	0.364
Control	Normal	29	1.586
Exper.	MHL	10	2.900
Exper.	Normal	33	0.424

The means reflect no significant difference for group, acuity or group by acuity.

Table 16 displays the ANOVA for eighth-grade Mathematical Reasoning by Acuity. (Note: only the factors group, acuity and group by acuity will be analyzed in this section.)

Table 16

Analysis of Variance Table for Reasoning Scores

Eighth Grade

Source	DF	Type 1 SS	F Value	PR>F
Group	1	1.295	0.05	0.818
Acuity	1	5.467	0.23	0.636
Group X Acuity	1	53.492	2.21	0.141
Zone	1	58.084	2.40	0.126
Group X Zone	1	4.897	0.20	0.654
Acuity X Zone	1	12.036	0.50	0.483
Group X Acuity X Zone	1	3.467	0.14	0.706
Error	75	1818.057		
Total	82	1956.795		

A review of the ANOVA table for mathematics reasoning by acuity at the eighth-grade level reveals that no significant difference is found in the first order interaction (Group by Acuity), or the main effects (Acuity, Group).

In response to the Questions of Interest related to the significance of Minimal Hearing Loss on the Linguistic Task Performance for both Mathematical Computation and Mathematical Reasoning the following inferences can be made.

Question 1. How prevalent is MHL in grades three and eight in the present school population? The examination of the data for this question reveals that at both the third- and eighth-grade levels approximately 25% (23.75% of the third-graders and 25.31% of the eighth-graders) displayed some degree of MHL.

Question 2. Does MHL have an effect on student achievement in the upper grades? The data for acuity clearly reflects that in both mathematical computation and mathematical reasoning at the third- and eighth-grade levels students exhibiting the presence of MHL were not adversely effected in terms of their achievement in comparison to students without MHL. The finding, of no significance at the .05 level, was consistent throughout the acuity data.

Question 3. Does the achievement of identified MHL students improve when exposed to voice amplification? At both the third- and eighth-grade levels in mathematical computation and mathematical reasoning, the finding of no significant difference at the .05 level for Group by Acuity was found. This represented the comparison of MHL control subjects and MHL experimental subjects. (Tables 9, 11, 13 and 15.) The achievement of MHL students did not improve when exposed to voice amplification.

Question 4. Do students with different ability levels respond differently to voice amplification? To respond to this question, Pearson's Correlation Coefficient was utilized to examine aptitude and mathematical computation and reasoning scores at the third- and eighth-grade levels. In all cases Pearson's Correlation Coefficients were not significant. At the third grade, computation/aptitude was equal to .09 (P=.21) while reasoning/aptitude was .06 (P=.43). At the eighth grade the computation/aptitude was

.12 (P=.26) while reasoning/aptitude reflected a .10 (P=.35) correlation coefficient. It is possible, therefore, to infer that students with different aptitudes did not respond differently to voice amplification.

Question 5. Do non-MHL students benefit from voice amplification? Tables 9 and 11 reflect the mean scores for third- and eighth-grade computation as do Tables 13 and 15 for third- and eighth-grade reasoning. In examining the Group by Acuity scores for control normal and experimental normal, no significant difference was found for either third- or eighth grade in either mean computation or mean reasoning scores. Therefore, in this particular instance, non-MHL students did not significantly benefit from voice amplification.

Separation Distance Analysis

The variable Separation Distance was used in this study to examine questions of interest regarding the effect of separation distance, i.e., the distance between the speaker (teacher) and the listener (student) and its impact on speech intelligibility as measured by the listener's linguistic task performance. Specific questions of interest which were incorporated into the study were:

1. Does separation distance affect achievement for students identified as having MHL?

2. Does decreased separation distance improve academic performance for younger children more than for older children?
3. Does the aptitude of students offset the effect of separation distance?
4. Does amplification of the teacher's voice affect student performance at different separation distances?
5. Which zone(s) seem to optimize linguistic task performance for students?

The procedures for measuring separation distance (referred to in the following tables as zone) and its effect on linguistic task performance are outlined in Chapter III. Tables 17-19 display data relative to mathematical computation and separation distance. Table 17 displays the mean scores for mathematical computation and separation distance for third grade.

Table 17

Third-Grade Test Means for Zones by Mathematical Computation

Group	N	Mean Computation
Control	84	7.643
Experimental	76	7.697
Acuity	**N**	**Mean Computation**
Normal	122	7.541
MHL	38	8.079
Zone	**N**	**Mean Computation**
A	75	7.787
B	85	7.565
Aptitude	**N**	**Mean Computation**
<=100	80	8.200
>=100	80	7.138

Group X Acuity		N	Mean Computation
Control	Normal	67	7.657
Control	MHL	17	7.588
Exper.	Normal	55	7.400
Exper.	MHL	21	8.476

Group X Zone		N	Mean Computation
Control	A	33	8.152
Control	B	51	7.314
Exper.	A	42	7.500
Exper.	B	34	7.941

Aptitude X Group		N	Mean Computation
<=100	Control	38	7.763
<=100	Experimental	42	8.595
>=100	Control	46	7.543
>=100	Experimental	34	6.588

Acuity X Zone		N	Mean Computation
Normal	A	60	8.050
Normal	B	62	7.048
MHL	A	15	6.733
MHL	B	23	8.957

Aptitude X Acuity		N	Mean Computation
<=100	Normal	62	7.726
<=100	MHL	18	9.833
>=100	Normal	60	7.350
>=100	MHL	20	6.500

Aptitude X Zone		N	Mean Computation
<=100	A	40	8.175
<=100	B	40	8.225
>=100	A	35	7.343
>=100	B	45	6.978

Group X Acuity X Zone			N	Mean Computation
Control	Normal	A	27	8.667
Control	Normal	B	40	6.975
Control	MHL	A	6	5.833
Control	MHL	B	11	8.545
Exper.	Normal	A	33	7.545
Exper.	Normal	B	22	7.182
Exper.	MHL	A	9	7.333
Exper.	MHL	B	12	9.333

Aptitude X Group X Acuity			N	Mean Computation
<=100	Control	Normal	32	7.219
<=100	Control	MHL	6	10.667
<=100	Exper.	Normal	30	8.267
<=100	Exper.	MHL	12	9.417
>=100	Control	Normal	35	8.057
>=100	Control	MHL	11	5.909
>=100	Exper.	Normal	25	6.360
>=100	Exper.	MHL	9	7.222

Aptitude X Group X Zone			N	Mean Computation
<=100	Control	A	18	8.000
<=100	Control	B	20	7.550
<=100	Exper.	A	22	8.318
<=100	Exper.	B	20	8.900

>=100	Control	A	15	8.333
>=100	Control	B	31	7.161
>=100	Exper.	A	20	6.600
>=100	Exper.	B	14	6.571

Aptitude	X Acuity	X Zone	N	Mean Computation
<=100	Normal	A	34	8.441
<=100	Normal	B	28	6.857
<=100	MHL	A	6	6.667
<=100	MHL	B	12	11.416
>=100	Normal	A	26	7.538
>=100	Normal	B	34	7.205
>=100	MHL	A	9	6.778
>=100	MHL	B	11	6.272

The comparison of the mean scores indicated findings of no significance. In fact the relative difference between all mean scores was small.

Likewise the accompanying ANOVA Table, 18, also indicates no second order interaction, no first order interaction and no significant main effects for separation distance and mathematical computation for third grade.

Table 18

Analysis of Variance Table for Zone by Computation

Third Grade

Source	DF	Type I SS	F Value	PR>F
Group	1	0.118	0.00	0.9488
Acuity	1	8.275	0.29	0.5919
Zone	1	2.736	0.10	0.7578
Aptitude	1	45.812	1.60	0.2082
Group X Acuity	1	7.346	0.26	0.6134
Group X Zone	1	8.081	0.28	0.5963
Aptitude X Group	1	34.206	1.19	0.2765
Acuity X Zone	1	54.057	1.89	0.1718
Aptitude X Acuity	1	43.219	1.51	0.2215
Aptitude X Zone	1	1.492	0.05	0.8199
Group X Acuity X Zone	1	32.621	1.14	0.2879
Aptitude X Group X Acuity	1	77.452	2.70	0.1024
Aptitude X Group X Zone	1	1.454	0.05	0.8221
Aptitude X Acuity X Zone	1	67.944	2.37	0.1259
Error	152	4426.657		
Total	159	4541.444		

Table 19 reflects the eighth-grade mean scores for computation by zone.

Table 19

Eighth-Grade Test Means for Zone by Mathematical Computation

Group	N	Mean Computation
Control	40	-0.950
Experimental	44	0.545
Acuity	**N**	**Mean Computation**
Normal	62	-0.194
MHL	22	-0.091
Zone	**N**	**Mean Computation**
A	34	-0.235
B	50	-0.120
Aptitude	**N**	**Mean Computation**
<=100	45	0.385
>=100	39	-0.644
Group X Acuity	**N**	**Mean Computation**
Control Normal	29	-1.103
Control MHL	11	-0.545
Exper. Normal	33	0.606
Exper. MHL	11	0.364
Group X Zone	**N**	**Mean Computation**
Control A	15	-0.867
Control B	25	-1.000
Exper. A	19	0.263
Exper. B	25	0.760
Aptitude X Group	**N**	**Mean Computation**
<=100 Control	26	-0.692
<=100 Exper.	19	-0.579
>=100 Control	14	-1.429
>=100 Exper.	25	1.400
Acuity X Zone	**N**	**Mean Computation**
Normal A	27	-0.778
Normal B	35	0.257
MHL A	7	1.857
MHL B	15	-1.000
Aptitude X Acuity	**N**	**Mean Computation**
<=100 Normal	36	-0.750
<=100 MHL	9	-0.222
>=100 Normal	26	0.577
>=100 MHL	13	0.000
Aptitude X Zone	**N**	**Mean Computation**
<=100 A	19	-1.211
<=100 B	26	-0.230
>=100 A	15	1.000
>=100 B	24	0.000

Group X Acuity X Zone			N	Mean Computation
Control	Normal	A	12	-1.750
Control	Normal	B	17	-0.647
Control	MHL	A	3	2.667
Control	MHL	B	8	-1.750
Exper.	Normal	A	15	0.000
Exper.	Normal	B	18	1.111
Exper.	MHL	A	4	1.250
Exper.	MHL	B	7	-0.143

Aptitude X Group X Acuity			N	Mean Computation
<=100	Control	Normal	20	-0.900
<=100	Control	MHL	6	0.000
<=100	Exper.	Normal	16	-0.563
<=100	Exper.	MHL	3	-0.667
>=100	Control	Normal	9	-1.556
>=100	Control	MHL	5	-1.200
>=100	Exper.	Normal	17	1.706
>=100	Exper.	MHL	8	0.750

Aptitude X Group X Zone			N	Mean Computation
<=100	Control	A	10	-0.600
<=100	Control	B	16	-0.750
<=100	Exper.	A	9	-1.889
<=100	Exper.	B	10	0.600
>=100	Control	A	5	-1.400
>=100	Control	B	9	-1.444
>=100	Exper.	A	10	2.200
>=100	Exper.	B	15	0.867

Aptitude X Acuity X Zone			N	Mean Computation
<=100	Normal	A	15	-2.067
<=100	Normal	B	21	0.190
<=100	MHL	A	4	2.000
<=100	MHL	B	5	-2.000
>=100	Normal	A	12	0.833
>=100	Normal	B	14	0.357
>=100	MHL	A	3	1.667
>=100	MHL	B	10	-0.500

The comparison of means indicate that no significant difference is present at the eighth grade in relation to computation and zone. The ANOVA, Table 20, which reflects computation and separation distance for eighth grade also indicates that there is no second order interaction, no first order interaction, nor main effects which are significant.

Table 20

Analysis of Variance Table for Computation Score

Eighth Grade

Source	DF	Type I SS	F Value	PR>F
Group	1	46.856	1.78	0.186
Acuity	1	0.370	0.01	0.906
Zone	1	0.735	0.03	0.868
Aptitude	1	10.258	0.39	0.534
Group X Acuity	1	2.876	0.11	0.742
Group X Zone	1	2.320	0.09	0.767
Aptitude X Group	1	40.000	1.52	0.222
Acuity X Zone	1	66.491	2.53	0.116
Aptitude X Acuity	1	10.034	0.00	0.971
Aptitude X Zone	1	13.325	0.51	0.479
Group X Acuity X Zone	1	3.813	0.14	0.705
Aptitude X Group X Acuity	1	0.138	0.01	0.942
Aptitude X Group X Zone	1	15.500	0.59	0.445
Aptitude X Acuity X Zone	1	16.420	0.62	0.432
Error	69	1814.532		
Total	83	1022.667		

The second Linguistic Task Performance analysis for separation distance is that of mathematics reasoning. This analysis is presented in Tables 21-23. Table 21 reflects the mean scores for third-grade reasoning.

Table 21

Third-Grade Test Means for Zone by Mathematical Reasoning

Group	N	Mean Reasoning
Control	84	4.464
Experimental	76	4.526
Acuity	**N**	**Mean Reasoning**
Normal	122	4.425
MHL	38	4.711
Zone	**N**	**Mean Reasoning**
A	75	4.987
B	85	4.059
Aptitude	**N**	**Mean Reasoning**
<=100	80	4.525
>=100	80	4.463
Group X Acuity	**N**	**Mean Reasoning**
Control Normal	67	4.358
Control MHL	17	4.882
Exper. Normal	55	4.509
Exper. MHL	21	4.571

Group X Zone		N	Mean Reasoning
Control	A	33	4.758
Control	B	51	4.275
Exper.	A	42	5.167
Exper.	B	34	3.735

Acuity X Zone		N	Mean Reasoning
Normal	A	60	4.533
Normal	B	62	4.323
MHL	A	15	6.800
MHL	B	23	3.348

Aptitude X Group		N	Mean Reasoning
<=100	Control	38	4.763
<=100	Exper.	42	4.310
>=100	Control	46	4.214
>=100	Exper.	34	4.794

Aptitude X Acuity		N	Mean Reasoning
<=100	Normal	62	4.500
<=100	MHL	18	4.611
>=100	Normal	60	4.350
>=100	MHL	20	4.800

Aptitude X Zone		N	Mean Reasoning
<=100	A	40	4.925
<=100	B	40	4.125
>=100	A	35	5.057
>=100	B	45	4.000

Group X Acuity X Zone			N	Mean Reasoning
Control	Normal	A	27	4.370
Control	Normal	B	40	4.350
Control	MHL	A	6	6.500
Control	MHL	B	11	4.000
Exper.	Normal	A	33	4.667
Exper.	Normal	B	22	4.273
Exper.	MHL	A	9	7.000
Exper.	MHL	B	12	2.750

Aptitude X Group X Acuity			N	Mean Reasoning
<=100	Control	Normal	32	4.469
<=100	Control	MHL	6	6.333
<=100	Exper.	Normal	30	4.533
<=100	Exper.	MHL	12	3.750
>=100	Control	Normal	35	4.357
>=100	Control	MHL	11	4.091
>=100	Exper.	Normal	25	4.480
>=100	Exper.	MHL	9	5.667

Aptitude X Group X Zone			N	Mean Reasoning
<=100	Control	A	18	5.556
<=100	Control	B	20	4.050
<=100	Exper.	A	22	4.409
<=100	Exper.	B	20	4.200
>=100	Control	A	15	3.800
>=100	Control	B	31	4.419
>=100	Exper.	A	20	6.000
>=100	Exper.	B	14	3.071

Aptitude X	Acuity X	Zone	N	Mean Reasoning
<=100	Normal	A	34	4.824
<=100	Normal	B	28	4.107
<=100	MHL	A	6	5.500
<=100	MHL	B	12	4.167
>=100	Normal	A	26	4.154
>=100	Normal	B	34	4.500
>=100	MHL	A	9	7.667
>=100	MHL	B	11	2.455

The analysis of the mean scores indicated that there was a finding of significance in the second order interaction of Aptitude by Group by Zone. Subjects in this interaction possessed an aptitude greater than 100, resided in the experimental group, and were located in either Zone A or Zone B. A significant first order interaction was also found for Acuity by Zone between MHL-Zone A and MHL-Zone B. These findings are displayed in the ANOVA, Table 22, which reflects third-grade mathematical reasoning scores by zone. The Aptitude by Group by Zone ($F=3.94$, $P<.05$) and the Acuity by Zone ($F=4.40$, $P<.05$) were significant.

Table 22

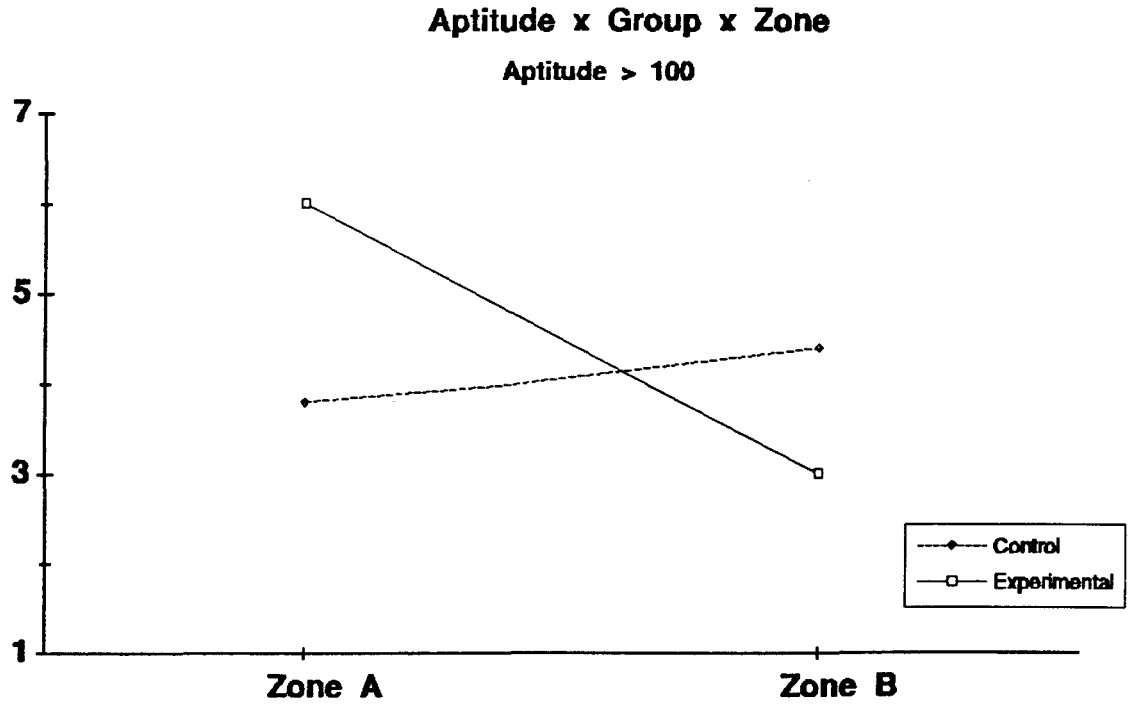
Analysis of Variance for Zone by Reasoning Scores

Third Grade

Source	DF	Type I SS	F-Value	PR>F
Group	1	0.154	0.01	0.920
Acuity	1	2.256	0.15	0.701
Zone	1	36.560	2.39	0.124
Aptitude	1	0.023	0.00	0.969
Group X Acuity	1	0.870	0.06	0.812
Group X Zone	1	9.301	0.61	0.437
Aptitude X Group	1	8.410	0.55	0.459
Acuity X Zone	1	67.244	4.40	0.037
Aptitude X Acuity	1	1.200	0.08	0.780
Aptitude X Zone	1	0.114	0.01	0.931
Group X Acuity X Zone	1	4.761	0.31	0.578
Aptitude X Group X Acuity	1	4.906	0.32	0.572
Aptitude X Group X Zone	1	60.272	3.94	0.048
Aptitude X Acuity X Zone	1	49.916	3.27	0.072
Error	145	2216.006		
Total	159	2461.994		

Figure 4 illustrates the disordinal interaction found between Aptitude by Group by Zone. The data indicates that of the subjects who exceeded 100 in aptitude, those in the experimental group, performed significantly better than the subjects who were in the control group when placed in Zone A. In Zone B the opposite was true. However, the means were not significantly different. This second order disordinal interaction is difficult to interpret, especially since none of the main effects were found to be significant.

Figure 4



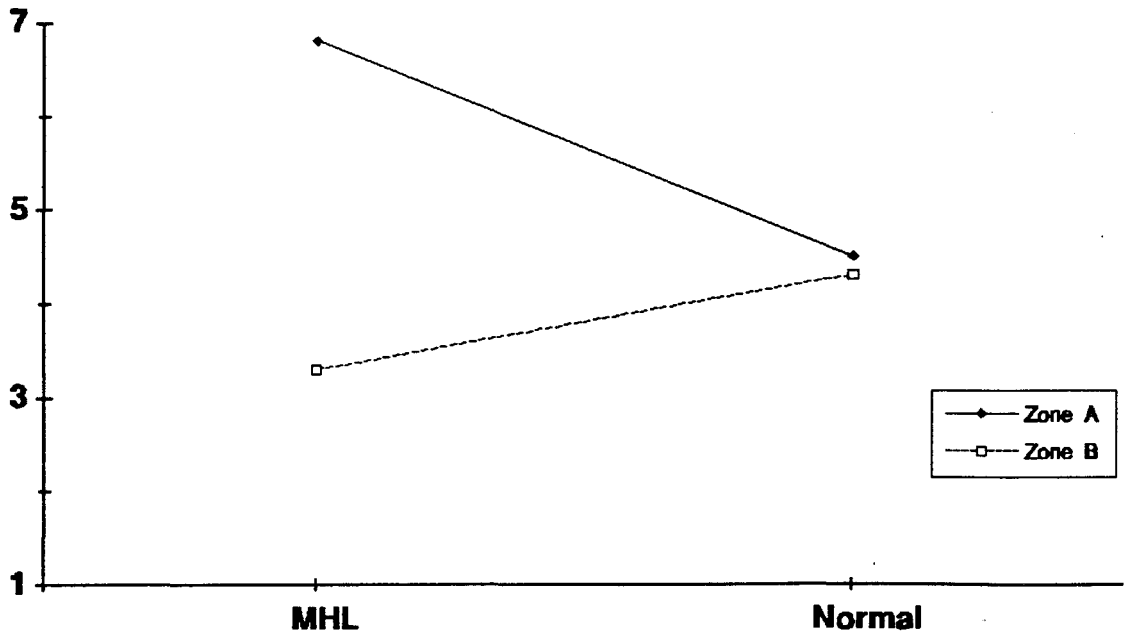
Kerlinger (1973) discusses interaction by noting:

> A possible cause of interaction is some extraneous, unwanted, uncontrolled effect operating at one level of an experiment but not another. Such a cause of interaction is particularly to be watched for in non-experimental uses of the analysis of variance, that is, in the analysis of variance of data gathered after independent variables have already operated (p. 268).

Figure 5 depicts the ordinal interaction of Acuity by Zone. The figure illustrates the significant difference

Figure 5

Acuity x Zone



between the means of MHL students in Zone A versus the MHL students who were located in Zone B. One could infer from this data that MHL students benefitted from the lesser amount of separation distance between the speaker and the listener found in Zone A, (Flexer, Wray, Ireland, 1989), based on their linguistic task performance in mathematical reasoning.

At the eighth-grade level the mean scores for reasoning by zone are reported on table 23.

Table 23

Eighth-Grade Test Means by Zone for Reasoning

Group	N	Mean Reasoning
Control	40	1.250
Experimental	43	0.977
Acuity	**N**	**Mean Reasoning**
Normal	62	0.968
MHL	22	1.500
Zone	**N**	**Mean Reasoning**
A	34	2.118
B	50	0.420
Aptitude	**N**	**Mean Reasoning**
<=100	45	0.756
>=100	39	1.513
Group X Acuity	**N**	**Mean Reasoning**
Control Normal	29	1.586
Control MHL	11	0.364
Exper. Normal	33	0.424
Exper. MHL	11	2.636
Group X Zone	**N**	**Mean Reasoning**
Control A	15	2.067
Control B	25	0.760
Exper. A	19	2.158
Exper. B	25	0.080
Aptitude X Group	**N**	**Mean Reasoning**
<=100 Control	26	0.885
<=100 Exper.	19	0.579
>=100 Control	14	1.929
>=100 Exper.	25	1.280

Acuity	X	Zone	N	Mean Reasoning
Normal		A	27	1.667
Normal		B	35	0.429
MHL		A	7	3.857
MHL		B	15	0.400

Aptitude	X	Acuity	N	Mean Reasoning
<=100		Normal	36	0.722
<=100		MHL	9	0.889
>=100		Normal	26	1.308
>=100		MHL	13	1.923

Aptitude	X	Zone	N	Mean Reasoning
<=100		A	19	1.158
<=100		B	26	0.462
>=100		A	15	3.333
>=100		B	24	0.375

Group	X	Acuity	X	Zone	N	Mean Reasoning
Control		Normal		A	12	2.167
Control		Normal		B	17	1.176
Control		MHL		A	3	1.167
Control		MHL		B	8	-0.125
Exper.		Normal		A	15	1.267
Exper.		Normal		B	18	-0.278
Exper.		MHL		A	4	5.500
Exper.		MHL		B	7	1.000

Aptitude	X	Group	X	Acuity	N	Mean Reasoning
<=100		Control		Normal	20	1.250
<=100		Control		MHL	6	-0.333
<=100		Exper.		Normal	16	0.063
<=100		Exper.		MHL	3	3.333
>=100		Control		Normal	9	2.333
>=100		Control		MHL	5	1.200
>=100		Exper.		Normal	17	0.765
>=100		Exper.		MHL	8	2.375

Aptitude	X	Group	X	Zone	N	Mean Reasoning
<=100		Control		A	10	1.200
<=100		Control		B	16	0.688
<=100		Exper.		A	9	1.111
<=100		Exper.		B	10	0.100
>=100		Control		A	5	3.800
>=100		Control		B	9	0.889
>=100		Exper.		A	10	3.100
>=100		Exper.		B	15	0.067

Aptitude	X	Acuity	X	Zone	N	Mean Reasoning
<=100		Normal		A	15	0.600
<=100		Normal		B	21	0.810
<=100		MHL		A	4	3.250
<=100		MHL		B	5	-1.000
>=100		Normal		A	12	3.000
>=100		Normal		B	14	-0.143
>=100		MHL		A	3	4.667
>=100		MHL		B	10	1.100

The analysis of the mean scores reflected no significant difference between mathematical reasoning and zone. The ANOVA, Table 24, reflects the mean score analysis in that no second order interaction, first order interaction or main effect has any significance at the .05 level.

Table 24

Aanaysis of Variance of Zone by Mathematical Reasoning

Eighth Grade

Source	DF	Type I SS	F-Value	PR>F
Group	1	1.558	0.06	0.805
Acuity	1	4.453	0.17	0.677
Zone	1	63.744	2.50	0.118
Aptitude	1	14.617	0.57	0.451
Group x Acuity	1	43.812	1.72	0.194
Group x Zone	1	6.076	0.24	0.627
Aptitude x Group	1	2.623	0.10	0.749
Acuity x Zone	1	17.502	0.69	0.410
Aptitude x Acuity	1	0.884	0.03	0.853
Aptitude x Zone	1	26.805	1.05	0.308
Group x Acuity x Zone	1	4.002	0.16	0.693
Aptitude x Group x Acuity	1	0.816	0.03	0.859
Aptitude x Group x Zone	1	0.055	0.00	0.963
Aptitude x Acuity x Zone	1	14.330	0.56	0.456
Error	69	1756.760		
Total	83	1958.036		

In examining the Questions of Interest related to separation distance and Linguistic Task Performance for both mathematical computation and mathematical reasoning the following inferences can be made.

Question 1. Does separation distance affect achievement for students identified as having MHL? At the third-grade level, mathematical computation scores were not significant when Acuity by Zone or Zone were analyzed. For third-grade mathematical reasoning the main effect, Zone, also was not significant. However, the first order interaction of Acuity by Zone was significant. The

interaction indicated that the mean score for MHL students in Zone A was significant in relation to MHL students in Zone B.

At the eighth-grade level no main effect or interaction was found to be significant for either computation or reasoning. In summary, an inference can be made that a MHL student's achievement at the third-grade level is positively affected in mathematical reasoning by being in Zone A which is closer to the speaker then in Zone B which is further removed. Other than this instance, separation distance did not seem to affect achievement for students identified as having MHL at either third- or eighth grade.

Question 2. Does decreased separation distance improve performance for younger children more than for older children? As noted earlier in third-grade reasoning, significance was found in the first order interaction of Acuity by Zone. In this instance, third-grade students with MHL and assigned to Zone A performed significantly better than MHL students in Zone B. No significance was found in the main effect, Zone. At the eighth-grade level no significance was found in either computation or reasoning for any higher order interaction or the main effect. Therefore, data seems to indicate that separation distance is important for younger children, especially if they possess MHL. Those seated in Zone A close to the speaker performed significantly better then those placed further

away in Zone B. MHL-Zone A students also performed better then their normal hearing peers placed in Zone B when compared with each other in mathematical reasoning.

Question 3. Does the aptitude of students offset the effect of separation distance? At both the third- and eighth-grade levels in mathematical computation, neither the second order nor the first order interaction, nor the main effect Aptitude, was significant. This finding of no significance for Aptitude was also repeated by the eighth-grade subjects in mathematical reasoning.

At the third-grade level in mathematical reasoning no significance for the main effect, Aptitude, was found. Also, no first order interaction was found to be significant. However, significant second order interaction was found in the factor containing Aptitude, Group and Zone. This interaction was found to be disordinal. (Figure 5) Subjects whose aptitude exceeded 100, and who were in the experimental group located in Zone A, outperformed like students in Zone A in the control group. The reverse was true in Zone B where the control group outperformed the experimental group, although the difference was not significant. Based on the results of no significance for the main effect or first order interaction for Separation Distance/Aptitude within third-grade mathematical reasoning, no inference is advanced relative to the disordinal finding, although an uncontrolled or extraneous effect operating on

one level of the experiment is suspected. In examining the overall data related to aptitude it would be reasonable to infer that a student's aptitude does not seem to offset the effect of separation distance at either the third- or eighth grade in mathematical computation or reasoning.

Question 4. Does amplification of the teacher's voice affect student performance at different separation distances? In reviewing the data for third- and eighth-grade students in both computation and reasoning there is no significance found in the main effects, Group, Acuity or Zone. In examining other higher order interactions which involve group, i.e., Group by Acuity, Group by Zone, or Group by Acuity by Zone, no significant differences among the means were revealed. Therefore, it may be inferred that voice amplification for the speaker (teacher) did not counteract separation distance for any student regardless of their distance from the speaker.

Question 5. Which zone(s) seem to optimize linguistic task performance for students? Based on the results of the data a limited inference can be posited. Zone A, for third-grade students with MHL, would be the preferred placement related to student performance in mathematical reasoning. No other zones were identified that optimized linguistic task performance.

Noise Abatement Analysis

The variable noise abatement was used in this study to examine questions of interest regarding the effect of noise abatement (soundproofing) on the performance of students related to their linguistic task performance. Specific questions of interest which were incorporated into the study were:

1. Is the effect of soundproofing more beneficial for students with MHL than students without MHL?
2. Does teacher-voice-signal amplification have a positive effect for students with MHL in soundproofed and non-soundproofed environments?
3. Does soundproofing affect or mitigate the variable of separation distance?

The procedures for analyzing noise abatement (listed as soundproofing in the ANOVA analysis) and its effect on Linguistic Task Performance are outlined in Chapter III. As noted earlier, only one building, a K-6 attendance center (site 1), had undergone noise abatement treatment during the time of this study. Therefore, the only grade comparisons that could be made were between site 1 and the other two sites housing third-grade classrooms, sites 3 and 4.

Table 25 displays the mean scores for noise abatement and mathematical computation for third grade.

Table 25

Third-Grade Test Means for Noise Abatement by Mathematical Comprehension

Soundproof	N	Mean Comprehension
No	111	8.153
Yes	49	6.571

Group	N	Mean Comprehension
Control	84	7.643
Experimental	76	7.697

Acuity	N	Mean Comprehension
Normal	122	7.541
MHL	38	8.079

Zone	N	Mean Comprehension
A	75	7.787
B	85	7.565

Soundproof X Group		N	Mean Comprehension
No	Control	60	8.450
No	Exper.	51	7.804
Yes	Control	24	5.625
Yes	Exper.	25	7.480

Soundproof X Acuity		N	Mean Comprehension
No	Normal	82	8.183
No	MHL	29	8.069
Yes	Normal	40	6.225
Yes	MHL	9	8.111

Soundproof X Zone		N	Mean Comprehension
No	A	50	8.420
No	B	61	8.069
Yes	A	25	6.520
Yes	B	24	6.625

Group X Acuity		N	Mean Comprehension
Control	Normal	67	7.657
Control	MHL	17	7.588
Exper.	Normal	55	7.400
Exper.	MHL	21	8.476

Group X Zone		N	Mean Comprehension
Control	A	33	8.152
Control	B	51	7.314
Exper.	A	42	7.500
Exper.	B	34	7.941

Acuity X Zone		N	Mean Comprehension
Normal	A	60	8.500
Normal	B	62	7.048
MHL	A	15	6.733
MHL	B	23	8.957

Soundproof X Group X Acuity			N	Mean Comprehension
No	Control	Normal	46	8.500
No	Control	MHL	14	8.286
No	Exper.	Normal	36	7.778

No	Exper.	MHL	15	7.867
Yes	Control	Normal	21	5.810
Yes	Control	MHL	3	4.333
Yes	Exper.	Normal	19	6.684
Yes	Exper.	MHL	6	10.000

Soundproof	X Group	X Zone	N	Mean Comprehension
No	Control	A	22	9.455
No	Control	B	38	7.868
No	Exper.	A	28	7.607
No	Exper.	B	23	8.043
Yes	Control	A	11	5.545
Yes	Control	B	13	5.692
Yes	Exper.	A	14	7.286
Yes	Exper.	B	11	7.727

Soundproof	X Acuity	X Zone	N	Mean Comprehension
No	Normal	A	38	9.105
No	Normal	B	44	7.386
No	Exper.	A	12	6.250
No	Exper.	B	17	9.353
Yes	Normal	A	22	6.227
Yes	Normal	B	18	6.222
Yes	Exper.	A	3	8.667
Yes	Exper.	B	6	7.833

Soundproof	X Group	X Acuity	X Zone	N	Mean Comprehension
No	Control	Normal	A	16	10.813
No	Control	Normal	B	30	7.267
No	Control	MHL	A	6	5.833
No	Control	MHL	B	8	10.125
No	Exper.	Normal	A	22	7.864
No	Exper.	Normal	B	14	7.643
No	Exper.	MHL	A	6	6.667
No	Exper.	MHL	B	9	8.667
Yes	Control	Normal	A	11	5.545
Yes	Control	Normal	B	10	6.100
Yes	Control	MHL	A	11	6.909
Yes	Control	MHL	B	3	4.333
Yes	Exper.	Normal	A	11	6.909
Yes	Exper.	Normal	B	8	6.375
Yes	Exper.	MHL	A	3	8.667
Yes	Exper.	MHL	B	3	11.333

In analyzing the mean scores found on Table 25, some variance in scores can be found. However, the means do not exhibit any significant difference. It should also be noted that the n's in selected cells, especially in the second and third order interactions, are small and the assumptions of the model regarding normal distribution may not have been met.

Table 26 presents the change in computation scores utilizing the ANOVA procedure.

Table 26

Analysis of Variance Table for Noise Abatement by Mathematical Computation Third Grade

Source	DF	Type 1 SS	F-value	PR>F
Soundproof	1	85.047	2.99	0.086
Group	1	0.604	0.02	0.884
Acuity	1	4.269	0.15	0.699
Zone	1	4.070	0.14	0.706
Soundproof X Group	1	53.293	1.87	0.173
Soundproof X Acuity	1	15.487	0.54	0.462
Soundproof X Zone	1	3.960	0.14	0.710
Group X Acuity	1	16.461	0.58	0.448
Group X Zone	1	20.102	0.71	0.402
Acuity X Zone	1	107.026	3.76	0.054
Soundproof X Group X Acuity	1	43.209	1.52	0.220
Soundproof X Group X Zone	1	20.831	0.73	0.394
Soundproof X Acuity X Zone	1	3.189	0.11	0.738
Soundproof X Group X Acuity X Zone	1	40.334	1.42	0.236
Error	145	4123.562		
Total	159	4541.444		

The examination of the ANOVA table indicated that there was no third order, no second order, and no first order interaction present. In addition, none of the main effects were found at the .05 level to be significant.

Table 27 reflects the mean score for soundproofing and mathematical reasoning for the third grade.

Table 27

Third-Grade Test Means for Noise Abatement by Mathematical Reasoning

Soundproof	N	Mean Reasoning
No	111	4.261
Yes	49	5.020
Group	**N**	**Mean Reasoning**
Control	84	4.464
Experimental	76	4.526

Acuity	N	Mean Reasoning
Normal	122	4.426
MHL	38	4.711

Zone	N	Mean Reasoning
A	75	4.987
B	85	4.059

Soundproof X Group	N	Mean Reasoning
No Control	60	4.167
No Exper.	51	4.373
Yes Control	24	5.208
No Exper.	25	4.840

Soundproof X Acuity	N	Mean Reasoning
No Normal	82	4.146
No MHL	29	4.586
Yes Normal	40	5.000
Yes MHL	9	5.111

Soundproof X Zone	N	Mean Reasoning
No A	50	4.940
No B	61	3.705
Yes A	25	5.080
Yes B	24	4.958

Group X Acuity	N	Mean Reasoning
Control Normal	67	4.358
Control MHL	17	4.882
Exper. Normal	55	4.509
Exper. MHL	21	4.571

Group X Zone	N	Mean Reasoning
Control A	33	4.758
Control B	51	4.275
Exper. A	42	5.167
Exper. B	34	3.735

Acuity X Zone	N	Mean Reasoning
Normal A	60	4.533
Normal B	62	4.323
MHL A	15	6.800
MHL B	23	3.348

Soundproof X Group X Acuity	N	Mean Reasoning
No Control Normal	46	3.957
No Control MHL	14	4.857
No Exper. Normal	36	4.389
No Exper. MHL	15	4.333
Yes Control Normal	21	5.238
Yes Control MHL	3	5.000
Yes Exper. Normal	19	4.737
Yes Exper. MHL	6	5.167

Soundproof X Group X Zone	N	Mean Reasoning
No Control A	22	4.955
No Control B	38	3.711

No	Exper.	A	28	4.929
No	Exper.	B	23	3.696
Yes	Control	A	11	4.364
Yes	Control	B	13	5.923
Yes	Exper.	A	14	5.643
Yes	Exper.	B	11	3.818

Soundproof X	Acuity X	Zone	N	Mean Reasoning
No	Normal	A	38	4.368
No	Normal	B	44	3.955
No	MHL	A	12	6.750
No	MHL	B	17	3.059
Yes	Normal	A	22	4.818
Yes	Normal	B	18	5.222
Yes	MHL	A	3	7.000
Yes	MHL	B	6	4.167

Soundproof X	Group X	Acuity X	Zone	N	Mean Reasoning
No	Control	Normal	A	16	4.375
No	Control	Normal	B	30	3.733
No	Control	MHL	A	6	6.500
No	Control	MHL	B	8	3.625
No	Exper.	Normal	A	22	4.364
No	Exper.	Normal	B	14	4.429
No	Exper.	MHL	A	6	7.000
No	Exper.	MHL	B	9	2.556
Yes	Control	Normal	A	11	4.364
Yes	Control	Normal	B	10	6.200
Yes	Control	MHL	B	3	5.000
Yes	Exper.	Normal	A	11	5.273
Yes	Exper.	Normal	B	8	4.000
Yes	Exper.	MHL	A	3	7.000
Yes	Exper.	MHL	B	3	3.333

Again, although the various mean reasoning scores displayed exhibit some variability, no significant differences among the means were found. As with computation, the n's for reasoning, especially in selected cells in the second and third order interactions, are small and the assumption of the model regarding normal distribution may not have been met.

The ANOVA for the third-grade soundproofing by reasoning is displayed in Table 28.

Table 28

Analysis of Variance for Noise Abatement by Mathematical Reasoning Third Grade

Source	DF	Type 1 SS	F-Value	PR>F
Soundproof	1	19.591	1.25	0.266
Group	1	0.034	0.00	0.963
Acuity	1	3.610	0.23	0.633
Zone	1	34.439	2.19	0.141
Soundproof X Group	1	2.322	0.15	0.701
Soundproof X Acuity	1	0.029	0.00	0.966
Soundproof X Zone	1	9.303	0.59	0.443
Group X Acuity	1	0.680	0.04	0.836
Group X Zone	1	11.922	0.76	0.385
Acuity X Zone	1	74.411	4.73	0.031
Soundproof X Group X Acuity	1	0.007	0.00	0.983
Soundproof X Group X Zone	1	17.427	1.11	0.294
Soundproof X Acuity X Zone	1	0.867	0.06	0.815
Soundproof X Group X Acuity X Zone	1	6.623	0.42	0.517
Error	145	2280.727		
Total	159	2461.994		

The ANOVA for reasoning at the third-grade level reveals that the third order, the second order, and the first order interactions, along with the main effects, are not significant at the .05 level.

In examining the questions of interest related to noise abatement (soundproofing) and Linguistic Task Performance for both mathematical computation and mathematical reasoning the following inferences can be made:

Question 1. Is the effect of soundproofing more beneficial for students with MHL than students without MHL? In examining the data for both mathematical computation and mathematical reasoning no statistically significant results were found for the higher order interactions or the main effect of MHL (acuity) and soundproofing. Therefore, based on this data, soundproofing had no beneficial effect on the

achievement of the students possessing MHL over those students possessing normal hearing in relation to their linguistic task performance for both mathematical computation and mathematical reasoning.

Question 2. Does teacher-voice-signal amplification have a positive effect for students with MHL in soundproofed and non-soundproofed environments? Examination of mathematical computation and mathematical reasoning data revealed that the interaction, Group by Soundproofing and the main effects, Group and Soundproofing, disclosed no statistically significant results. Therefore, based on this data, teacher-voice-signal amplification did not have a positive effect on MHL students' linguistic task performance in either soundproofed or non-soundproofed environments.

Question 3. Does soundproofing affect or mitigate the variable separation distance? This question was scrutinized from the perspective of both mathematical computation and mathematical reasoning. The second order interaction, Soundproofing by Acuity by Zone, was examined as was the first order interaction, Soundproofing by Zone, and the main effects, Zone and Soundproofing, and in all instances the finding was one of no significance at the .05 level. Therefore, the noise abatement procedures utilized (the soundproofing of the building) had no impact on the variable of separation distance and students' linguistic task performance.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to investigate three variables which were thought to affect the speech intelligibility of children: minimal hearing loss (MHL), separation distance, i.e., the distance between speaker and listener in the classroom, and noise abatement, i.e., attenuation of sound within a building.

A west suburban Chicago school district located next to Chicago's O'Hare International Airport was selected for the study. Noise readings conducted by the FAA had identified the high level of noise (60-75 LDN) that impacts the community.

The current study utilized third- and eighth-grade students housed in four separate sites within the school district. A theoretical paradigm, The Speech Chain, (Figure 1) was utilized to illustrate the sequence of events between the speaker and the listener at three levels, i.e., acoustic, physiological and linguistic. Imposed on the paradigm was the cause variable, speech communication interference, and the effect variable, linguistic task performance. The treatment conditions, teacher-voice-signal

amplification, separation distance zones, and noise abatement, were incorporated into an experimental design as intervening treatment to offset speech interference between the speaker (teacher) and listener (student). Comparisons of linguistic task performance (the dependent variable) were made between experimental subjects who received treatment(s) and control subjects who did not by measuring each subject's performance on tests of mathematical computation and mathematical reasoning.

Following is a discussion of the results reported in Chapter IV. The Questions of Interest, along with interpretative information and the relative importance of the findings, are provided.

Minimal Hearing Loss Summary

Five questions of interest were grouped to provide information about MHL and to evaluate the treatment effect.

Question 1. How prevalent is MHL in grades three and eight in the present school population? In the third-grade 23.75% of all subjects and in the eighth-grade 25.30% of all subjects evidenced some degree of MHL. Thus, the percentage of students at both grade levels is quite similar. The third-grade percentage of 23.75 contrasts sharply with Kaufman's (1985) local data set for third-grade which reflected 51% of the population exhibiting some degree of MHL. The data does, however, align itself with an exterior data set which reported 30.3% of the students in the sample

exhibiting MHL at some level (MARRS, 1983). Although no interpretation is being advanced relative to the variance in the data sets between the third-graders (a similar exterior data set does not exist for eighth-grade subjects), it is important to note in both cases the high number of students unaccounted for in the present State of Illinois Hearing Conservation Program.

Question 2. Does MHL have an effect on student achievement in the upper grades? The data for acuity in both mathematical computation and mathematical reasoning at the third- and eighth grades revealed no significant difference in performance between students exhibiting the presence of MHL and students exhibiting normal hearing. This finding may be interpreted in several ways. First, most mathematics lessons contain visual as well as auditory components. That is, teachers explain, read or discuss mathematical concepts while simultaneously providing visual models and examples using the blackboard, overhead projector, manipulatives, books, or paper and pencil procedures. Students may have learned to compensate in mathematics for minimal hearing loss by utilizing one of the other contextual experience options provided during the lesson.

The second possibility, posited earlier by Kaufman (1985), was that MHL is an age-dependent physiological variable. This postulate assumes that as students develop

and mature the prevalence of MHL decreases since the physiological causes of MHL (infections of the nose, throat, and the formation of otitis media caused by frequent colds, allergies and general sinus infections) decrease as a child matures.

Rittenhouse and Kenyon (1991) also report that for mildly hearing-impaired children their ability to understand is linked to their overall cognitive development which is also influenced by life experiences. They suggest that as these children mature their increased capacity for learning can be realized with proper instruction.

Thus, the reduction of the impact of MHL on older students stems from the contextual compensation which takes place, the decrease in prevalence of MHL due to temporary physical causes, and their continued exposure to a variety of life experiences. Therefore, the inference can be made that for both mathematical computation and reasoning at the upper grades, student performance is not adversely affected by MHL.

Question 3. Does the achievement of identified MHL students improve when exposed to voice amplification? There were no significant differences between the means for mathematical computation and mathematical reasoning for MHL students receiving voice amplification and those receiving no treatment effect. The inclusion of both mathematical computation and mathematical reasoning in this study was an

attempt to separate the more nonverbal mathematical tasks (computation) from the more verbal mathematical tasks (reasoning).

The findings of no significant difference can be analyzed in several ways. First, mathematics, especially computation, has a visual component which does not depend on hearing to the extent that reading does. This is due, in large part, to the visual cues which are incorporated into most daily lessons of mathematics. The second consideration is that of time. The 95 days allotted for the study may not have been enough time for the linguistic task performance in reasoning to be affected. Jagielski (1991) found that problem solving (reasoning) was not only difficult to teach but also posited that a more longitudinal approach was needed to change student performance in this area.

Question 4. Do students with different ability levels respond differently to voice amplification? Pearson's correlation coefficient was utilized to examine the correlation of aptitude to mathematical computation and reasoning performance. Kaufman (1985), found at the first- and second-grade level in reading, high ability students with MHL responded better to teacher voice-signal-amplification than did average or low ability students. Contrary to expectations, within the discipline of mathematics, voice amplification did not interact with aptitude at any level. The relationship of the linguistic

task performance in different subject matter, to students of varying levels of aptitude, appears to be one area in need of further research in voice amplification treatment studies.

Question 5. Do non-MHL students benefit from voice amplification? Students classified as non-MHL subjects did not significantly differ from students identified as exhibiting MHL in either mathematical computation or mathematical reasoning. Since students with normal hearing, who were exposed to voice amplification, did not exhibit elevated growth in mathematics, the effort to improve their performance in this academic discipline will need to incorporate research which has identified other variables that increase mathematical performance.

Preliminary Conclusions

Based on analysis of MHL data the following conclusions can be drawn:

1. Approximately 25% of both the third- and eighth-grade students exhibited some degree of MHL.
2. MHL did not have an effect on the Linguistic Task Performance of identified students in either mathematical computation or mathematical reasoning at the third- or eighth-grade level.

3. Voice amplification did not improve performance of MHL students at the third- or eighth-grade level when compared to the performance of non-MHL students.
4. Regardless of the ability level of the student, voice amplification did not significantly affect their performance in either mathematical computation or mathematical reasoning.
5. Non-MHL students did not benefit from voice amplification in either mathematical computation or mathematical reasoning at the third- or eighth-grade levels.

Separation Distance Summary

Five questions of interest were grouped to provide information about separation distance and to evaluate the treatment effect.

Question 1. Does separation distance affect achievement for students identified as having MHL? For computation at the third grade, and for computation and reasoning at the eighth grade, no significant differences were found. However, at the third-grade level for mathematical reasoning, the first order interaction, Acuity by Zone, was significant. The inference of this finding is that MHL third-grade students seated in Zone A, which placed

them closer to the speaker than students in Zone B, benefitted significantly when Linguistic Task performance in Mathematical Reasoning was analyzed.

Although this finding was consistent with the literature that separation distance is a factor in speech intelligibility, the lack of consistency in the finding, i.e., eighth-grade reasoning, leads this investigator to accept Pimentel's (1988) observation that other factors such as visual cues, acoustics of the room, age, background noise and the listener's familiarity with the topic all impact on speech intelligibility.

Question 2. Does decreased separation distance improve performance for younger children more than for older children? The finding of significant first order interaction between Acuity and Zone in third-grade mathematical reasoning but not eighth-grade mathematical reasoning supports the age-dependent effect postulated by Kaufman (1985) and Rittenhouse and Kenyon (1991). Younger students have less mastery of the spoken language than do older children who possess not only a larger vocabulary but greater language experience as well. Since mathematical reasoning is dependant on the use of verbal skills that are needed for reading, this finding relates to and supports earlier findings on the impact of separation distance and speech intelligibility/reading (Kaufman, 1985, Loven and

Collins, 1988, and Finitzo, 1988) that decreased separation distance has a positive influence on student performance.

Question 3. Does the aptitude of students offset the effect of separation distance? The second order interaction, Aptitude by Group by Zone, was significant at the .05 level. The interaction was disordinal. This investigator makes no inference in regard to this finding since it is strongly suspected that an uncontrolled or extraneous effect interacted on this variable. The outcome of such an interaction as reported by Kerlinger (1973), is that an effect operates at one level on an experiment but not at another. Extraneous factors in such a case can cause significant interaction but it is not the result of "true" interaction.

Question 4. Does amplification of the teacher's voice affect students performance at different separation distances? The data for linguistic task performance in third- and eighth-grade mathematical computation and mathematical reasoning, displayed no significant differences between the means for second or first order interactions, Group by Acuity by Zone, Group by Acuity or Group by Zone. Also, the results of the main effects, Group, Acuity, and Zone, indicated that no significant differences existed. This finding is consistent with the earlier reported MHL data in this study which found voice amplification having no effect on student linguistic task performance. Although

this result is contrary to expectations, especially for the area of Mathematical Reasoning, it is postulated, based on Jagielski's (1991) work, that the finding of no significance in reasoning was related to the shortness of the study (95 days), and thus the treatment effect did not have the necessary time to positively impact student performance.

Question 5. Which Zone(s) seem to optimize linguistic task performance for students? Third-grade MHL students in mathematical reasoning located in Zone A performed significantly better than similar students in Zone B. This finding would support two conclusions. First, speech intelligibility is an age-dependent factor since this finding did not occur again in eighth grade where students are older and their language and experiential background more developed; second, that separation distance is more critical for activities which are more verbal in nature and rely less on visual or kinesthetic cues.

Preliminary Conclusions

Based on analysis of data on separation distance the following conclusions can be drawn:

1. Separation distance in mathematics becomes a factor for MHL students when their linguistic task includes verbal skills, and they have little or no exposure to visual cues which may enhance speech intelligibility.

2. In mathematics reasoning the performance of younger students is more enhanced by decreasing separation distance than is the performance in mathematical reasoning for older students.
3. There is no consistent evidence that the aptitude of students at any level is statistically significant with the variable separation distance in terms of student's linguistic task performance in either mathematical computation or mathematical reasoning.
4. Teacher voice amplification does not affect students' linguistic task performance regardless of the distance (zone) involved.
5. Zone A is the optimal placement for third-grade students involved in mathematical reasoning task performance if they exhibit MHL.

Noise Abatement Summary

Three questions of interest were grouped to provide information about noise abatement and to evaluate the treatment effect.

Question 1. Is the effect of soundproofing more beneficial for students with MHL than students without MHL? The analysis of both mathematical computation and mathematical reasoning at the third- and eighth-grade levels indicated findings of no significant difference when the first order interaction, Soundproofing by Acuity, or the

main effects, Soundproofing and Acuity were analyzed in relation to linguistic task performance for MHL and non-MHL students. Two possible explanations can be posited for this finding. The first is that the effect of previous high levels of noise exposure on speech intelligibility is long lasting. Thus, a longer reprieve from noise is needed to counteract the effects of noise than the four months allotted from the time the site was soundproofed until the time this study commenced. Second, since students are exposed to a high level of noise outside of school, a quieter classroom may not have been sufficient intervention. In either case, future studies will be needed to examine the effectiveness of noise abatement in relation to students' linguistic task performance in other subjects.

Question 2. Does teacher-voice-signal amplification have a positive effect for students with MHL in soundproofed and non-soundproofed environments? The Linguistic Task Performance for both third- and eighth-grades in mathematical computation and mathematical reasoning displays no significant results for the first order interaction, Group by Soundproofing or the main effects, Group, and Soundproofing. Again, it is noted that mathematics does not seem to be significantly affected by voice amplification. Other factors noted earlier (MHL Analysis, question #2) seem to allow students to compensate for MHL sufficiently and thus serve as an effective intervention.

Question 3. Does soundproofing affect or mitigate the variable separation distance? The second order interaction, Soundproofing by Acuity by Zone, the first order interaction, Soundproofing by Zone, and the main effects Zone, and Soundproofing, all exhibited no significant differences. This finding is consistent with earlier data that revealed that linguistic task performance in mathematical computation and mathematical reasoning was not significantly affected by separation distance except in specific instances (see question #2 Separation Distance). In addition, the same reasons posited in response to question #1 of this section would apply to this question of interest, especially the need to develop further studies regarding the effect of soundproofing on linguistic task performance.

Preliminary Conclusions

Based on analysis of data for noise abatement the following conclusions can be drawn:

1) Noise abatement has no effect on the linguistic task performance for either MHL or non-MHL students in mathematical computation or mathematical reasoning.
2) Teacher voice-signal-amplification is not a significant intervention on student performance in the linguistic tasks of

mathematical computation and reasoning in either an abated or non-abated environment.

3) Soundproofing does not mitigate the variable separation distance for students in terms of their linguistic task performance in mathematics.

Investigation Conclusions

In the following discussion the findings from the various components of this study are integrated and prioritized from the perspective of this investigator.

Three variables (MHL, separation distance and noise abatement) were selected for this study. From the review of literature each were thought to significantly affect students' linguistic task performance due to their impact on speech intelligibility.

The descriptive data identified approximately 25% of all third- and eighth-graders exhibiting some degree of minimal hearing loss. The distribution of students with MHL was fairly equal among all four sites included in this study. A similar distribution also prevailed for students placed in the two separation distance zones. The noise abatement portion of the study was limited to one site at the third-grade level.

The results of this study were contrary to expectations. The findings for the minimal hearing loss portion indicated that although MHL is present among the

population selected for the study, neither minimal hearing loss, nor the treatment effect, teacher voice-signal-amplification, had any significant impact on the linguistic task performance of third- or eighth-grade students. Further, students with normal hearing, as well as students with various aptitudes, did not benefit from voice amplification.

An interpretation for these findings was advanced. This investigator attributes the findings of no significance to both the aural and visual procedures that are utilized in the teaching of mathematics, especially the extensive use of visual cues, allowing for students to compensate for MHL. The aural and visual procedures also mitigate the effect of voice amplification on student performance. Together they serve as the major mediating factors impacting the results of this portion of the study. In addition, the impact of MHL on student performance, due to the age-dependent effect, decreases as the student develops and matures since the causes of MHL are often physiological in nature. Finally, the insufficient amount of time allotted to the area of mathematical reasoning for treatment effects to be significant, was discussed.

The findings for the separation distance variable revealed that only mathematical reasoning for MHL students in the third grade resulted in an effect that was statistically significant. This result supports the concept

of preferential seating to mitigate separation distance for the MHL student, i.e., a position closer to the speaker, especially if the student is in the primary grades and engaged in verbal tasks (Finitzo, 1988). Lack of other significant findings were attributed to the brief duration (95 days) of the study, especially for mathematical reasoning and the effect of the aural/visual instructional procedures utilized in the teaching of mathematics.

For the variable noise abatement no significant results were found for the effect of abatement on student linguistic task performance. This investigator attributed this finding to an insufficient reprieve from noise (four months) prior to students experiencing the treatment effect of this study. In addition, since students are exposed to a high level of speech interference outside the classroom, a quieter classroom may not have been a sufficient intervention in and of itself. Also, due to factors discussed previously, separation distance and voice amplification did not significantly affect students in a noise abated environment.

Recommendations

The following recommendations are presented to assist in: a) applying the findings to school organizations, b) replicating this study and, c) conducting future research.

Applications

1. Speech communication interference from minimal hearing loss should be evaluated through an ongoing hearing conservation program through the schools. For primary children this should be done each year, while intermediate and older children should be tested every other year or on an as needed basis. A program of this type would exceed standards of hearing conservation currently in place throughout the State of Illinois.
2. The local school district needs to develop data sets for all grade levels identifying the prevalence of MHL. This would allow for longitudinal tracking of individual students identified as exhibiting MHL.
3. There is also, for the local school district, a need to develop norms which present the relationship between hearing acuity and academic performance.
4. The separation distance paradigm is an important factor in speech intelligibility for students in classrooms where speech communication interference is prevalent. During instruction for mathematics reasoning, preferential seating to reduce the speaker-to-listener distance should be utilized, especially in primary grades.

Replication/Extension of this Research

Based upon the experiences and problems encountered in this investigation, the following methodological adjustments are recommended.

1. Treatment intervention should be extended to one or more school years. This is especially critical in adequately examining the treatment effects on mathematical reasoning.
2. When collecting data across more than one grade level, the interval between grade levels should not exceed two years, e.g., 3-5-7 or 4-6-8 to allow for analysis of performance over intervals which more closely account for general development and growth of students.
3. The test instrument used to collect mathematical reasoning data should be revised in future studies to be more sensitive to changes in student performance in this area.
4. A student aptitude variable needs to be incorporated into the design with various treatment effects to allow for analysis of an optimal treatment effects curve.

Future Research

1. Continuation of voice amplification research is recommended in a variety of different educational environments, grade levels and academic tasks.

2. The development of short units of study which are sensitive to verbal instruction and utilize a variety of specific instructional methods should be constructed and incorporated into future research.
3. For students exhibiting MHL, longitudinal studies in verbal task performance areas, especially for grades K-8, needs to be developed.
4. Using the appropriate paradigm, additional variables which may cause speech intelligibility interference within the classroom environment, e.g., reverberation time and signal-to-noise ratio, will need to be included in future studies.

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APPENDICES

Appendix A

Note: The FAA documents are copies of the letter and application for approval of the site 1 noise abatement project.

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

GRANT AGREEMENT

Part 1 - Offer

Date of Offer SEP 2 5 1984

Chicago O'Hare International Airport/Planning Area

Project No. 3-17-0022-N3

Contract No. AIP-FA84-GL-500

TO: Village of Bensenville

(herein called the "Sponsor")

FROM: The United States of America (acting through the Federal Aviation Administration, herein called the "FAA")

WHEREAS, the Sponsor has submitted to the FAA a Project Application dated September 12, 1984, for a grant of Federal funds for a project at the Mohawk School Airport/Planning Area together with plans and specifications for such development project, or the planning work definition for such Planning Project, which Project Application, as approved by the FAA, is hereby incorporated herein and made a part hereof; and

WHEREAS, the FAA has approved a project for the Airport or Planning Area (herein called the "Project") consisting of the following:

Soundproof Mohawk School for noise compatibility, Village of Bensenville, 700 W. Irving Park Road, Bensenville, Illinois 60176

all as more particularly described in the Project Application.

FAA Form 5100-37 PG 1 (8-82)

FEDERAL ASSISTANCE

2. APPLICANT'S APPLICATION	a. NUMBER: 3-17-0022-N3	3. STATE APPLICATION IDENTIFIER	a. NUMBER:
	b. DATE (Year month day): 1984 9 12		b. DATE ASSIGNED (Year month day): 19

1. TYPE OF ACTION (Mark appropriate box)
- ☐ PREAPPLICATION
- ☒ APPLICATION
- ☐ NOTIFICATION OF INTENT (Opt.)
- ☐ REPORT OF FEDERAL ACTION

Leave Blank

SECTION I—APPLICANT/RECIPIENT DATA

4. LEGAL APPLICANT/RECIPIENT

a. Applicant Name: Village of Bensenville and
b. Organizational Unit: Ill. D.O.T., Division of Aeronautics
c. Street/P.O. Box: 1 Langhorne Bond Dr., Capital Airport
d. City: Springfield
e. County: Sangamon
f. State: Illinois
g. ZIP Code: 62706
h. Contact Person (Name & telephone No.): Roger H. Barcus, Chief Engineer : (217) 753-4400

5. FEDERAL EMPLOYER IDENTIFICATION NO.

6. PROGRAM (From Federal Catalog)
a. NUMBER: 20.106
b. TITLE: A.I.P.

7. TITLE AND DESCRIPTION OF APPLICANT'S PROJECT

Soundproofing Mohawk
School in Bensenville, Illinois

SEP 1984 RECEIVED AIRPORTS DIST OFFICE

8. TYPE OF APPLICANT/RECIPIENT
A—State; B—Interstate; C—Substate District; D—County; E—City; F—School District; G—Special Purpose District; H—Community Action Agency; I—Higher Educational Institution; J—Indian Tribe; K—Other (Specify):
Enter appropriate letter: E

9. TYPE OF ASSISTANCE
A—Basic Grant; B—Supplemental Grant; C—Loan; D—Insurance; E—Other
Enter appropriate letter(s): A

10. AREA OF PROJECT IMPACT (Names of cities, counties, States, etc.)
Village of Bensenville

11. ESTIMATED NUMBER OF PERSONS BENEFITING
400

12. TYPE OF APPLICATION
A—New; B—Renewal; C—Revision; D—Continuation; E—Augmentation
Enter appropriate letter: A

13. PROPOSED FUNDING

a. FEDERAL	$ 492,880.00
b. APPLICANT	61,610.00
c. STATE	---.00
d. LOCAL	---.00
e. OTHER	61,610.00
f. TOTAL	$ 616,100.00

14. CONGRESSIONAL DISTRICTS OF:
a. APPLICANT
b. PROJECT

16. PROJECT START DATE (Year month day): 1984 05 11

17. PROJECT DURATION: Months

18. ESTIMATED DATE TO BE SUBMITTED TO FEDERAL AGENCY (Year month day): 19 84 09 12

15. TYPE OF CHANGE (For 11c or 11e)
A—Increase Dollars; B—Decrease Dollars; C—Increase Duration; D—Decrease Duration; E—Cancellation; F—Other (Specify):
Enter appropriate letter(s):

19. EXISTING FEDERAL IDENTIFICATION NUMBER

20. FEDERAL AGENCY TO RECEIVE REQUEST (Name, City, State, ZIP code)
FAA, CHI-ADO, Des Plaines, Illinois 60018

21. REMARKS ADDED
☐ Yes ☒ No

SECTION II—CERTIFICATION

22. THE APPLICANT CERTIFIES THAT ▶
a. To the best of my knowledge and belief, data in this preapplication/application are true and correct, the document has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.
b. If received by OMB Circular A-95 this application was submitted, pursuant to instructions therein, to appropriate clearinghouses and all responses are attached:

	No response	Response attached
(1)	☐	☐
(2) (See Preapplication)	☐	☐
(3)	☐	☐

23. CERTIFYING REPRESENTATIVE
a. TYPED NAME AND TITLE: Lawrence Bieneman, Village President
b. SIGNATURE: Lawrence Bieneman
c. DATE SIGNED (Year month day): 19 84 09 12

SECTION III—FEDERAL AGENCY ACTION

24. AGENCY NAME
25. APPLICATION RECEIVED (Year month day): 19
26. ORGANIZATIONAL UNIT
27. ADMINISTRATIVE OFFICE
28. FEDERAL APPLICATION IDENTIFICATION
29. ADDRESS
30. FEDERAL GRANT IDENTIFICATION

31. ACTION TAKEN
- ☐ a. AWARDED
- ☐ b. REJECTED
- ☐ c. RETURNED FOR AMENDMENT
- ☐ d. DEFERRED
- ☐ e. WITHDRAWN

32. FUNDING

a. FEDERAL	$ .00
b. APPLICANT	.00
c. STATE	.00
d. LOCAL	.00
e. OTHER	.00
f. TOTAL	$ .00

33. ACTION DATE ▶ (Year month day): 19
34. STARTING DATE (Year month day): 19
35. CONTACT FOR ADDITIONAL INFORMATION (Name and telephone number)
35. ENDING DATE (Year month day): 19
37. REMARKS ADDED
☐ Yes ☐ No

38. FEDERAL AGENCY A-95 ACTION
a. In taking above action, any comments received from clearinghouses were considered. If agency response is due under provisions of Part I, OMB Circular A-95, it has been or is being made.
b. FEDERAL AGENCY A-95 OFFICIAL (Name and telephone no.)

STANDARD FORM 424 PAGE 1 (10-75)
Prescribed by GSA, Federal Management Circular 74-7

Appendix B

Note: The Educational Development Series Copyright by Scholastic Testing Service, Inc., Bensenville, Illinois. Test is available from the publisher. The original data are available from the author.

Third Grade
Mathematics

I. Computation

A. Whole numbers
   1. Addition, involving:
      a. One- and/or two-digit addends, with regrouping
      b. Three one- and/or two-digit addends
      c. Three-digit addends
   2. Subtraction, involving:
      a. One- and/or two-digit numbers, with regrouping
      b. Three-digit numbers
      c. One-, two-, and three-digit combinations
   3. Multiplication, involving:
      a. Two one-digit numbers
      b. One-digit multipliers without regrouping
   4. Division involving:
      a. One-digit divisors, without remainders

B. Decimals
   1. Addition, involving:
      a. Two decimals, tenths, and hundredths
   2. Subtraction, involving:
      a. Tenths and hundredths

II. Reasoning

A. Numbers/numerals/counting
   1. Recognize words for numbers
      a. 101 - 1,000
   2. Recognize odd/even numbers

B. Measurement
   1. Linear length estimation
   2. Read a thermometer

C. Place value
   1. To 1,000's and 10,000's

D. Pictorial representation
   1. Interpret pictograph

E. Fractions/percents/ratios
   1. Parts of an object or set

F. Geometry
   1. Recognize simple closed figures
   2. Lines/locating points
   3. Lines/operations on the line
   4. Perimeter of plane figure

G. Equations
   1. Symbols
   2. Operations to solve equations
   3. Combine numbers
      a. with plus and minus

H. Using common process
   1. Addition
   2. Subtraction
   3. Addition and subtraction
   4. Multiplication

I. Using common measures
   1. Clock

Eighth Grade Mathematics

I. Computation

A. Whole numbers
   1. Addition, involving:
      a. Any type addends
   2. Subtraction, involving:
      a. Three- and four-digit combinations
   3. Multiplication, involving:
      a. Two-digit multipliers, two-digit multiplicands
      b. Four- and five-digit multipliers
   4. Division, involving:
      a. One-digit divisors, with remainders
      b. Two-digit divisors, without remainders
      c. Two-digit divisors, with remainders

B. Decimals
   1. Addition, involving:
      a. Two decimals, tenths and hundredths
      b. Two decimals, thousandths
   2. Subtraction, involving:
      a. Tenths and hundredths
      b. Tenths, hundredths, and thousandths
   3. Multiplication of decimals
   4. Division of decimals

C. Fractions
   1. Addition, involving:
      a. Mixed numbers
   2. Subtraction, involving:
      a. Two fractions with like denominators
      b. Two fractions with unlike denominators or mixed numbers
   3. Multiplication, involving:
      a. Two common fractions
      b. More than two common fractions
      c. Mixed numbers
   4. Division, involving:
      a. Common fractions
      b. Mixed numbers

D. Negative and positive integers
    1. Addition
    2. Subtraction
    3. Multiplication
    4. Division
E. Exponents
    1. Addition
    2. Subtraction
    3. Multiplication

II. Reasoning

A. Measurement
    1. Linear/length estimation
B. Pictorial representation
    1. Interpret graphs and tables
C. Fractions/percents/ratios
    1. Reduce to lowest form
    2. Percent of numbers
D. Geometry
    1. Line segments, angles
    2. Perimeter of plane figure
    3. Area of plane figure
    4. Volume of solid figure
    5. Angle measurement
E. Equations
    1. Linear equations
    2. Inequalities
F. Properties
G. Estimating
    1. Rounding numbers

H. Multiples and factors
    1. Recognize least common multiples and factors
    2. Recognize least common denominator
I. Exponents
    1. Interpret
    2. Decomposition by powers of ten
J. Roots
    1. Square roots of integers
K. Coordinate geometry
    1. Finding point coordinates
L. Using common process
    1. Subtraction
    2. Multiplication
    3. Division
    4. Multiplication/Division/Addition/Subtraction
    5. Find the mean
M. Applications
    1. Proportions and percents
    2. Time, rate, distance probability

Appendix C

Note: The following noise exposure map is part of the Chicago O'Hare International Airport "FAR Part 150 Noise Campatibility Planning Study", prepared for the City of Chicago, Department of Aviation, by Landrum & Brown.

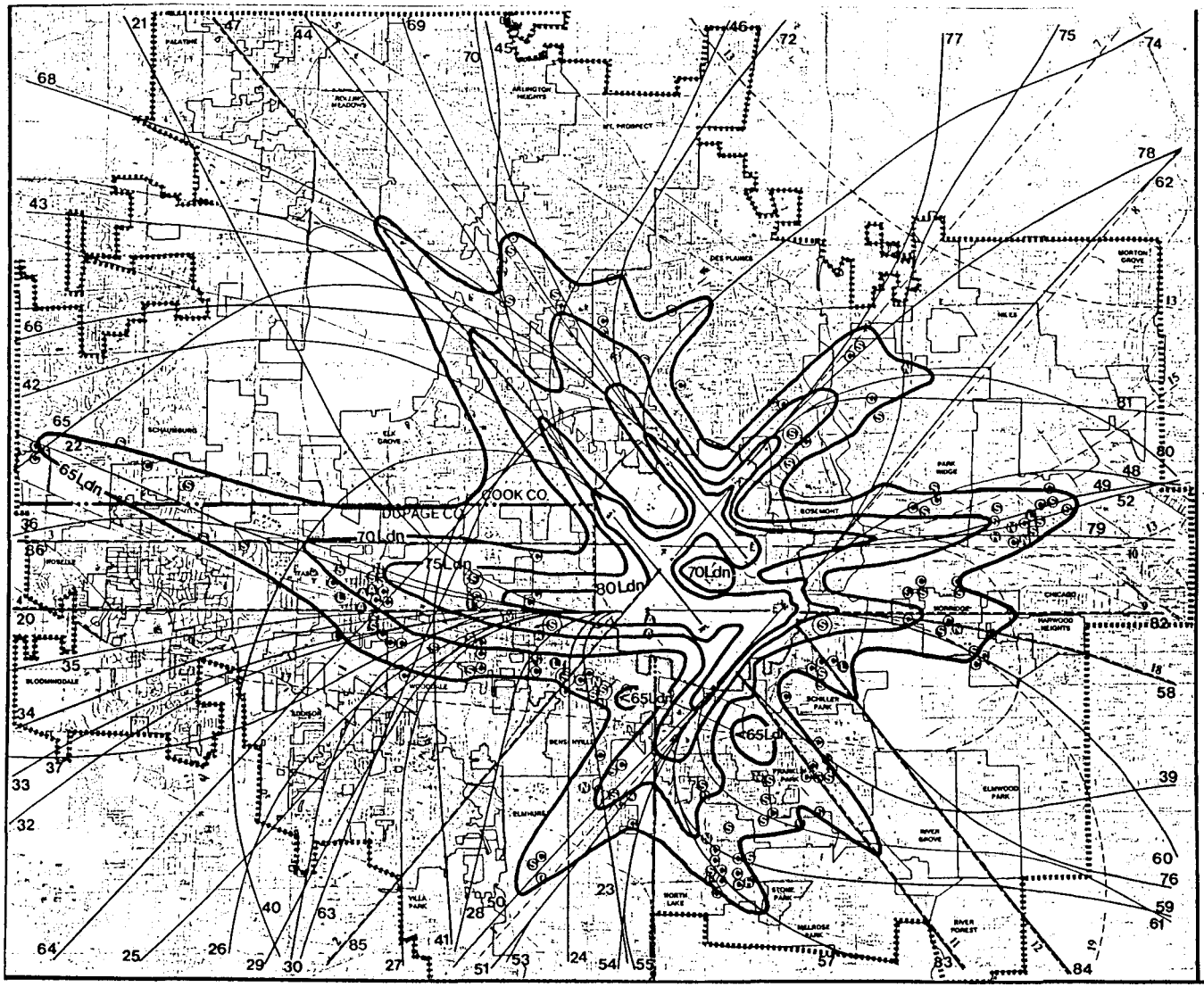

Exhibit 1

EXISTING NOISE EXPOSURE MAP

LEGEND

BOUNDARIES

Study Area ····· County Line ——

Community —— Airport ——

EXISTING LAND USE

Incompatible Uses (Residential, Public)

Non-Impact Uses (Residential. Public)

Hospitals (H) Noise Contour

Nursing Homes (N) Arrival

Library (L) Tracks - - -

School (S) Departure

Church (C) Tracks ——

Historic Site (A)

Soundproofed (S)

Scale in Feet

0 4000 8000

N

SPONSOR'S CERTIFICATION

The Noise Exposure Maps and accompanying documentation for the Noise Exposure Maps for Chicago O'Hare International Airport, submitted in accordance with Federal Aviation Regulation Part 150 and prepared with the best available information, are hereby certified as true and complete to the best of my knowledge and belief.

Howard Stanback, Ph.D.
Acting Commissioner of Aviation
City of Chicago

AUG 3,1988
Date

Part 150 Noise Compatibility Study

Chicago O'Hare International Airport

City of Chicago
Eugene Sawyer
Acting Mayor

Department of Aviation
Howard Stanback, Ph.D.
Acting Commissioner of Aviation

Aviation Consultant
Landrum&Brown

DISSERTATION APPROVAL SHEET

The dissertation submitted by Loren David May has been read and approved by the following committee:

Dr. Allan Ornstein, Director
Professor, Curriculum and Instruction
Loyola University of Chicago

Dr. Barney Berlin
Professor, Curriculum and Instruction
Loyola University of Chicago

Dr. Jack Kavanagh
Chairman, Professor, Counseling and Educational Psychology
Loyola University of Chicago

Dr. Kenneth Kaufman
Adjunct Faculty
Loyola University of Chicago

The final copies have been examined by the director of the dissertation and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is, therefore, accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

11/23/92
Date

Director's Signature