Spring 2012

# Development of an elementary school background noise

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# DEVELOPMENT OF AN ELEMENTARY SCHOOL

# BACKGROUND NOISE

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Audiology

COLLEGE OF LIBERAL ARTS
LOUISIANA TECH UNIVERSITY

May 2012

LOUISIANA TECH UNIVERSITY

**THE GRADUATE SCHOOL**

2/27/2012

Date

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entitled

Development of an Elementary School Background Noise

be accepted in partial fulfillment of the requirements for the Degree of

Doctor of Audiology

Supervisor of Dissertation Research

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GS Form 13a
(6/07)

## ABSTRACT

The deleterious effects of noise on hearing, comprehension, and academic development have been widely studied. In an effort to accurately observe the effects of noise on specific listening environments, researchers have relied on commercially available forms of background noise. However, these commercially available recordings only contain adult speech and background noises associated with adult environments. A commercially available form of background noise that represents the sounds associated with elementary and middle schools are not readily available. Given that much effort has gone into examining the effects of background noise on classroom performance, it would appear prudent that a background noise designed specifically for that population and environment become available. Therefore, the purpose of the present project was to observe and record noises from various elementary and middle schools for the production of an elementary school based background noise to accurately represent the unique sound environment found in elementary school settings. Recordings were taken from various environments within five elementary and middle schools and digitally mixed to produce an elementary school based background noise. The acoustic characteristics of the individual school recordings, along with the commercially available recordings and the elementary school based background noise produced in this project are compared and clinical implications are discussed.

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## DEDICATION

I dedicate this Dissertation to my loving family and friends for all of their support and prayers throughout the past four years.

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# ACKNOWLEDGEMENTS

I would like to thank the following committee members for assistance in completing this research: Steven Madix, Ph.D., Melinda Bryan, Ph.D., and Matthew Bryan, Au.D. I would also like to show my appreciation to Sheryl Shoemaker, Ph.D., the head of the Department of Speech at Louisiana Tech University and Mrs. Tracy Shrell, the secretary of the Department of Speech for their continuous support.

# CHAPTER I

# INTRODUCTION

Audible sound is described as a vibration created when air molecules are sent colliding against one another when disturbed by some force. Sound is sent outward from the source of the disturbance in the form of alternating increases and reductions in density and pressure between the air molecules. Sound can consist of pure tones, complex tones, or noise. Noise, being the most complex, is continuous and random, with variances in frequency, intensity, and pressure. Previous research has shown that increased levels of noise can have a negative effect on speech discrimination, vocal behavior, attention span, focused behavior, and other speech understanding abilities (Anderson, 2001; Crandell & Smaldino, 1999; Dockrell & Shield, 2006; Fallon, Trehub, & Schneider, 2000; Hygge, 2003; Knecht, Nelson, Whitelaw, & Feth, 2002; Larsby, Hällgren, Lyxell, & Arlinger, 2005; Larson & Peterson, 1978; Ljung, Sörqvist, & Hygge, 2009; McAllister, Granqvist, Sjölander, & Sundberg, 2008; Plomp, 1994; Saramplis, Kalluri, Edwards, & Hafter, 2009; Shield & Dockrell, 2008;  and Stansfeld et al., 2005). The effect of noise on active listening and speech discrimination has been widely studied and much effort has been spent on improved listening in noise.

Active listening is a critical component for learning. Many of the activities that happen in the classroom require students to listen, and in the presence of background noise, this can become a difficult task (Anderson, 2001; Crandell & Smaldino, 1999; and

Plomp, 1994). Several acoustical factors have been identified as important when discussing the effects of noise in classrooms (American Speech-Language-Hearing Association, 2005b). These include background noise, signal-to-noise ratio (SNR), and reverberation time. Background noise, its area of derivation, and its effects on learning environments have become topics of great importance in previous years and widely studied.

Research has shown that noise levels, signal-to-noise ratios, and reverberation times present in a typical classroom often exceed the recommendations made by the American Speech-Language-Hearing Association (ASHA) in 1995 (Larson & Peterson, 1978; and Knecht et al., 2002). These recommendations included background noise in classrooms not to exceed levels of 30 decibels on the A-weighted scale (dB[A]), a reverberation time of less than or equal to 0.4 seconds, and an overall teacher SNR of plus 15 dB (American Speech-Language-Hearing Association, 1995). ASHA redefined these recommendations in 2005 to address unoccupied classrooms. ASHA (2005) stated that noise levels should not exceed 35 dBA, the SNR should be at least plus 15 dB, and reverberation times should not exceed 0.6 seconds in smaller classrooms and 0.7 seconds in larger classrooms (American Speech-Language-Hearing Association, 2005a). These recommendations are supported by the American National Standards Institute's (ANSI) Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools (American National Standards Institute, 2002; Lubman & Sutherland, 2004; and Smaldino, 2011). According to the ASHA Guidelines for Addressing Acoustics in Educational Settings (2005b), current classrooms, both occupied and unoccupied are considered to be noise-filled and reverberant environments with noise levels ranging from 53 to 74 dBA. These levels were viewed as negative when compared to the recommended levels. Similar studies reported unoccupied classroom noise levels between 34.4 and 65.9 dBA (Knecht et al., 2002) and occupied classroom noise levels between 81.5 and 83.6 dBA (McAllister et al., 2008). Research has shown classrooms to have SNRs of only plus six dB and reverberation times measured 0.2 to 1.27 seconds (Bess, 1999; and Knecht et al., 2002). These studies indicated that even though standards are in place to control for noise levels, SNRs, and reverberation times, in reality they may be difficult to adhere to and are not enforced.

The importance of good classroom acoustics, both internally and externally, and decreased noise levels as they improve learning has been documented (American National Standards Institute, 2002; Anderson, 2001; Dockrell & Shield, 2006; Knecht et al., 2002; Larson & Peterson, 1978; Lubman & Sutherland, 2004; and Smaldino, 2011). Larson and Peterson (1978) stated the need to use protection from noise and to consider not using the arrangements of open-plan learning environments. It was also recommended to have acoustically treated surfaces in the classroom, and seating children, especially those with hearing impairments, closer to the speaker. In agreement, the ASHA Guidelines for Addressing Acoustics in Educational Settings (2005b) offered several acoustical modifications that can be made to classrooms which included selecting acoustically acceptable wall, floor, and ceiling tiles and materials; noise isolation protection of windows, walls, and doors; wall sealant treatments; and remodeling to rid of using wall partitions. Noise has been seen to have significant effects on children's listening and learning abilities (Anderson, 2001; Bess, 1999; Crandell & Smaldino, 1999;

Dockrell & Shield, 2006; Hygge, 2003; Knecht et al., 2002; Larsby et al., 2005; Larson & Peterson, 1978; Ljung et al., 2009; McAllister et al., 2008; Plomp, 1994; Sarampalis, et al., 2009; Shield & Dockrell, 2008; and Stansfeld et al., 2005). Research has presented testing conditions that consisted of varying the SNR or measuring the amounts of classroom noise, internal noise, and or external noise. With these measurements in mind, assessments such as reading and spelling assignments, mathematical tests, standardized tests, recall and recognition assignments, and memory and or cognitive tests were given. Results from these studies reported similar findings; in comparison to quiet conditions, a low SNR along with high levels of classroom, internal, and external noise affected assessment scores and learning abilities in a negative way.

The noises found in elementary school classrooms are somewhat unique to others found in areas such as hospital cafeterias or adult cocktail parties. For example, in a typical classroom, there are a variety of noises including combinations of external, internal, and classroom noises (Dockrell & Shield, 2006; Hygge, 2003; Knecht et al., 2002; Larsby et al., 2005; Larson & Peterson, 1978; Ljung et al., 2009; McAllister et al., 2008; Shield & Dockrell, 2008; and Stansfeld et al., 2005). These include such noises as road traffic, aircraft, students, teachers, ventilation systems, hallway noise, etc. All of these noises are known to affect the abilities of students in the classroom.

Much attention has gone to the effects of noise on hearing and academic development; however, commercially available forms of background noise for research purposes currently used may not adequately replicate the noises found in an elementary school setting. Given the uniqueness of background noise found in schools, especially elementary and middle schools, and the importance of understanding its effect on academic performance, it would be prudent to examine noises recorded in the elementary and middle schools. Therefore, the purpose of this project is to observe and record noises for the production of an elementary school based background noise. This will be done by recording and analyzing the spectral content of noise present in elementary and middle schools and comparing it to the commercially available background noises that are traditionally used in experiments where the effects of noise are measured.

# CHAPTER II

# REVIEW OF LITERATURE

According to Anderson (2001), speech in noise discrimination allows listeners to pay attention to a specific speaker while background noise is present. With loud levels, this may or may not be feasible, particularly when active listening is required for learning in elementary or middle school classrooms. As seen in the following sections, it has also been noted that vocal quality, attention span, focused behavior, and other speech understanding abilities are negatively affected by noise, especially in the classroom (Anderson, 2001; McAllister, 2008; and Saramplis et al., 2009).

## Sound and Noise

Plack (2005) described sound and a variety of its characteristics. When air molecules are disturbed, they are set into motion by static pressure, causing a constant colliding of the molecules against one another. In turn, this creates a vibration from the sound source sending sound waves outward. These waves are created by an alternating pattern of condensations and rarefactions, or a slight increase and decrease in density and pressure between the molecules. One form of sound, the pure tone, is a simple sinusoidal deviation in pressure over a certain period of time. This is the simplest and purest form of sound. This differs from our usual environmental sounds, which are more complex. The most complex type of sound is noise, which is aperiodic and made up of continuous, yet random disparities and distributions of frequency components with greater variations in intensity and pressure over time. In meaning, the pressure changes are random, not predictable in nature, and do not carry information. Plack (2005) referred to noise as an unwanted and irritating sound that may affect our ability to hear important information. This is particularly true when noise is present in classrooms, affecting the listening and learning abilities of students.

## Listening in the Classroom

Active listening is a critical component for learning in the classroom. According to an interview conducted by Sangster and Anderson (2009), students' perspectives of listening in the classroom are considered to be a commitment. Many students who participated described listening as a social obligation to themselves and their peers and a responsibility to be attentive out of respect for their teachers. Commitments in the classroom included using appropriate turn taking, engaging in discussions, being responsive to others, reflecting seriously on what others have noted, being expressive in nature, and achieving personal understanding of thoughts and actions. These commitments are often seen as difficult when any noise is introduced.

## Acoustical Factors within a Classroom

### Background noise.

Noise is a complex sound made up of continuous, but random variances of frequency components with many differences in intensity and pressure (Plack, 2005). Background noise is considered to be any auditory interruption that hinders a person's listening abilities (Crandell & Smaldino, 1999). It is thought to derive from several conditions: externally to an environment, internally to an environment, or within an environment (Bess, 1999). One such example is outside a building, inside a building, and inside one particular room within a building. Examples of each are: road traffic noise as external noise, ventilation systems as internal noise, and children talking in a classroom as within an environment noise.

Several recommendations have been made for the ideal acceptable background noise levels. One such recommendation included is that published by ASHA which stated background noise in classrooms should not exceed levels of 30 dBA (American Speech-Language-Hearing Association, 1995). ASHA later redefined these recommendations to address unoccupied classrooms and noise levels that should not exceed 35 dBA (American Speech-Language-Hearing Association, 2005a). These recommendations are supported by ANSI's Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools (American National Standards Institute, 2002; Lubman & Sutherland, 2004; and Smaldino, 2011).

**Signal-to-noise ratio.**

The signal-to-noise ratio (SNR) is commonly used to refer to the intensity differences, in the form of a ratio, between the signal needing to be heard and the background noise present (Bess, 1999). This is measured, in decibels, at the level of the ear. According to the recommendations of ASHA and ANSI, it is considered ideal to have a SNR that is at least plus 15 dB in an unoccupied classroom (American National Standards Institute, 2002; and American Speech-Language-Hearing Association, 2005a).

When speech is present in noise, some segments of the speech are covered by the noise (Katz, 1994). Speech recognition scores are generally greater when the SNR is high and poorer when the SNR is low. One such example of a high SNR is that of a teacher lecturing within the classroom that can be measured 15 dB greater than other background noise present in the room, such as over the air conditioner or multiple children's speech. An example of a low SNR is that of a teacher lecturing within the classroom that cannot be measured greater than other background noise present in the room or is only measured several decibels over the speech, which is often seen (Knecht et al., 2002; and Lubman & Sutherland, 2004).

### Reverberation time.

Crandell and Smaldino (1999) referred to reverberation as the prolongation of sound within an enclosed space that causes sound waves to reflect off hard surfaces, such as the floor, ceiling, or walls present in that environment (Bess, 1999). Reverberation time, or decay time, is defined as the length of time it takes for any sound at a specific frequency to decrease by 60 dB following the end of the stimulus presentation (Crandell & Smaldino, 1999). The sound waves continue to reflect off the hard surfaces present in the environment until the signal has decreased significantly or has been absorbed (Bess, 1999). Smaller environments tend to have shorter reverberation times than larger environments. As recommended by ANSI in 2002 and by the ASHA Position Statement of 2005, unoccupied classroom reverberation times should not exceed 0.6 seconds in smaller classrooms of volumes greater than 10,000 cubic feet and 0.7 seconds in larger classrooms of volumes greater than 10,000 cubic feet but less than 20,000 cubic feet.

## Noise and Its' Effects on Communication

To examine noise, Larsby, Hällgren, Lyxell, & Arlinger (2005) observed the effects of different background noises on cognitive processes involved with speech understanding, such as perceived effort, accuracy, and processing speed or reaction time.

Participants included four groups of 12 members, divided into groups by their hearing status and age. The first group, being young normal hearing listeners (mean age = 29.5 years), had hearing thresholds better than 20 decibels hearing level (dB HL). The second group, being elderly listeners (mean age = 69.0 years), also had normal hearing. The third and fourth groups, being young hearing-impaired listeners (mean age = 30.3 years) and elderly hearing-impaired listeners (mean age = 70.7 years), respectively, had mild-to-moderate sensorineural hearing loss.

All participants were tested through the use of the Speech and Visual Information Processing System (SVIPS) test, which presented stimuli in a visual (i.e., text), an auditory, and an audiovisual modality. Three subtests included: semantic decision-making, to determine if a word was grouped with a semantic or language category; lexical decision-making, to determine if a group of letters created a real or a nonsense word; and name matching, to determine if two letters were the same or different. All tests were given in four different background noise conditions including ICRA noise, Hagerman's noise, speech noise, and a no noise condition. ICRA noise is random noise that most spectrally resembles speech; Hagerman's noise consists of slightly amplitude-modulated samples of sentences read by a female talker; the speech noise consisted of a story read aloud by a female talker; and in the no noise condition, no additional noise was incorporated. There was a plus 10 SNR used for the auditory and audiovisual modalities. Following each test in each noise condition, the participants had to rate their perceived degree of effort.

Results of this study were discussed according to the modality used, hearing status, age, visual contributions, and background noise conditions. The results showed for the text modality (i.e., visual modality), accuracy was not affected by hearing status and was slightly affected by age. The results further showed for the text modality, the reaction time was greatly affected by hearing status, age, and noise condition. Finally, perception of effort in the text modality was affected by three of the four background noise conditions and was not affected by the no noise condition. For both the auditory and audiovisual modalities, accuracy, reaction time, and perceived efforts were affected by the three noise conditions. For each modality, the hearing-impaired participants reported increased perceptions of effort and had more difficulties in background noise, especially for ICRA and speech noise conditions, when compared to the normal hearing participants. Age too showed effects on testing due to the elderly group having longer reaction times and being less accurate, especially on the lexical test in noise. Visual contributions positively affected results by increasing accuracy, decreasing perception of effort, and showing significant relationships between the noise conditions and the modality, especially in the lexical and semantic tests. The background noise conditions from most difficult to the least being ICRA, speech, and Hagerman, negatively affected test results for the auditory and audiovisual modalities, semantic tests, reaction times, and perceptions of effort. ICRA noise most spectrally resembles speech, then Hagerman's noise, and finally speech noise, so each was perceived as more difficult when testing semantic decision making, lexical decision making, and name matching, especially when no visual contributions were available.

From these results, the authors made several conclusions. First, when hearing-impaired participants are compared to normal hearing listeners, they perform worse in noise, such as ICRA and speech noise, which have temporal variations, and they perceive higher levels of effort. Secondly, elderly participants perform worse in noise with temporal variations, but do not report higher levels of effort than the younger participants. Next, visual contributions offer better accuracy in noise and lower levels of perceived effort. Finally, they concluded that performing cognitive processing tasks (SVIPS) in the text modality, without auditory content and noise, still caused a high level of perceived effort, but an even higher level of perceived effort was seen for the subtests given in the noise conditions.

In another study, Sarampalis, et al. (2009) examined the effects of noise and noise reduction on communication and the speed of processing. The authors described communication as the process that involves auditory functions including attentiveness to sound, memory storage, and the ability to use context information, understanding, and appropriate responsiveness. Just as in other studies, it was believed that in the communication process, especially in the classroom setting, attention and other communication abilities are affected by noise. The study was completed by conducting mutli-tasking cognitive tasks, such as repeating then later recalling words and sentences which had previously been presented, in noise, reduced noise, and in quiet. The words and sentences were presented at 65 dB sound pressure level (SPL) in the quiet condition. In the noise condition, four-speaker babble was incorporated at 65 dB SPL. In the noise reduction condition, the speech was presented at a plus four SNR. Results of this study showed that background noise, especially when presented equally with speech tasks, had negative effects on the communication processes of listening, performing multiple tasks, recall, and responding to complex assignments. In the noise reduction condition, speech was not considered more intelligible. However, in this condition, perceived effort was decreased, and recall was improved. The authors concluded that higher levels of noise had greater negative effects on communication processes.

## Effects of Noise in Classrooms and Learning Environments

### Classroom acoustics.

Acoustical factors to consider within a classroom, that may affect classroom learning, include the level of background noise present, the signal-to-noise ratio of the speech against the noise, and the reverberation time. Many of the studies reported found classroom and learning environments to have higher levels of noise, signal-to-noise ratios, and reverberation times than the recommendations set (American National Standards Institute, 2002; American Speech-Language-Hearing Association, 1995; American Speech-Language-Hearing Association, 2005a; Knecht et al., 2002; and Lubman & Sutherland, 2004). These are considered recommendations or standards, but are not mandatory and governed requirements (American National Standards Institute, 2002; Lubman & Sutherland, 2004; Smaldino, 2011; and Snyder, 2010). As recommended by ANSI in 2002 and by the ASHA Position Statement of 2005, classroom acoustics should follow these guidelines: unoccupied classroom noise levels should not exceed 35 decibels on the A-weighted scale (dB[A]), the signal-to-noise ratio (SNR) should be at least plus15 dB when measured at the child's ears, and reverberation times should not exceed 0.6 to 0.7 seconds dependent on the size of the classroom. Studies have shown that proper classroom acoustics can help children hear, attend, and learn (American National Standards Institute, 2002; Anderson, 2001; and Lubman & Sutherland, 2004).

The American Speech-Language-Hearing Association Position Statement (2005a) also noted that increased levels of reverberation and background noise can negatively affect all of the following: speech perception, reading and spelling ability, classroom behavior, attention, concentration, and educational achievement. According to the ASHA Guidelines for Addressing Acoustics in Educational Settings (2005b) classrooms are considered to be noise-filled and reverberant environments with noise levels ranging from 53 dBA to 74 dBA. Similar studies reported unoccupied classroom noise levels between 34.4 and 65.9 dBA (Knecht et al., 2002) and occupied classroom noise levels between 81.5 and 83.6 dBA (McAllister et al., 2008). Research has shown classrooms to have SNRs of only plus six dB and reverberation times measured 0.2 to 1.27 seconds (Bess, 1999; and Knecht et al., 2002). ASHA (2005b) has recommended several techniques of acoustic modifications or remodeling to decrease these levels. These include: selecting acoustically acceptable wall, floor, ceiling tiles and materials, noise isolation protection of windows, walls, and doors, wall sealant treatments, and remodeling to rid the use of wall partitions.

**Effects of classroom noise.**

Larson and Peterson (1978) explored the abilities of noise to limit the learning of young listeners by comparing speech discrimination performance of children and adults. This examination was done to show elementary school teachers and educators the effects of noise in their schools and to make possible recommendations for optimum learning environments. Participants included 40 young elementary school children ages five and a half to six and a half years and 40 adults between the ages of 20 and 26 years. All participants were examined and considered to have normal hearing. For the study, monosyllabic words were presented through a loudspeaker in four noise conditions: quiet, then with white noise at a SNR of plus 20, plus 15, and plus 10 dB.

Results of this study showed that scores for testing in quiet were similar between children and adults, with the children's average score being only two percent lower than the adult average score. When white noise was presented with the speech, scores decreased significantly for both children and adults. With a SNR of plus 20 dB, scores for the children dropped 17 percent below their original average in quiet, and scores for adults dropped seven percent. Scores continued to drop for a SNR of plus 15 dB, and even more so for the plus 10 dB SNR condition.

From these results, the authors concluded that the ideal listening condition for both children and adults is a quiet environment. These authors also concluded that children have an increased chance of experiencing difficulty in background noise than adults, and this may happen in both high and low levels of background noise. With these conclusions, the authors made several recommendations for optimum learning environments to the elementary school educators including, using protection from noise, considering not using the arrangements of open-plan learning environments, having acoustically treated surfaces in the classroom, and seating children, especially those with hearing impairments, closer to the speaker. These findings have been supported by other researchers as well. When compared to adults, children need more favorable SNRs (Fallon, Trehub, & Schneider, 2000). In these studies, the authors concluded that children needed SNRs more favorable by approximately five decibels or more, than adults to accurately identify target words in the presence of noise, such as background speech babble.

In relation to these studies on background noise, Knecht, Nelson, Whitelaw, and Feth (2002) examined the levels of noise and reverberation in unoccupied elementary classrooms. Schools that partook in the study included 32 unoccupied elementary school classrooms from several areas throughout the state of Ohio. The rooms were of different sizes and volumes, and each was exposed to different internal and external noise levels. After each classroom's volume was determined, five strategically chosen points were marked from which measurements were taken. The amplifier and speaker, setup as an omnidirectional system, were placed in the front left corner of the rooms. A sound level meter was used to measure the level of noise and reverberation times at each of the five points within the classrooms, for both the already existent noise and for when additional noise was added into the classroom via the speakers. These measurements were compared to ASHA's recommendations of 1995 and ANSI's recommendations of 2002.

Results of this study revealed a range of noise levels in the classrooms between 34.4 dBA and 65.9 dBA. On average, these levels of background noise greatly exceeded the ASHA recommendations of 1995 of 30 dBA. Results for reverberation times portrayed a range from 0.2 milliseconds to 1.27 seconds. Again, these results suggest that reverberation times of 13 of the 32 classrooms surpassed that of the recommendations. One variable that had to be taken into consideration was the volume of each of the classrooms. Rooms with higher ceilings and or larger volumes had longer reverberation times. In opposition, rooms with smaller volumes had shorter reverberation times. Another factor taken into account was that of window installation. Results revealed classrooms with new and thickened window panes had less background noise and shorter reverberation times than those classrooms with older and less thick panes. In summary, it was concluded that size and volume have an impact on the amount of background noise and reverberation within a classroom, and most classrooms do not meet the recommendations for classroom acoustics.

McAllister, Granqvist, Sjölander, and Sundberg (2008) too explored the levels of background noise, but also its effects on the vocal quality of daycare children. Participants included 11 five year old children, all of which had no previous otologic or speech history, from three daycare centers in the southeastern part of Sweden. The children's vocal behavior was recorded three times during a typical day at the daycare center; first upon arrival during morning activities, second during lunch and silent play, and third during inside free play. The children were asked to say "A blue car," "A yellow car," and "A red car," three times, the first as a baseline and the last two for analysis. The recordings were analyzed for parameters such as quality, pitch, hoarseness, breathiness, and hyperfunction. The noise levels were measured within all daycare centers at each recording time. On average, the noise levels for all three of the daycare centers were 82.6 dBA, with the range being 81.5 dBA to 83.6 dBA.

Results of this study were arranged according to gender and vocal quality. The second daycare center had the highest averages for both noise levels and voice quality, including characteristics such as hoarseness, breathiness, and hyperfunction. For all centers, it was seen that girls had a greater increase in voice level, hyperfunction, breathiness, and roughness throughout the day. Only a minor increase in hoarseness and hyperfunction was seen for the males, and it was noted that they were typically louder than the girls to begin the study. From these results, the authors concluded that a typical day in the day care center, with varying high noise levels, had an effect on the voice quality of children and that children themselves are sometimes the primary noise source.

**Effects of classroom, internal, and external noise.**

A study of noise completed by Hygge (2003) explored the effects of several noise sources and sound levels on the long-term recall and recognition abilities of children. Participants included 80 classes, consisting of a total of 1,358 seventh grade students between 12 and 14 years of age. All of these students participated in reading sessions, followed by tests measuring their recall and recognition abilities. During each session, noise set at either 55 or 66 dBA was played through two loudspeakers in the front corners of their classrooms. Ten noise conditions were tested: aircraft noise at 66 dBA, road traffic noise at 66 dBA, train noise at 66 dBA, verbal noise at 66 dBA, aircraft noise at 55 dBA, road traffic noise at 55 dBA, aircraft dominating over train noise at 55 dBA, train dominating over aircraft noise at 66 dBA, aircraft dominating over train noise at 66 dBA, and road traffic dominating over aircraft noise at 66 dBA. The learning sessions consisted of reading three texts covering the ancient cultures of Arabian, Chinese, and Sumerian. In the first session, the Chinese text was read. In session two, there was a 15 minute memory test including six open-ended recall questions and 12 multiple choice questions on the Chinese text, and then another text was read. In the third session, another 15 minute memory test was given on the second text, and then the third text was read. In the fourth session the last 15 minute memory test was given. All reading sessions were done in quiet and noise, and all testing sessions were done in quiet.

The participants were also asked to fill out a questionnaire regarding the difficulty of the text, their perceived effort and devotion to reading and learning from the text, their effort into taking the tests compared to normal school tests, and how knowledgeable they previously were with the information in the texts. They also participated in a second questionnaire regarding their perception of their stress, energy, and fatigue levels and on their perception and awareness of noise during the reading tasks.

Results of the questionnaires reported a significant decrease in effort from the noise conditions to the quiet conditions. The results from the testing were arranged by the noise condition and its effects on recall and recognition. From study one using aircraft noise, verses study three using train noise, the difference was significant with both noises effecting recall and recognition, especially when using aircraft noise. In the fourth study using verbal noise, there was no effect on long-term learning and recognition, but there was an effect on the perception of difficulty to read and learn the text information. In the condition of road traffic dominating over aircraft noise, there was an effect on recall and recognition abilities. When long-term recall was assessed in the aircraft and the road traffic noises, there was an effect at both 55 dBA and 66 dBA, even more so when road traffic noise was presented at the higher level. Intervening variables such as perceived and reported effort, difficulty, energy, stress, and fatigue, had no major effects on recall and recognition. From these results, the authors concluded that the use of different noises produced differing results, and that exposure to noise is linked to decreased long-term recall and recognition abilities in children.

In a similar study, Stansfeld et al. (2005) studied the relationship between exposure to noise, such as aircraft and road traffic, on the cognition and health of school children. Participants included 89 schools, accounting for 2,844 nine and ten year old children, throughout three countries: United Kingdom, Spain, and the Netherlands. These schools were assigned to a group associated with the types of noise present in the school environment: elevated aircraft noise where low road traffic noise was present, elevated road traffic noise where low aircraft noise was present, and both elevated aircraft and road traffic noise. At all schools, noise levels were measured externally on the dBA scale and internally within the classroom to account for any noises present other than aircraft and road traffic noise. All children's health and cognitive abilities were tested in areas such as reading comprehension, episodic memory for time delayed cued recall and delayed recognition, sustained attention, working memory, and prospective memory. This was done through the use of nationally standardized tests, reading scales, readability indexes, and comprehension tests. The children and their parents were also given two questionnaires to assess the children's health and noise annoyance perceptions.

Results of this study were reported based on the effects of each testing area and the noise type present. In all three countries, chronic aircraft noise exposure had major effects on reading comprehension, showing a reading delay in both the United Kingdom and Spain. Aircraft noise exposure was also shown to impact recognition. This type of noise, probably due to its intensity and unpredictability, had greater effects on the children's learning abilities than road traffic noise. Road traffic noise exposure had effects on episodic memory and recall, but showed no effects on reading comprehension, recognition, working or prospective memory, and sustained attention. Results from the questionnaire on perception of noise annoyance showed the children's increased annoyance by both aircraft and road traffic noises. Overall, these noises had similar effects on all students in all three countries, United Kingdom, Spain, and the Netherlands.

Dockrell and Shield (2006) examined literacy and speed performance of primary school children when in the presence of common classroom noise. Some of these common or typical classroom noises included ventilation systems, lighting, computers, and children's speech. Participants included 158 children (mean age = 8 years 6 months), whom collectively revealed to have normal reading capabilities. These participants were assigned to their regular classrooms, and each classroom was randomly assigned a noise condition: classroom babble, babble plus environmental noise, or a quiet classroom. Each child answered a questionnaire on noise levels within their classroom. Then each child participated in the following five test measures: aptitude using the AH4 ability test, verbal skills of both reading and spelling, a non-verbal test of speed of information processing, and arithmetic. Noise was only presented when the tests were given, not during test instructions.

Results of this study were characterized by the test presented and the order of best performance. For the two verbal tests in reading and spelling, the children performed best in the babble plus environmental noise condition, then the quiet condition, and the worst in the babble condition. Results were similar for the arithmetic task; however, the children performed best in the quiet condition. For the nonverbal test, the children performed the best in the quiet condition, then babble, and the worst in the babble plus environmental noise condition. This study also looked at the performance of both students with English as a second language and students with Special Education Needs (SEN). Results for the children with English as a second language presented performance in the quiet and babble conditions to be higher than in babble plus environmental noise. For those children with SEN, results demonstrated lower scores in all areas and noise conditions when compared to children without special needs. The children with SEN had lower scores overall, especially from the babble plus environmental noise; however, the babble alone condition was not as disadvantageous due to their already decreased speed and processing skills. From these results, the authors concluded that varying noise conditions provide for different effects on several aspects of classroom testing. The authors also concluded that during some of the testing conditions, the prediction of distracting noise interfered with testing performance, indicating the need for acoustically sound classrooms.

A similar study by Shield and Dockrell (2008) reviewed the effects of external and internal noise exposure on test results in young school aged children. Participants included 142 primary schools from the London area, with a focus on 16 schools from three different boroughs for both external, that is environmental noise, and internal, or classroom noise measurements. Within these schools, test scores from the Standardized Assessment Tests (SATs) in areas such as English, Mathematics, and Science were taken on primary and secondary aged school children, termed Key Stage One (KS1) for average age seven and Key Stage Two (KS2) for average age 11. These scores were then compared to noise levels measured both externally and internally within the schools. The range of noise measured outside the schools was 49 dBA to 75 dBA. Internal measurements were taken in different locations within the schools including occupied and unoccupied classrooms and hallways. These measurements were recorded as averaged ambient and background noise levels. The noise levels were compared to the test subjects and to the average school SAT scores.

Results of this study were arranged by the three boroughs which were studied. For borough A, representing a suburban area, negative relationships were seen when external noise and test scores in all subjects were compared. This was especially true for ambient levels with the KS2 children. For all boroughs, A, B, and C, in which the latter two represented inner city schools with both external and internal noise measured, the KS1 children were affected by typical external background noise, while the KS2 children were affected most by individual external noise events, such as trains, planes, or motorcycles. An example of typical external background noise was road traffic, which was considered to be the dominant external noise source to these schools. For internal noise measurements, negative relationships were seen in all environments within the school and for all test subjects, except for mathematics for the KS2 children. One noted example of typical internal classroom noise that was considered detrimental was classroom babble. With these results, the authors concluded that consistent exposure to external and internal noise, such as road traffic and classroom babble, especially in large amounts, had a detrimental effect on test results in young school aged children.

In a related study, Ljung, Sörqvist, and Hygge (2009) examined the effects of road traffic noise and irrelevant speech on children's reading and mathematical performance. Participants included 187 12 and 13 year old children from nine school classes around Sweden. Each class was assigned to a noise group: road traffic noise, irrelevant speech noise, and silence. The children were tested in the areas of reading, basic mathematics, mathematical reasoning, and word comprehension. The reading test consisted of a four-page story in which words were presented randomly and the child had to choose which word was used in the correct context. This measured reading speed and comprehension. The basic mathematics test assessed multiplication and division, naming points in a coordinate system, fractional expressions in relation to areas of figures, distance and numerical expressions, and measuring distances. The mathematical reasoning test consisted of word problems with numerical answers. The word comprehension test measured the verbal ability of the children by presenting target words within synonymous words. Testing began in silence, then road traffic noise and or irrelevant speech noise was introduced. Both noises were played from a digital recording at 66 dBA. Both had a continuous level of 62 dBA, and the road traffic noise had peaks of up to 78 dBA.

Results of this study were reported according to the test area and the noise type. For the reading test, speed was affected by the road traffic noise, in which the children read slower in noise. Noise, road traffic, nor irrelevant speech affected reading comprehension. On the basic mathematics test, road traffic noise negatively affected performance. For mathematical reasoning, no major affects were seen by any of the noise conditions when compared to the silent noise condition. Based on these results, the authors concluded that the children's performance was affected by road traffic noise more so than irrelevant speech, especially in the areas of reading speed and basic mathematics.

**Characteristics of Commercially Available Background Noise**

Commercially available forms of background noise include those available from Auditec, Inc., such as cafeteria noise and speech babble (Auditec, Inc., *n.d.*). These types of noise are not considered standardized noise, in terms of spectral content being standardized or regulated, nor do they include the use of children's speech or typical children's noise. Cafeteria noise was recorded in an employee cafeteria of a hospital, and then given a constant level which included intelligible speech and many transients. Speech babble noises include multi-talker noise, four-talker noise, and cocktail party noise. Multi-talker noise was recorded using twenty young adults simultaneously reading different speech passages, making the target signal unintelligible. Four-talker noise was recorded using three female speakers and one male speaker reading different speech passages, presented simultaneously, where the male speaker is intelligible. Cocktail party noise was recorded during an adults' congregation where speech and many competing sounds were present (Bronkhorst, 2000). These noise recordings were created as tasks to hear a target signal, usually a speech signal, amongst other speech and noise signals (McDermott, 2009). This was done to test the auditory system to segregate the target signal from the sum of signals being presented.

Although these noise recordings are available, there is a lack of information provided from the publication companies entailing the noises' spectral content. All that is available is how each noise recording was produced and how testing with these recordings may be performed. As previously mentioned, these noise recordings only take into account the use of adult speech and environmental sounds, not the speech of children or sounds that accompany children in elementary or middle school settings.

Given the uniqueness of background noise found in elementary and middle schools and the importance of understanding its effect on academic performance, it would be prudent to examine noises recorded in these schools. There are commercially available forms of background noise for research purposes that may not adequately replicate the noises found in an elementary or middle school setting. Also, there are school noise recordings found on the internet, which may or may not adequately replicate the noises found in most elementary or middle school settings. Therefore, the purpose of this project is to observe and record noises in elementary and middle schools in order to produce an elementary school based background noise.

# CHAPTER III

# METHODS

## Participants

Five schools participated in this project. Within each school, several environments were observed, including inside unoccupied and occupied classrooms, hallways, gymnasiums, outside the gymnasiums, and outside play areas. Only the contents typically found in that designated area were allowed to be within that area during testing; however, no contents were removed from these areas. The criteria for inclusion only consisted of each area being an elementary or middle school environment where students spend part of the school day. Recordings were taken once for up to five minutes at each designated location within the school.

Commercially available forms of background noise, such as Auditec, Inc.'s cafeteria noise, four-talker noise, and multi-talker noise, as well as other school noise recordings, such as those commonly found on the internet, were also used (AudioMicro, 2009a; AudioMicro, 2009b; Auditec, Inc., *n.d.,* Kittappa, 2010; Make4Fun, 2007; NFHuth, 2001; Partners in Rhyme, 2009; and X-Ray Sound Studios, 2010). These internet tracks were recordings taken from elementary school hallways, playgrounds, and classrooms. Just as the commercially available forms of background noise mentioned previously, these internet recordings are not standardized, in terms of spectral content being regulated. Because of this and because these recordings may or may not adequately replicate the noises found in most elementary schools, these internet recordings were only observed to view which school environments were crucial to make recordings.

**Materials**

Materials used in this project included a sound level meter, a digital sound recorder, and audio analyzing software. The sound level meter used was the Ex Tech Precision Sound Level Meter, model 407768, which was under the manufacturer's calibration certificate. An Olympus Digital Voice recorder VN-3100 made by Olympus Imaging Corporation was used to digitally record the school environment noise. Both the sound level meter and the digital voice recorder were considered to be hand held devices, and for the purpose of this project, both were used as hand held devices and or placed on some center surface in each designated location within the school for measurement recordings. It was dependent on the structure and amenities of the environment to decide whether the devices were used in hand or on some center surface. The audio analyzing software used in this project was Adobe Audition 1.5. This software allowed for analysis of spectral content and amplitude measurements of the noises recorded.

**Procedures**

Because no individual human subjects were used in this project, a review from the Institutional Review Board (IRB) was considered unnecessary. Prior to this project, an informed consent was signed by each of the principals of the elementary or middle schools examined. Each school, and its administrative staff, were given a detailed description of the project and its procedures (See Appendix A); all concurred to the project.

**Sound collection.**

During testing, the sound level meter, Ex Tech Precision Sound Level Meter, model 407768, was placed within hand or on some center surface in each designated location within the school. The order of the designated areas examined was of no importance and was not considered to have any effects on the results. The digital sound recorder, Olympus Digital Voice recorder VN-3100, was placed into the same designated areas of the school to record the noise present. These recordings were taken while the recorder was placed adjacent to the sound level meter. Noise was recorded in each designated area for up to five minutes, such as inside unoccupied and occupied classrooms, hallways, and gymnasiums, outside the gymnasiums, and outside play areas. Because of principal restrictions and time constraints, not all of these designated areas were observed within each school. Due to the insignificance of signal-to-noise ratio and reverberation time to this project, background noise was the only acoustical factor within the classroom measured and recorded.

**Sound analysis.**

The analyzing software system, Adobe Audition 1.5, was loaded onto a computer. The elementary school noise recordings, along with the commercially available recordings, were uploaded to the computer hard drive and then to Adobe Audition 1.5. This audio analyzing software system was used to visualize the spectral content and amplitude measurements of the recorded noise from each designated location within the school.

This software system reports amplitude in terms of decibels below full scale in digital audio (dBFS). Like a tuner or tuning system, such as a radio dial, the maximum possible amplitude is zero dBFS; all amplitudes below that are expressed as negative numbers (Adobe Systems Incorporated, 2007). As negative values approached zero dBFS, they were considered to be loud or high. A specified dBFS value, which is similar to measurements made in hearing level (HL) because it was based on normative data, did not directly correspond to the original sound pressure level measured in acoustic dB, which is seen as a positive value.

Each recording was uploaded individually, and opened using Adobe Audition 1.5. Although each individual recording totaled a longer length of time, only 1.00 to 2.00 minutes was analyzed, so that each was analyzed in equal time. The space between 1.00 and 2.00 minutes was highlighted, then "show frequency analysis" was chosen from the Analyze menu option. The software was designed to analyze the recordings by frequency in Hertz (Hz), peak amplitude in dBFS, and pictorially by waveform or spectral view. The mean or average noise level for each frequency in each designated area's recording was calculated. This was done by moving the cursor across the frequency spectrum on the frequency analysis spectrogram. Frequencies included: 125, 250, 500, 1000, 2000, 3000, 4000, 6000, 8000, 10,000 and 12,000 Hz. Due to limitations of the software, exact frequency measurements could not be displayed; instead the nearest to the frequency point was selected. Instead of 125 Hz being chosen, 129.1 Hz was used. In continuance the other frequencies used for each recording's analysis included: 258.3, 516.7, 990.5, 2024.0, 2971.0, 4005.0, 4995.0, 5986.0, 8010.0, 10,030.0, and 12,010.0 Hz. Each was recorded into chart form (See Appendix B). All spectral content and amplitude measurements analyzed are reported in the results section.

After the recordings were analyzed individually, including the average noise levels and amplitude measurements, the measurements were compared between the recordings. Comparisons were made among the individual school recordings, between each school, between each commercially available recording, between the school recordings and the commercially available recordings, and between the produced elementary school based background noise and the commercially available recordings. No comparisons were made between the school recordings or commercially available recordings, against the internet recordings. The comparison measurements which were made are reported in the results section.

**Sound production and its analysis.**

After each recording was analyzed by frequency in Hertz, peak amplitude in dBFS, and pictorially by waveform or spectral view, and after comparisons measurements were made, the recordings were mixed or integrated, and modified using Adobe Audition 1.5 to produce an elementary school based background noise. A new session was opened and each of the individual school recordings was re-uploaded or re-imported into the Adobe Audition 1.5 software. Each uploaded recording was drug into the "multi track view" in slots from one to seventeen; one recording per slot. Each was selected or highlighted, then "mix down selected waves" was chosen from the tool bar of mixing options. This mixed or combined all of the recordings together to form one recording. For the purpose of this project, this recording was labeled as the mix down or the noise produced in this project. In producing the mix down of noise, the bandwidth or amplitude measurements were added together, to produce a noise that may have louder measureable levels than the original individual recordings.

After the mix down was complete, the "edit view" was chosen instead of "multi track view." Here, the space between 1.00 minutes and 2.00 minutes was highlighted, then "show frequency analysis" was chosen from the Analyze menu option. The software analyzed this new recording the same as each individual school recording and the commercially available recordings were analyzed; by frequency in Hertz, peak amplitude in dBFS, and pictorially by waveform or spectral view. The mean or average noise level for each frequency in each designated area's recording was calculated. These measurements are reported in the results section.

# CHAPTER IV

# RESULTS

The purpose of this project was to observe and record noises for the production of an elementary school based background noise; comparison measurements of the noise recordings and results are shown. These comparisons occurred between the individual school recordings, between each school, between each commercially available recording, between the school recordings and the commercially available recordings, and between the produced elementary school based background noise and the commercially available recordings.

## Comparisons Between Individual School Recordings

The first comparisons completed were between each individual school recording for each school. For the first school observed, School A, and for each subsequent school, the sound pressure levels measured in acoustic dB (dB SPL) using the sound level meter, varied with each designated area. The designated areas for School A included two hallways and an occupied classroom. The first hallway measured a range of 50.2 dB SPL to 71.9 dB SPL; the second hallway measured a range of 32.5 dB SPL to 63.4 dB SPL, and the occupied classroom measured a range of 51.8 dB SPL to 70.6 dB SPL. In terms of sound pressure level, the first hallway measured to be the loudest environment of the designated areas measured within this school.

Using Adobe Audition 1.5, each of these recordings was analyzed in terms of dBFS. The first hallway measured its loudest levels of -51.44 dBFS at 1000 Hz and -51.51 dBFS at 500 Hz; its softest levels of -119.70 dBFS occurred at 12,000 Hz and -97.85 dBFS at 10,000 Hz. The second hallway measured its loudest levels of -50.28 dBFS at 125 Hz and -50.53 dBFS at 2000 Hz; its softest levels of -119.50 dBFS occurred at 12,000 Hz and -73.10 dBFS at 500 Hz. The occupied classroom measured its loudest levels of -35.74 dBFS at 250 Hz and -36.34 dBFS at 500 Hz; its softest levels of -123.50 dBFS occurred at 6000 Hz and -121.90 dBFS at 12,000 Hz.

As seen in Figure 1, which displays the spectral content of noise from elementary School A, noise recorded in the occupied classroom had the loudest levels in dBFS from 125 to 2000 Hz, 4000 Hz, 8000 Hz, and 10,000 Hz. The occupied classroom had the least amount of noise between the three recordings at 3000 Hz, 6000 Hz, 12,000 Hz. Noise recorded in the first hallway never had the loudest noise level in comparison to the other designated areas, but had the softest noise levels in comparison to the other designated areas in dBFS from 125 to 250 Hz, 2000 Hz, and 10,000 Hz. Again, in comparison to the other designed areas, noise recorded in the second hallway had the loudest level in dBFS at 3000 Hz, 6000 Hz, and 12,000 Hz, and had the least amount of noise 500 Hz. Overall, the occupied classroom had the loudest levels for this school. Furthermore, loudest levels of noise were recorded from 125 Hz to 2000 Hz (see Figure 1).

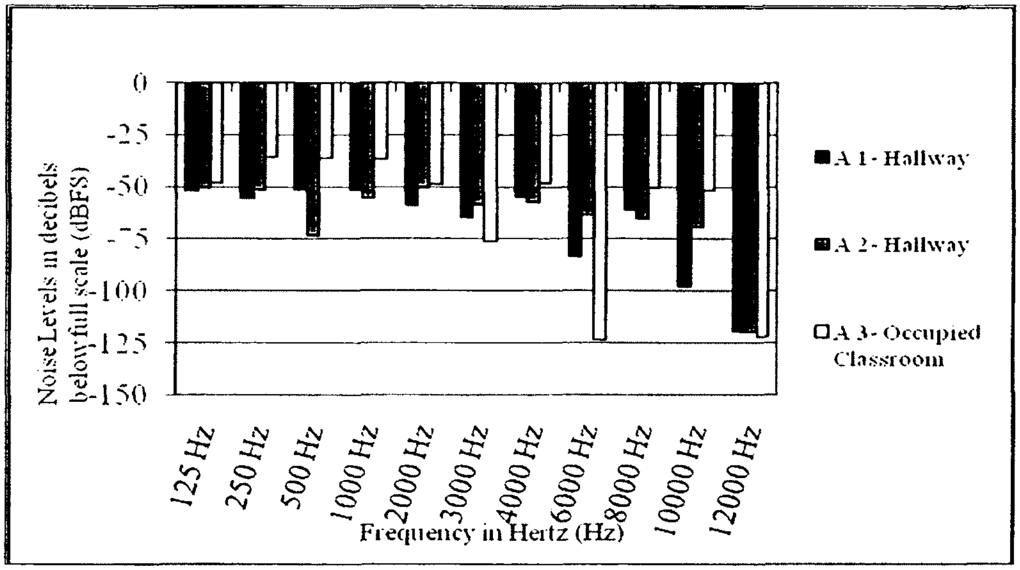


Figure 1. Spectral Content of Noise Levels from School A

The designated areas for School B included two hallways and an unoccupied classroom. The first hallway measured a range of 52.8 dB SPL to 72.3 dB SPL; the unoccupied classroom measured a range of 52.0 dB SPL to 61.5 dB SPL, and the second hallway measured a range of 51.4 dB SPL to 68.0 dB SPL. In terms of sound pressure level, the first hallway measured to be the loudest environment of the designated areas measured within this school.

Using Adobe Audition 1.5, each of these recordings was analyzed in terms of dBFS. The first hallway measured its loudest levels of -32.63 dBFS at 125 Hz and -37.47 dBFS at 1000 Hz; its softest levels of -85.49 dBFS occurred at 12,000 Hz and -64.05 dBFS at 10,000 Hz. The unoccupied classroom measured its loudest levels of -47.21 dBFS at 250 Hz and -50.31 dBFS at 2000 Hz; its softest levels of -116.10 dBFS occurred at 12,000 Hz and -71.82 dBFS at 10,000 Hz. The second hallway measured its loudest levels of -49.24 dBFS at 3000 Hz and -49.63 dBFS at 500 Hz; its softest levels of -119.10 dBFS occurred at 12,000 Hz and -73.83 dBFS at 10,000 Hz.

As seen in Figure 2, which displays the spectral content of noise from elementary School B, noise recorded in the first hallway had the loudest levels in dBFS across all frequencies observed. Noise recorded in the unoccupied classroom had the second highest levels in dBFS at all frequencies observed with the exception of 125 Hz, 500 Hz, and 3000 Hz, in which this area had the least levels of noise. Noise recorded in the second hallway had the softest levels in dBFS for this school. Overall, the loudest levels of noise were recorded from 125 Hz to 3000 Hz.

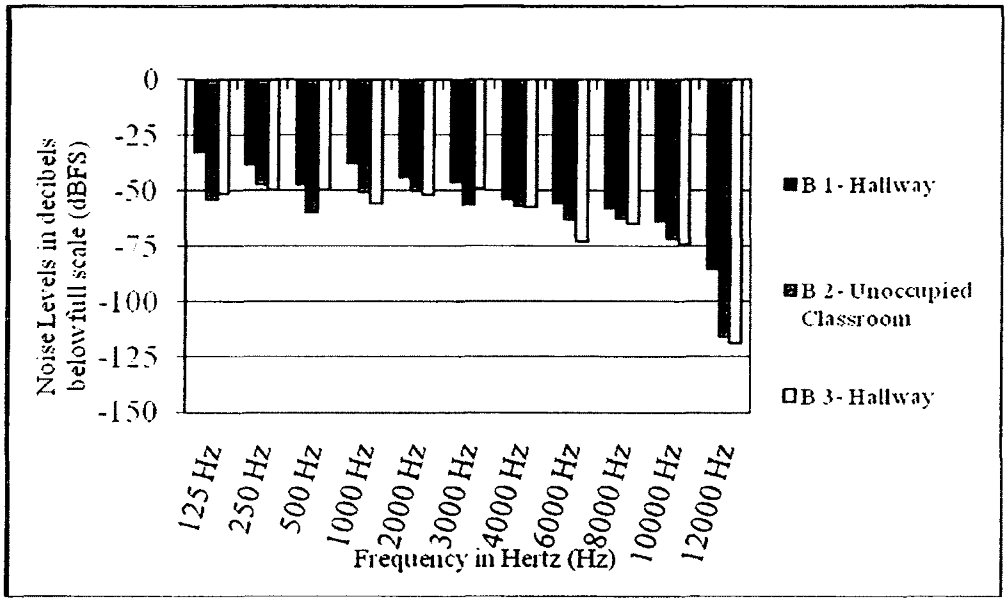


Figure 2. Spectral Content of Noise Levels from School B

In School C, the designated areas included a hallway, an unoccupied classroom, a gymnasium, an area outside the gymnasium, and an occupied classroom. The hallway measured a range of 52.3 dB SPL to 75.4 dB SPL, the unoccupied classroom measured a range of 49.5 dB SPL to 61.6 db SPL, the gymnasium measured a range of 46.3 dB SPL to 80.1 dB SPL, the area outside of the gymnasium measured a range of 50.6 dB SPL to 75.3 dB SPL, and the occupied classroom measured a range of 51.2 dB SPL to 75.8 dB

SPL. In terms of sound pressure level, the gymnasium measured to be the loudest environment of the designated areas measured within this school.

Using Adobe Audition 1.5, each of these recordings was analyzed in terms of dBFS. The hallway measured its loudest levels of -45.95 dBFS at 1000 Hz and -49.91 dBFS at 125 Hz; its softest levels of -66.95 dBFS occurred at 12,000 Hz and -63.11 dBFS at 10,000 Hz. The unoccupied classroom measured its loudest levels of -52.47 dBFS at 250 Hz and -55.27 dBFS at 500 Hz; its softest levels of -104.00 dBFS occurred at 12,000 Hz and -79.13 dBFS at 125 Hz. The gymnasium measured its loudest levels of -23.17 dBFS at 1000 Hz and -29.71 dBFS at 3000 Hz; its softest levels of -124.80 dBFS occurred at 12,000 Hz and -79.24 dBFS at 10,000 Hz. The area outside the gymnasium measured its loudest levels of -52.11 dBFS at 500 Hz and -54.64 dBFS at 250 Hz; its softest levels of -103.80 dBFS occurred at 12,000 Hz and -67.31 dBFS at 10,000 Hz. The occupied classroom measured its loudest levels of -45.57 dBFS at 500 Hz and -51.09 dBFS at 3000 Hz; its softest levels of -143.30 dBFS occurred at 12,000 Hz and -70.90 dBFS at 10,000 Hz.

As seen in Figure 3, which displays the spectral content of noise from elementary School C, noise recorded in the gymnasium had the loudest levels in dBFS across all frequencies except for 250 Hz, 10,000 Hz, and 12,000 Hz. The unoccupied classroom and small area outside the gymnasium often had the least amounts of noise present in comparison to the other designated areas. Overall, the loudest levels of noise were recorded from 125 Hz to 3000 Hz.

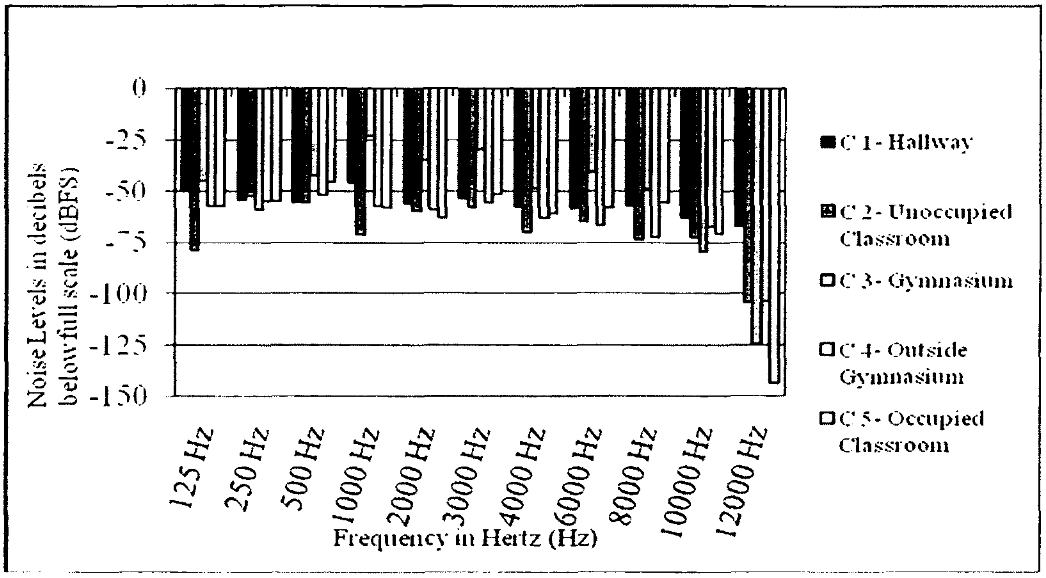


Figure 3. Spectral Content of Noise Levels from School C

The designated areas for School D included an unoccupied classroom, an area outside the gymnasium, a hallway, and an occupied classroom. The unoccupied classroom measured a range of 38.7 dB SPL to 52.3 dB SPL, the area outside of the gymnasium measured a range of 32.3 dB SPL to 84.2 dB SPL, the hallway measured a range of 50.3 dB SPL to 66.7 dB SPL, and the occupied classroom measured a range of 52.7 dB SPL to 73.1 dB SPL. In terms of sound pressure level, the area outside the gymnasium measured to be the loudest environment of the designated areas measured within this school.

Using Adobe Audition 1.5, each of these recordings was analyzed in terms of dBFS. The unoccupied classroom measured its loudest levels of -48.86 dBFS at 250 Hz and -55.62 dBFS at 500 Hz; its softest levels of -118.50 dBFS occurred at 12,000 Hz and -70.94 dBFS at 10,000 Hz. The area outside the gymnasium measured its loudest levels of -38.36 dBFS at 8000 Hz and -44.76 dBFS at 3000 Hz; its softest levels of -87.95 dBFS occurred at 12,000 Hz and -65.41 dBFS at 125 Hz. The hallway measured its loudest levels at -49.87 dBFS at 1000 Hz and -51.92 dBFS at 6000 Hz; its softest levels of -66.07 dBFS occurred at 12,000 Hz and -60.86 dBFS at 3000 Hz. The occupied classroom measured its loudest levels at -41.07 dBFS at 125 Hz and -43.57 dBFS at 500 Hz; its softest levels of -116.90 occurred at 12,000 Hz and -76.01 dBFS at 10,000 Hz.

As seen in Figure 4, which displays the spectral content of noise from elementary School D, noise recorded in the occupied classroom had the loudest levels in dBFS in the lower frequencies including 125 to 500 Hz and was approximately equal in loudness to that of the unoccupied classroom in the higher frequencies 4000 to 12,000 Hz. Noise recorded in the unoccupied classroom had the least amount of noise levels across the all frequencies observed in comparison to the other designated areas. Overall the area outside of the gymnasium had the loudest levels. Furthermore, the loudest levels of noise were recorded from 125 Hz to 8000 Hz.

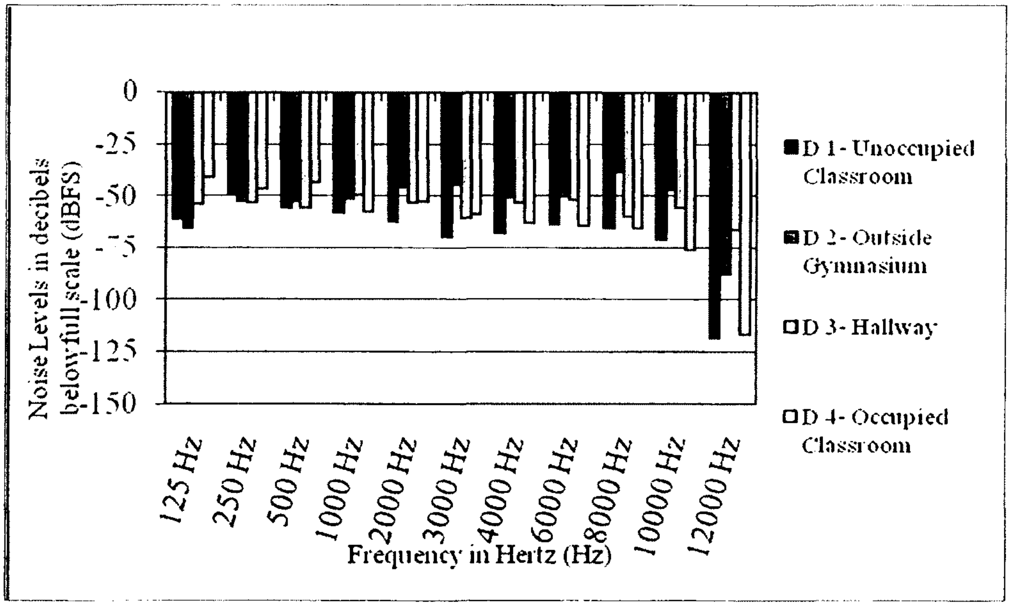


Figure 4. Spectral Content of Noise Levels from School D

The designated areas for School E included an outside play area and two hallways. The outside play area measured a range of 56.4 dB SPL to 72.8 dB SPL, the first hallway measured a range of 52.2 dB SPL to 69.8 dB SPL, and the second hallway measured a range of 48.9 dB SPL to 63.5 dB SPL. The recording for the second hallway was omitted from this project due to being erased while being uploaded to the computer hard drive. In terms of sound pressure level, the outside play area measured to be the loudest environment of the designated areas measured within this school.

Using Adobe Audition 1.5, each of these recordings was analyzed in terms of dBFS. The outside play area measured its loudest levels of -39.99 dBFS at 125 Hz and -46.82 dBFS at 1000 Hz; its softest levels of -121.20 dBFS occurred at 12,000 Hz and -75.88 dBFS at 6000 Hz. The hallway measured its loudest levels of -37.23 dBFS at 500 Hz and -49.34 dBFS at 125 Hz; its softest levels of -106.20 dBFS occurred at 12,000 Hz and -67.31 dBFS at 10,000 Hz.

As seen in Figure 5, which displays the spectral content of noise from elementary School E, noise levels recorded in the outside play area were loudest from 125 to 250 Hz and 1000 to 4000 Hz. Noise levels recorded in the hallway were louder in dBFS at 500 Hz and 6000 to 12,000 Hz in comparison to the other designated area observed. Overall the outside play area had the loudest levels in the lower frequencies and the hallway had the loudest levels in the higher frequencies. Furthermore, the loudest levels of noise were recorded from 125 Hz to 1000 Hz.

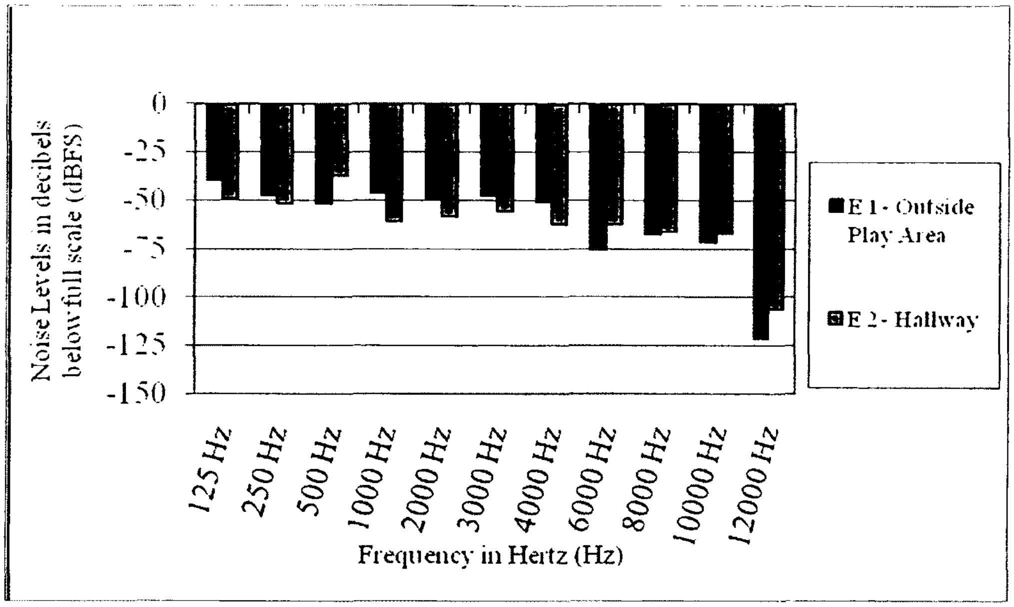


Figure 5. Spectral Content of Noise Levels from School E

**Comparisons Between Schools**

Next, comparisons were made between the schools. This was done in terms of sound pressure level and decibels below full scale when analyzed using Adobe Audition 1.5. The sound pressure levels measured using the sound level meter, varied with each designated area measured within each school. School D had the highest measurements of 84.2 dB SPL measured in the area outside of the gymnasium. This school's environment also had the softest level of 32.2 dB SPL of all the schools measured.

Collectively, all schools had the loudest levels in dBFS from 125Hz to 3000 Hz when analyzed using Adobe Audition 1.5, with only School D having the loudest levels through 8000 Hz. Table 1 displays the noise levels measured in dBFS for each designated area according to each frequency observed. When broken down by frequency, School B had the loudest levels at 125 Hz measured in the first hallway; School A had the loudest levels at 250 Hz and 500 Hz both measured in the occupied classroom, and School C had the loudest levels at 1000 Hz, 2000 Hz, and 3000 Hz all measured in the gymnasium.

Also with the loudest levels, School A had the loudest levels at 4000 Hz measured in the occupied classroom; School C had the loudest levels at 6000 Hz measured in the gymnasium; and School D had the loudest levels at 8000 Hz, 10,000 Hz, and 12,000 Hz, all of which were measured in the area outside the gymnasium. School E never had the loudest levels at any frequency in comparison to the other schools observed. When broken down by frequency, School C had the softest levels at 125 Hz measured in the unoccupied classroom and 250 Hz measured in the gymnasium; School A had the softest levels at 500 Hz measured in the second hallway; School C had the softest levels at 1000 Hz measured in the unoccupied classroom and 2000 Hz measured in the occupied classroom; and School A had the softest levels at 3000 Hz measured in the occupied classroom. Also with the softest levels, School C had the softest levels at 4000 Hz measured in the unoccupied classroom; School A had the softest levels at 6000 Hz measured in the occupied classroom; School C had the softest levels at 8000 Hz measured in the unoccupied classroom; School A had the softest levels at 10,000 Hz measured in the first hallway; and School C had the softest levels at 12,000 Hz measured in the occupied classroom. Overall, Schools A and C had some of the loudest and softest environments of all the schools observed (see Table 1).

Table 1: Spectral Content of Noise Levels From All the Elementary Schools

| Recording | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 3000 Hz |
|---|---|---|---|---|---|---|
| A 1- Hallway | -52.32 | -55.60 | -51.51 | -51.44 | -58.96 | -64.72 |
| A 2- Hallway | -50.28 | -51.44 | -73.10 | -55.81 | -50.53 | -58.25 |
| A 3- Occupied Classroom | -48.25 | -35.74 | -36.34 | -36.67 | -48.80 | -76.38 |
| B 1- Hallway | -32.63 | -38.35 | -47.55 | -37.47 | -43.83 | -46.35 |
| B 2- Unoccupied Classroom | -54.02 | -47.21 | -60.10 | -50.73 | -50.31 | -56.30 |
| B 3- Hallway | -51.42 | -49.85 | -49.63 | -55.82 | -52.06 | -49.24 |
| C 1- Hallway | -49.91 | -54.28 | -55.52 | -45.95 | -56.00 | -53.42 |
| C 2- Unoccupied Classroom | -79.13 | -52.47 | -55.27 | -71.06 | -59.35 | -57.94 |
| C 3- Gymnasium | -45.04 | -59.08 | -42.56 | -23.17 | -34.83 | -29.71 |
| C 4- Outside Gymnasium | -57.00 | -54.64 | -52.11 | -56.97 | -58.85 | -55.66 |
| C 5- Occupied Classroom | -57.11 | -55.03 | -45.57 | -57.97 | -63.35 | -51.09 |
| D 1- Unoccupied Classroom | -61.02 | -48.86 | -55.62 | -58.09 | -62.39 | -70.18 |
| D 2- Outside Gymnasium | -65.41 | -52.48 | -52.44 | -51.67 | -46.07 | -44.76 |
| D 3- Hallway | -53.72 | -53.09 | -55.50 | -49.87 | -53.43 | -60.86 |
| D 4- Occupied Classroom | -41.07 | -46.56 | -43.56 | -57.73 | -52.61 | -58.82 |
| E 1- Outside Play Area | -39.99 | -48.06 | -51.51 | -46.82 | -49.59 | -47.76 |
| E 2- Hallway | -49.34 | -51.60 | -37.23 | -60.85 | -58.32 | -55.49 |

| Recording | 4000 Hz | 6000 Hz | 8000 Hz | 10000 Hz | 12000 Hz |
|---|---|---|---|---|---|
| A 1- Hallway | -55.23 | -83.76 | -61.28 | -97.85 | -119.70 |
| A 2- Hallway | -57.20 | -63.49 | -65.30 | -69.22 | -119.50 |
| A 3- Occupied Classroom | -48.34 | -123.50 | -50.45 | -51.53 | -121.90 |
| B 1- Hallway | -53.98 | -56.09 | -58.42 | -64.05 | -85.49 |
| B 2- Unoccupied Classroom | -56.86 | -63.45 | -62.71 | -71.82 | -116.10 |
| B 3- Hallway | -57.73 | -72.90 | -64.82 | -73.83 | -119.10 |
| C 1- Hallway | -58.00 | -58.62 | -57.42 | -63.11 | -66.95 |
| C 2- Unoccupied Classroom | -70.25 | -64.89 | -73.64 | -72.53 | -104.00 |
| C 3- Gymnasium | -48.44 | -40.59 | -49.18 | -79.24 | -124.80 |
| C 4- Outside Gymnasium | -63.23 | -66.44 | -72.56 | -67.31 | -103.80 |
| C 5- Occupied Classroom | -60.65 | -57.72 | -55.73 | -70.90 | -143.30 |
| D 1- Unoccupied Classroom | -67.89 | -64.03 | -65.52 | -70.94 | -118.50 |
| D 2- Outside Gymnasium | -50.87 | -50.44 | -38.36 | -47.32 | -87.95 |
| D 3- Hallway | -53.19 | -51.92 | -59.81 | -55.49 | -66.07 |
| D 4- Occupied Classroom | -62.96 | -64.34 | -65.79 | -76.01 | -116.90 |
| E 1- Outside Play Area | -50.97 | -75.88 | -67.84 | -71.76 | -121.20 |
| E 2- Hallway | -62.42 | -62.54 | -66.54 | -67.31 | -106.20 |

**Comparisons Between Commercially Available Recordings**

Comparison measurements of the noise recordings and results are also shown for the commercially available background noise recordings. Sound pressure levels could not be measured for these recordings due to the nature of how these recordings were available. Using Adobe Audition 1.5, each of these recordings was analyzed for its spectral content and amplitude measurements.

For Auditec Inc.'s cafeteria noise, Adobe Audition 1.5 was used to analyze its spectral content in terms of dBFS. As seen in Figure 6, which displays the spectral content of this noise recording, the loudest levels of noise measured -20.49 dBFS at 250 Hz and -21.93 dBFS at 500 Hz; its softest levels of -72.83 dBFS occurred at 12,000 Hz and -61.23 dBFS at 10,000 Hz. Overall, the loudest levels of noise were recorded from 125 Hz to 4000 Hz, which never exceeded a level of -50.00 dBFS.

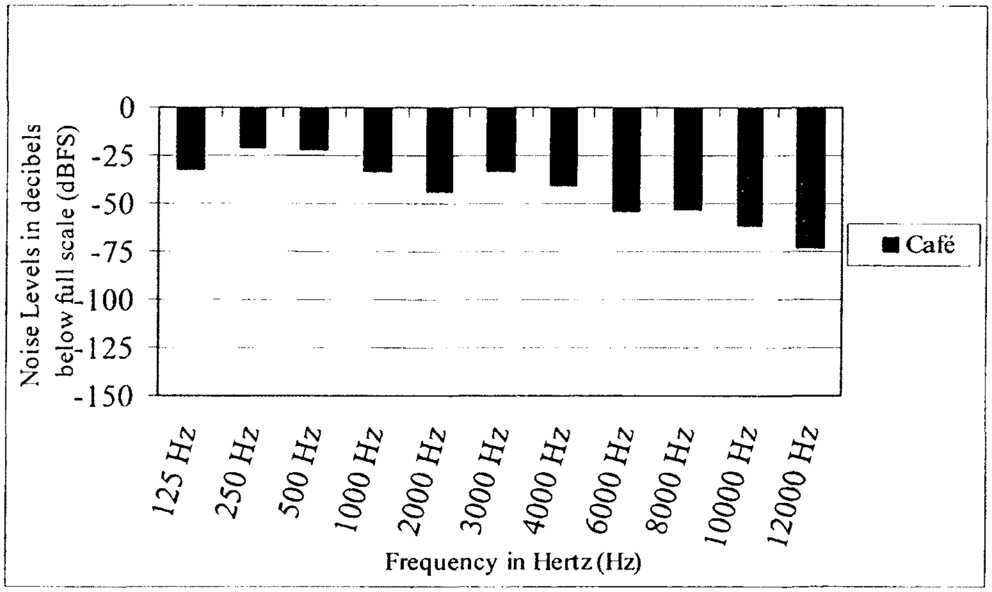


Figure 6. Spectral Content of Noise Levels from Auditec's Cafeteria Noise

For Auditec Inc.'s four-talker noise, Adobe Audition 1.5 was used to analyze its spectral content in terms of dBFS. As seen in Figure 7, which displays the spectral content of this noise recording, the loudest levels of noise measured -31.71 dBFS at 125 Hz and -33.17 dBFS at 500 Hz; its softest levels of -85.07 dBFS occurred at 6000 Hz and -83.85 dBFS at 12,000 Hz. Overall, the loudest levels of noise were recorded from 125 Hz to 2000 Hz, which never exceeded a level of -50.00 dBFS.

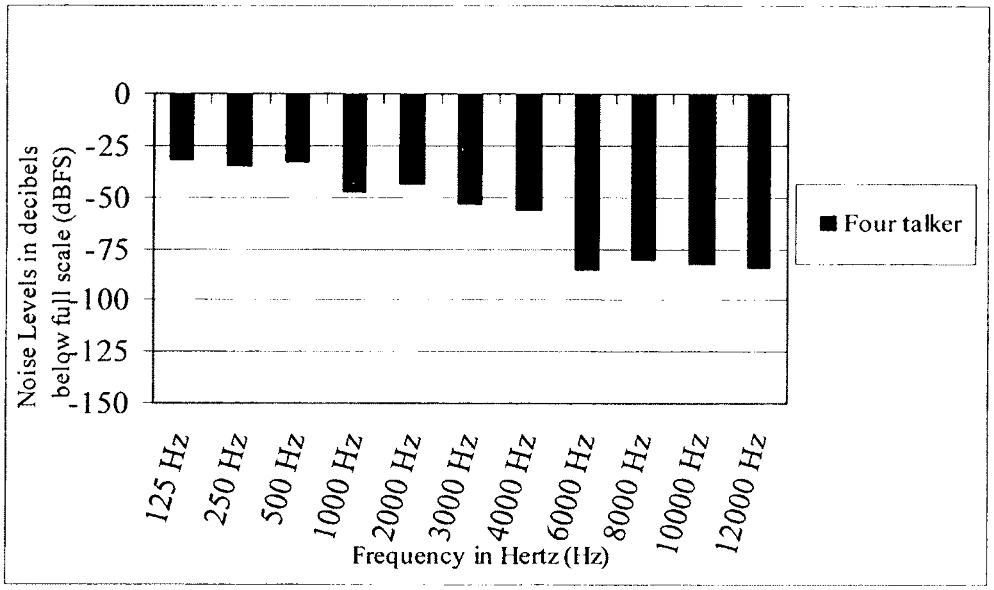


Figure 7. Spectral Content of Noise Levels from Auditec's Four-talker Noise

For Auditec Inc.'s multi-talker noise, Adobe Audition 1.5 was used to analyze its spectral content in terms of dBFS. As seen in Figure 8, which displays the spectral content of this noise recording, the loudest levels of noise measured -24.66 dBFS at 250 Hz and -25.65 dBFS at 125 Hz; its softest levels of -84.30 dBFS occurred at 12,000 Hz and -74.52 dBFS at 8000 Hz. Overall, the loudest levels of noise were recorded from 125 Hz to 3000 Hz, which never exceeded a level of -50.00 dBFS.

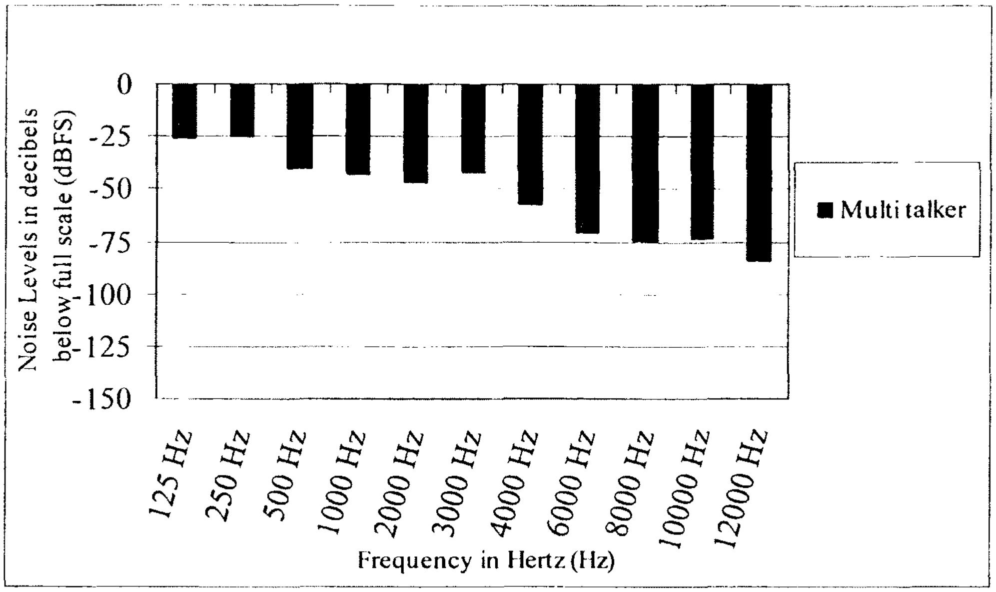


Figure 8. Spectral Content of Noise Levels from Auditec's Multi-talker Noise

In the comparison study between each of the commercially available background noise recordings, several findings were noted. All recordings had the loudest levels from 125 Hz to 4000 Hz when analyzed using Adobe Audition 1.5. As seen in Figure 9, the cafeteria noise had the loudest noise levels of the three recordings across the frequency range observed with the exception of 125 Hz, that showed the softest level of noise. Overall, the four-talker noise recording had the softest levels of the three recordings, specifically in the higher frequencies from 3000 Hz to 12,000 Hz with the exception of 4000 Hz. Multi-talker noise only had the loudest levels of the three recordings at 125 Hz and 250 Hz; it had the softest levels of the three recordings at 500 Hz, 2000 Hz, and 4000 Hz.

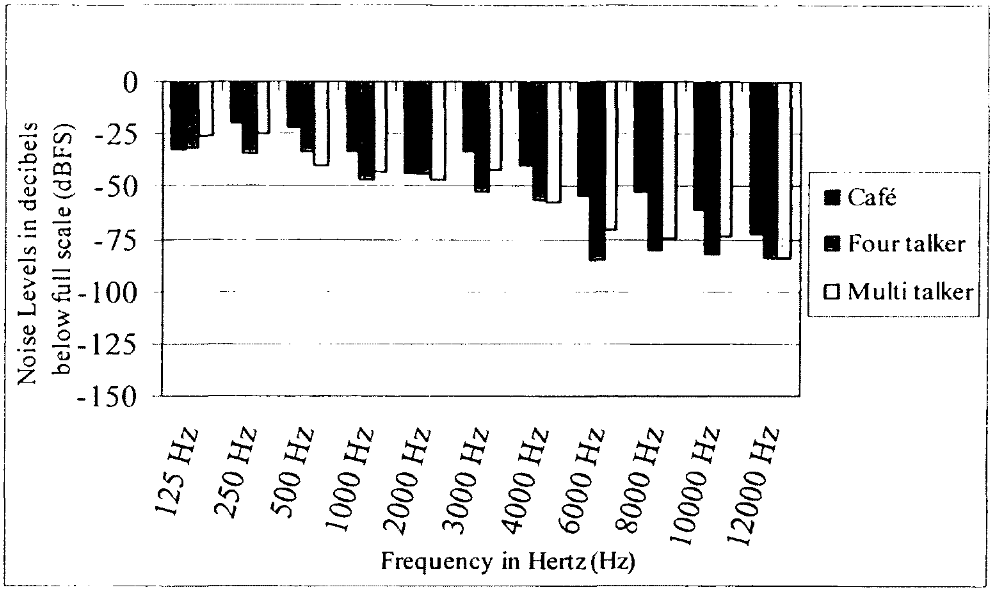


Figure 9. Spectral Content of Noise Levels from Auditec's Commercially Available Background Noise

**Comparisons Between School and Commercially Available Recordings**

Next, comparisons were made between the school recordings and the commercially available recordings. In terms of decibels below full scale, all schools had its loudest levels from 125Hz to 3000 Hz, with only School D having its the loudest levels through 8000 Hz. When broken down by frequency, Schools A, B, C, and D each had a designated area which measured the loudest levels in comparison to the other schools observed. These levels ranged up to -23.17 dBFS at 1000 Hz measured in the gymnasium at School C. School E never had a designated area that had the loudest levels in comparison to the other schools observed. When comparisons were made for the softest levels, Schools A and C had the softest levels which ranged down to -143.30 dBFS at 12,000 Hz measured in the occupied classroom at School C. When broken down by frequency, Schools B, D, and E never had the softest levels in comparison to the other schools observed. As previously mentioned, comparisons made between the commercially available recordings found all recordings had its loudest levels measured in decibels below full scale from 125 Hz to 4000 Hz. The noise levels for these commercially available recordings ranged from -20.49 dBFS measured at 125 Hz in Auditec Inc.'s cafeteria noise to -85.07 dBFS measured at 6000 Hz in Auditec Inc.'s four-talker noise.

When compared by frequency, Auditec Inc.'s multi-talker noise had the loudest noise level of -25.65 dBFS at 125 Hz; Auditec Inc.'s cafeteria noise with a level of -20.49 dBFS at 250 Hz and -21.93 dBFS at 500 Hz; and School C's gymnasium with a level of -23.17 dBFS at 1000 Hz, -34.83 dBFS at 2000 Hz, and -29.71 dBFS at 3000 Hz. Also with the loudest levels, Auditec Inc.'s cafeteria noise had -40.32 dBFS at 4000 Hz; School C's gymnasium with a level of -40.59 dBFS at 6000 Hz and -49.18 dBFS at 8000 Hz; School D's area outside of the gymnasium with a level of -47.32 dBFS at 10,000 Hz; and School D's hallway with a level of -66.07 dBFS at 12,000 Hz. When broken down by frequency, School C's unoccupied classroom had the softest noise level of -79.13 dBFS at 125 Hz and -59.08 dBFS at 250 Hz; School A's second hallway with a level of -73.10 dBFS at 500 Hz; School C's unoccupied classroom with a level of -71.06 dBFS at 1000 Hz and -63.35 dBFS at 2000 Hz; and School D's unoccupied classroom with a level of -70.18 dBFS at 3000 Hz. Also with the softest levels, School C's unoccupied classroom had -70.25 dBFS at 4000 Hz; School A's occupied classroom with a level of -123.5 dBFS at 6000 Hz; School C's unoccupied classroom with a level of -73.64 dBFS at 8000 Hz; School A's first hallway with a level of -97.85 dBFS at 10,000 Hz; and School C's occupied classroom with a level of -143.30 dBFS at 12,000 Hz. Auditec Inc.'s commercially available background noise recordings never had the softest levels of any frequency observed.

### Comparisons Between Produced Noise and Commercially Available Recordings

Finally, comparisons were made between the elementary school based background noise produced in this project and the commercially available recordings. The elementary school based background noise was produced by mixing or combining all of the individual school recordings together to form one recording. This recording was labeled as the mix down or the noise produced in this project. In producing the mix down of noise, the bandwidth or amplitude measurements were added together, to produce a noise that showed to have louder measureable levels than the original individual school recordings. As seen in Figure 10, which displays the spectral content of this produced noise recording, the loudest levels of noise measured -26.64 dBFS at 125 Hz and -31.32 dBFS at 250 Hz; its softest levels of -70.34 dBFS occurred at 12,000 Hz and -60.64 dBFS at 10,000 Hz.

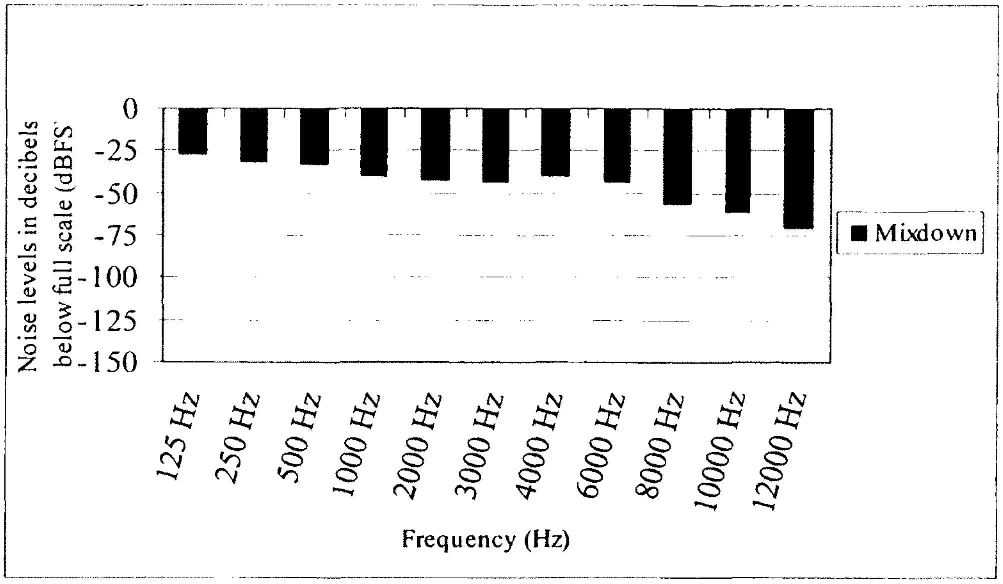


Figure 10. Spectral Content of Noise Levels from the Produced Elementary School Based Background Noise

In comparison to the commercially available recordings, the elementary school based background noise produced in this project had its loudest levels measured in dBFS from 125Hz to 6000 Hz. These measurements never exceeded a softness level of -50.00 dBFS; whereas Auditec Inc.'s commercially available recordings reached softer levels exceeding -50.00 dBFS at 3000 Hz and 4000 Hz rather than up to 6000 Hz. In meaning, the elementary school based background noise produced in this project had louder levels for more frequencies, and higher frequencies, than the commercially available recordings. One possible rationale for this sensation is due to the frequency range of speech and the uniqueness of noise, which here incorporates that of children's voices and noises found in elementary school classrooms.

In Figure 11, the spectral content of this produced noise recording in comparison to that of the three commercially available recordings observed can be seen. When compared by frequency, Auditec Inc.'s multi-talker noise had the loudest noise level of

-25.65 dBFS at 125 Hz; Auditec Inc.'s cafeteria noise had the loudest level of -20.49 dBFS at 250 Hz, -21.93 dBFS at 500 Hz, and -33.68 dBFS at 1000 Hz; the mix down had the loudest level of -42.30 dBFS at 2000 Hz; Auditec Inc.'s cafeteria noise had the loudest level of -33.80 dBFS at 3000 Hz and -40.32 dBFS at 4000 Hz; the mix down had the loudest level of -42.88 dBFS at 6000 Hz; Auditec Inc.'s cafeteria noise had the loudest level of -52.86 at 8000 Hz; and the mix down had the loudest level of -60.64 dBFS at 10,000 Hz and -70.34 dBFS at 12,000 Hz. When compared by frequency, Auditec Inc.'s cafeteria noise had the softest noise level of -32.49 dBFS at 125 Hz; Auditec Inc.'s four-talker noise had the softest level of –34.77 dBFS at 250 Hz; Auditec Inc.'s multi-talker noise had the softest level of -40.19 dBFS at 500 Hz; Auditec Inc.'s four-talker noise had the softest level of -46.96 dBFS at 1000 Hz; Auditec Inc.'s multi-talker noise had the softest level of -46.61 dBFS at 2000 Hz; Auditec Inc.'s four-talker noise had the softest level of -52.85 dBFS at 3000 Hz; Auditec Inc.'s multi-talker noise had the softest level of -56.99 dBFS at 4000 Hz; Auditec Inc.'s four-talker noise had the softest level of -85.07 dBFS at 6000 Hz,-80.18 dBFS at 8000 Hz, and –82.06 dBFS at 10,000 Hz; and Auditec Inc.'s multi-talker noise had the softest level of -84.33 dBFS at 12,000 Hz. The mix down recording produced in this project never had the softest levels of any frequency observed when in comparison to the commercially available recordings (see Figure 11). In comparison to commercially available recordings, the mix down recording produced in this project is most like Auditec Inc.'s cafeteria noise in terms of loudness, but because it is a combination of the individual school recordings, it is most like these recordings in terms of loudness and frequency. It is significantly different from the talker babbles in the 6000 to 10,000 Hz region.

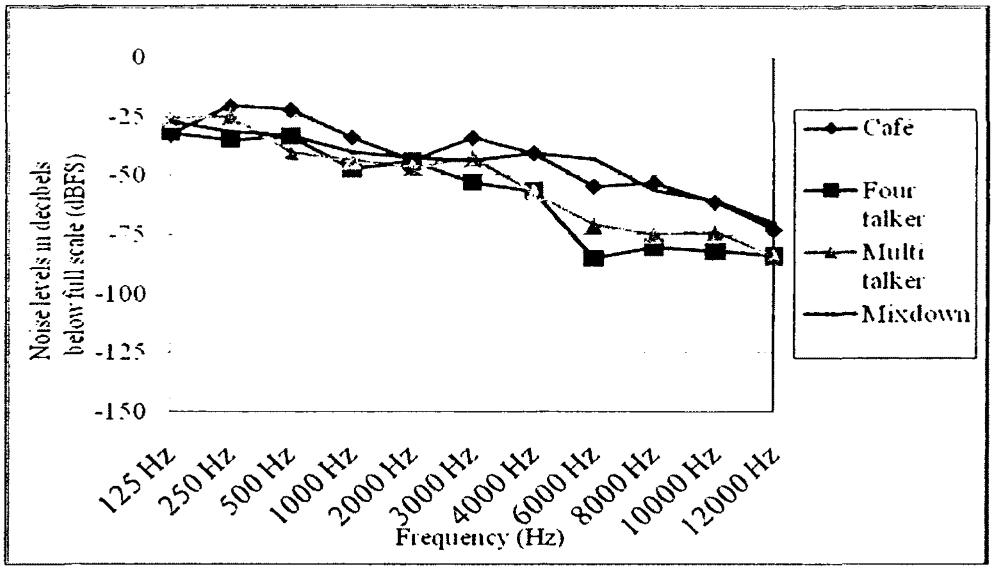


Figure 11. Spectral Content of Noise Levels from the Produced Elementary School Based Background Noise and from Auditec Inc.'s Commercially Available Recordings

# CHAPTER V

# DISCUSSION

The purpose of this project was to observe and record noises for the intention of producing of an elementary school based background noise. Given the uniqueness and variability of background noise found in elementary and middle schools and the importance of understanding its effect on academic performance, it was prudent to examine noises recorded in elementary and middle schools. This was done by recording and analyzing the spectral content of noise present in five elementary and middle schools in designated areas such as inside unoccupied and occupied classrooms, hallways, and gymnasiums, outside the gymnasiums, and outside play areas. Because of principal restrictions and time constraints, not all of these designated areas were observed within each school. These measurements were compared to those of the commercially available background noise recordings. An elementary school based background noise was produced by mixing or combining all of the individual school recordings together to form one recording. The spectral content of this new recording was also compared to the commercially available recordings.

Spectral and intensity differences were seen among the individual school recordings, among the commercially available forms of background noise, when comparing the school recordings to the commercially available noise recordings, and among the elementary school based background noise produced in this project compared to the commercially available recordings. When comparisons were made for the individual school recordings, all schools had the loudest levels in terms of dBFS from 125 Hz to 3000 Hz when analyzed using Adobe Audition 1.5, with only School D having the loudest levels through 8000 Hz. Schools A, B, C, and D each had a designated area which measured the loudest levels in comparison to the other schools observed. School E never had a designated area that had the loudest levels in comparison to the other schools observed. When comparisons were made for the softest levels, Schools A and C had the softest levels in comparison to the other schools observed. Schools B, D, and E never had the softest levels in comparison to the other schools observed.

When comparisons were made for the schools in terms of sound pressure level, the measurements varied with each designated area measured within each school. The measurements ranged from 32.2 dB SPL to 84.2 dB SPL on the A-weighted scale. These measurements are similar to those previously reviewed in the current literature, which showed occupied and unoccupied classrooms to have noise measurements ranging from 53 to 74 dBA, unoccupied classroom noise levels between 34.4 and 65.9 dBA, and occupied classroom noise levels between 81.5 and 83.6 dBA (American Speech-Language-Hearing Association, 2005b; Knecth et al., 2002; and McAllister et al., 2008).

When comparisons were made for the commercially available recordings, all of the commercially available recordings had the loudest levels from 125 Hz to 4000 Hz when analyzed using Adobe Audition 1.5. Auditec Inc.'s cafeteria noise had the loudest noise levels of the three commercially available recordings across the frequency range observed with the exception of 125 Hz, that showed the softest level of noise. Overall, the four-talker recordings had the softest levels of the three commercially available recordings, specifically in the higher frequencies from 3000 Hz to 12,000 Hz with the exception of 4000 Hz. Multi-talker noise only had the loudest levels of the three recordings at 125 Hz and 250 Hz.

When comparisons were made between the school recordings and the commercially available recordings, School C, School D, Auditec Inc.'s multi-talker noise, and Auditec Inc.'s cafeteria noise each had the loudest levels of noise for certain frequencies in comparison to the other recordings observed. School A, School B, and School E, and Auditec Inc.'s four-talker noise never had the loudest levels of noise for any certain frequency in comparison to the other recordings observed.

When comparisons were made between the elementary school based background noise produced in this project and the commercially available forms of background noise. The elementary school based background noise produced in this project had its loudest levels measured in dBFS from 125Hz to 6000 Hz; whereas Auditec Inc.'s commercially available recordings reached its loudest levels measured in dBFS at 3000 Hz and 4000 Hz. In meaning, the elementary school based background noise produced in this project had louder levels for more frequencies, and higher frequencies, than the commercially available recordings.

Results from this project showed that noise found in elementary school classrooms is unique in comparison to the commercially available forms of background noise that are currently used for research purposes. In comparison to the commercially available background noise recordings, the overall loudness levels were greater with the elementary school based background noise produced in this project. Also, the frequency range of loudness is greater for the elementary school based background noise produced in this project in comparison to the commercially available recordings. These commercially available background noise recordings such as cafeteria noise and speech babble only take into account the use of adult speech and environmental sounds. The elementary school based background noise produced in this project more adequately replicates the noises found in elementary and middle school settings because speech of the children and sounds that accompany children in the school settings were recorded and used.

Given the uniqueness of noise in elementary schools, using this produced elementary school based background noise as a published noise for research purposes may elicit a different reaction from children than when using the commercially available background noise recordings that are currently available. The focus of future studies in this area of concern should be to determine if the spectral differences are sufficient to produce measurable changes in listener performance in specific and controlled experiments. However, significantly different masking effects can be observed in spectrally similar background noises if the source of the masking is central and informational in nature. Furthermore, it would seem likely that informational masking effects would be greater in children than adults.

APPENDIX A

SUBJECTS CONSENT FORM

Date

Name of Principal
Principal
Name of School
Address of School
City, LA Zip

Dear Name of Principal:

I am writing you to request your permission to record noise samples for a research project that focuses on elementary school noise levels. The way that I would like to do this is to simply record segments of noise that occur in the halls when class is in session, outside of the cafeteria, inside the building when children are outside for recess, etc. The study does not require the evaluation of your students or teachers and therefore will not interfere with any portion of their school day, or the daily activities that occur on campus. I am only asking to record the noise levels that are present when a normal school day is in session.

The title of this project is "Development of an Elementary School Background Noise." One purpose of this study is to collect data on the noises that occur in a school as part of normal activity, and the loudness of those noises. Another purpose is to determine if there is a need for the development of an elementary school background noise for research purposes when simulating noises associated with elementary schools. Our contention is that the current commercially available background noises that are used in research may not accurately represent the sound spectrum that may be found in elementary schools. Much research has been conducted that addresses the negative impacts of excessive noise in academic settings, as well architectural modifications that can be employed to reduce or eliminate these noises. However, it is sometimes unclear what the actual "noise" consisted of. Therefore, our goal is to record noise samples and levels that are found in elementary schools and compare them to commercially available types of background noise that are used in research experiments that evaluate the effect of noise on learning, attention, etc.

Routine sound recording equipment will be used to capture the noise samples, and no known risks are involved with any of the procedures that will be used. No testing or interaction with your students or teachers is needed.

Please sign below whether this request is approved or not approved. If you have any questions regarding this study, please do not hesitate to contact me at (318) 257-2066 or by email at mailto:smadix@latech.edu.

______ I approve this request, and noise measurements may be recorded from Any Elementary School Campus.

______ I do not approve this request, and noise measurements may not be recorded from Any Elementary School Campus.

________________________________________
Signature of Individual Determining Approval for Request

________________________________________ ____________
Title of Individual Determining Approval for Request Date

Thank you for your consideration of this matter,

Steven G, Madix, Ph. D., CCC-A/SLP
Assistant Professor
Louisiana Tech University
PO Box 3165
Ruston, LA 71272

Amanda L. McCann, B.A.
Graduate Student
Louisiana Tech University
alm075@latech.edu

# APPENDIX B

# FREQUENCY ANALYSIS IN CHART FORM

Table 2: Frequency Analysis

| Recording | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 3000 Hz |
|---|---|---|---|---|---|---|
| A 1- Hallway | | | | | | |
| A 2- Hallway | | | | | | |
| A 3- Occupied Classroom | | | | | | |
| B 1- Hallway | | | | | | |
| B 2- Unoccupied Classroom | | | | | | |
| B 3- Hallway | | | | | | |
| C 1- Hallway | | | | | | |
| C 2- Unoccupied Classroom | | | | | | |
| C 3- Gymnasium | | | | | | |
| C 4- Outside Gymnasium | | | | | | |
| C 5- Occupied Classroom | | | | | | |
| D 1- Unoccupied Classroom | | | | | | |
| D 2- Outside Gymnasium | | | | | | |
| D 3- Hallway | | | | | | |
| D 4- Occupied Classroom | | | | | | |
| E 1- Outside Play Area | | | | | | |
| E 2- Hallway | | | | | | |

| Recording | 4000 Hz | 6000 Hz | 8000 Hz | 10000 Hz | 12000 Hz |
|---|---|---|---|---|---|
| A 1- Hallway | | | | | |
| A 2- Hallway | | | | | |
| A 3- Occupied Classroom | | | | | |
| B 1- Hallway | | | | | |
| B 2- Unoccupied Classroom | | | | | |
| B 3- Hallway | | | | | |
| C 1- Hallway | | | | | |
| C 2- Unoccupied Classroom | | | | | |
| C 3- Gymnasium | | | | | |
| C 4- Outside Gymnasium | | | | | |
| C 5- Occupied Classroom | | | | | |
| D 1- Unoccupied Classroom | | | | | |
| D 2- Outside Gymnasium | | | | | |
| D 3- Hallway | | | | | |
| D 4- Occupied Classroom | | | | | |
| E 1- Outside Play Area | | | | | |
| E 2- Hallway | | | | | |

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