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Assistive Listening Devices in Primary and Secondary Educational Settings: A Systematic Review

Paige Wagner-Skinner
wagnerpa@mnstate.edu

Assistive Listening Devices in Primary and Secondary Educational Settings: A Systematic Review

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Paige Wagner-Skinner

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Thesis Abstract

The purpose of this study was to identify the scientific evidence available to support the use of assistive listening devices in primary and secondary educational settings. The American Speech-Language-Hearing Association (ASHA) makes it clear that it is the role of the speech-language pathologist (SLP) to modify the classroom environment, as needed, to enhance communicative abilities for this population (ASHA, 2016; Carney, 1998). Each journal article included in this study was published in a peer reviewed journal between the years of 2000 and 2018, written in the English language, and comprised of scientific information relevant to the research question proposed. Experimental studies included participants who were school aged children in a primary or secondary educational location. Results indicated that frequency modulation systems are a highly explored and supported mode of sound transmission, while scientific evidence exploring a variety of modes of configuration remains less conclusive.

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Chapter 1

Introduction

The ability to hear impacts the development of speech and language, which significantly influences the development of communication skills in children and adolescents (Niskar, Kieszak, Holmes, Esteban, Rubin, & Brody, 1998). Nearly 15 out of every 100 children in the United States are diagnosed with hearing loss (Niskar et al., 1998). Communication skills supplement the acquisition of close relationships, and strongly influence educational success (Niskar et al., 1998). If individuals with a hearing impairment do not receive proper intervention in the primary and secondary educational settings, they may lack the foundational communicative functions necessary for a successful adulthood and high quality of life (Brackett, 1997).

There are many intervention approaches suitable for individuals with hearing loss; however, the focus of this study will be on assistive listening devices (ALDs). ALDs are a subcategory of a broader term known as hearing assistive technology systems (HATS) that may be used with or without hearing aids or cochlear implants to enhance communication in specific listening environments or situations (American Speech-Language-Hearing Association, 2016). Consequently, the implementation of personal, single speaker, or sound-field ALDs can be beneficial to children and adolescents in primary and secondary educational settings.

Statement of the Problem

Mainstream educational settings remain a suitable choice for most children with a hearing impairment due to the exceptionally stimulating and verbal environment, combined with consistent opportunities for multimodal communication (Brackett, 1997). In the primary and secondary educational setting, it is the role of the regular education, special education, and support service professionals (i.e., audiologist, speech-language pathologist, and teacher of the deaf and hard of hearing) to provide appropriate and effective intervention strategies for individuals with hearing loss (Brackett, 1997). Researchers have confirmed that individuals with hearing loss are benefited by intervention provided by speech-language pathologists, and the American Speech-Language-Hearing Association (ASHA) makes it clear that it is the role of the speech-language pathologist (SLP) to modify the environment to enhance communicative abilities for this population (ASHA, 2016; Carney, 1998). It is important for SLPs to know their role in the intervention process, understand the options for implementing intervention techniques, and have a point of reference throughout the process. However, systematically organized information regarding the level of evidence to support each type of hearing assistive technology systems (HATS) is not readily available within the literature, and assistive technology for the classroom is not always an area of expertise for SLPs.

Purpose of the Study

The purpose of this study was to systematically review the available literature on ALDs. It is designed to serve as an evidence-based resource for SLPs when implementing communication options for individuals with hearing loss in primary and secondary educational settings.

Research Question

What scientific evidence is available to support the use of assistive listening devices in primary and secondary educational settings?

Chapter 2

Review of the Literature

As the literature is explored for evidence relevant to HATS, clarification of terms can be useful. In addition to understanding the definitions of terminologies used, it can be helpful to understand how some are relevant to the research question proposed. Terms used within the literature that are related to students with hearing loss in primary and secondary educational settings were defined and further expanded in this chapter.

Hearing

Hearing is the process by which the outer, middle, and inner ear work together to convert acoustic energy into electrochemical energy (Seiker, King, & Drumright, 2010).

Outer ear. The outer ear is composed of the pinna, external auditory meatus, and ear canal (Hendry, Farley, & McLafferty, 2012). The pinna forms the outermost portion of the ear that surrounds the small opening into the temporal region of the head. They assist with sound localization and are commonly referenced by terms such as the ear lobe, cartilage, helix, and tragus. The external auditory meatus (i.e., ear canal) is a narrow opening that extends about 2.5 cm, beginning at the outermost portion of the ear, towards the middle ear, and ending at the point of the tympanic membrane (i.e., ear drum) (Seiker et al., 2010). The external auditory canal carries acoustic energy towards the tympanic membrane, which is a thin membranous tissue that separates the outer ear from the middle ear.

Middle ear. The middle ear is a hollow cavity that houses the tympanic membrane, eustachian tube, and ossicles (Hendry et al., 2012). As the sound waves reach the end of the external auditory canal, contact is made with the outermost layer of the tympanic membrane and a vibration begins (Hendry et al., 2012). This vibration causes movement of the ossicles (i.e., small bones) called the malleus, incus, and stapes (Seiker et al., 2010). The malleus comes first, sitting closest to the tympanic membrane (Seiker et al., 2010). The incus is second and acts as a channel between the malleus and the stapes (Hendry et al., 2012). Last, the stapes sits closest to the inner ear and against the oval window (Seiker et al., 2010). The initial vibration of the tympanic membrane causes movement of the malleus which creates a sort of chain reaction as each ossicle moves to create a hammer-like motion against the oval window of the inner ear. Additionally, the hollow nature of the middle ear requires a pressure equalizer known as the eustachian tube (Hendry et al., 2012). The eustachian tube is a narrow opening extending from the middle ear into the back of the nasopharynx that allows for fluid drainage and pressure equalization (Hendry et al., 2012).

Inner ear. The inner ear is composed of the vestibule, semicircular canals, and cochlea (Hendry et al., 2012). It is so small that it could fit on the eraser of a pencil and houses barely enough fluid to be seen by the human eye (Seiker et al., 2010). It is what converts acoustic energy to electrochemical energy and allows us to maintain our balance (Seiker et al., 2010). The stapes pounds against the outermost region of the inner ear and into the cochlea (Seiker et al., 2010). This mechanical force displaces hair cells within the cochlea which sends an electrochemical energy via the vestibulocochlear nerve to the brain to be interpreted as sound (Seiker et al., 2010).

Hearing Loss

Hearing loss is described by the assessment of three factors: type of hearing loss, degree of hearing loss, and configuration of hearing loss (ASHA, 2015b). It is diagnosed by an audiologist through a hearing test. An audiogram is a graph that displays the results of the hearing test (ASHA, 2015b). It displays the frequency (i.e., pitch) of the sound in Hertz (Hz) and the loudness (i.e., intensity) of the sound in decibels (dB) (ASHA, 2015b). A recent study conducted by Lin, Niparko, and Ferrucci (2011) released the first national estimates of hearing loss prevalence in the United States and estimated that 1 in 5 Americans have hearing loss.

Type of hearing loss. The three types of hearing loss commonly referred to by ASHA include conductive, sensorineural, and mixed. Hearing loss that is caused by complications of the outer or middle ear is defined as conductive, while hearing loss caused by complications within the inner ear is defined as sensorineural (ASHA, 2015b). A combination of these two types is defined as a mixed hearing loss. Per a study conducted by Dumanch, Holte, O'Hollearn, Walker, Clark, and Oleson (2017) that explored the risk factors associated with hearing loss in young children, the risk factors that most significantly influenced the likelihood of a child having congenital hearing loss included a wide variety of neurodegenerative disorders, syndromes, and congenital infections. Other causes of hearing loss might include, but are not limited to low birth weight, rubella, herpes, craniofacial anomalies, Hunter Syndrome, meningitis, and head injuries (Dumanch et al., 2017).

Degree of hearing loss. The following adjective descriptors are used to classify degree of hearing loss for children: normal, slight, mild, moderate, moderate-severe, severe, profound (Clark, 1981). They are classified by the level of hearing loss (i.e., threshold level) which is measured in units of decibels (see Table 1) (ASHA, 2015b).

Table 1

Degrees of Hearing Loss with Corresponding Threshold Level

Degree of Hearing Loss	Threshold Level
Normal	-10-15 dB HL
Slight	16-25 dB HL
Mild	26-40 dB HL
Moderate	41-55 dB HL
Moderate-Severe	56-70 dB HL
Severe	71-90 dB HL
Profound	91+ dB HL

Note. Adapted from Clark, J. G. (1981). Uses and abuses of hearing loss classification. ASHA, 23, 493–500.

Configuration of hearing loss. The configuration of hearing loss represents the pattern of hearing loss across the presented frequencies (ASHA, 2015b). For example, a hearing loss that only affected one ear would be configured as a unilateral (versus bilateral) hearing loss. Descriptors associated with these configurations include: (a) unilateral versus bilateral, (b) symmetrical versus asymmetrical, (c) progressive versus sudden, and (d) fluctuating versus stable.

Unilateral versus bilateral. Unilateral hearing loss refers to hearing loss in one ear, while a bilateral hearing loss refers to hearing loss in both ears. Per ASHA (2015b), 1 out of every 10,000 children is diagnosed with unilateral hearing loss while 3% of school age children have this diagnosis. The etiology of unilateral and bilateral hearing losses varies per person, and can be either congenital or acquired. Some examples of causes of unilateral hearing loss include genetics, physical malformations, Down or Usher syndrome, infections such as rubella, over exposure to loud noise, or a traumatic brain injury (ASHA, 2015b). Bowers (2017) mentioned that some cases of unilateral hearing loss may be idiopathic, meaning there is no identified etiology. In Lin et al.'s (2011) study of hearing loss prevalence in America, it was stated that 12.7% of Americans 12 years of age and older have bilateral hearing loss, which increased to 20.3% when including those with unilateral hearing loss.

Symmetrical versus asymmetrical. Hearing loss that is symmetrical is the same in both ear, meaning the degree of hearing loss and configuration of hearing loss is identical to that of the opposite ear. Asymmetrical hearing loss presents differently in one ear than in the other (ASHA, 2015b). Asymmetrical hearing loss is least common, accounting for an estimated 2.4% to 22.6% of cases, while symmetrical hearing loss is the most common (Masterson, Howard, Zi, Phillips, & Liu, 2016). Shin-ichi et al. (2017) concluded in their cohort study that the most common etiology for asymmetrical hearing loss in children was cochlear nerve damage. Additional etiologies included infections such as mumps and cytomegalovirus, and malformations of the structures of a single ear.

Progressive versus sudden. Progressive hearing loss slowly develops over an extended period, while sudden hearing loss presents itself abruptly and does not worsen over time (ASHA, 2015b). It is estimated that between five and thirty people per one-hundred thousand individuals are diagnosed with sudden hearing loss (Nosrati-Zarenoe et al., 2007). According to a review of the diagnosis, treatment and prognosis of sudden hearing loss conducted by Kuhn, Heman-Ackah, Shaikh, and Roehm (2011), it can be caused by one of the following broad categories:

infectious, autoimmune, traumatic, vascular, neoplastic, metabolic, or neurologic. However, for most people diagnosed with sudden onset hearing loss, the etiology is idiopathic (Kuhn, et al., 2011).

Fluctuating versus stable. Hearing loss that progresses and improves over time is defined as fluctuating, while hearing loss that does not change with time is defined as stable (ASHA, 2015b).

Hearing Loss in the Schools

On average, 2-3 out of 1,000 infants are born with hearing loss (CDC, 2010). Additionally, 20% of individuals 12 years of age and older have a hearing loss (Lin et al., 2011). Many children with hearing loss participate in mainstream education (Tye-Murray, 2009). Attending the mainstream classroom refers to learning in a classroom together with other children who have normal hearing (Tye-Murray, 2009).

The ability to hear impacts the development of speech and language, which significantly influences the development of communication skills in children and adolescents (Niskar et al., 1998). Communication skills supplement the acquisition of close relationships, and strongly influence educational success (Niskar et al., 1998). If individuals with a hearing impairment do not receive proper intervention in the primary and secondary educational settings, they may lack the foundational communicative functions necessary for a successful adulthood and high quality of life (Brackett, 1997). HATS can facilitate the normal development of these communicative functions and ensure success for children in primary and secondary educational settings.

Hearing Assistive Technology

As previously outlined, hearing assistive technology devices aid in the communication with others (ASHA, 2015a). It is an umbrella term that includes assistive listening devices, telephone devices, and alerting devices. Assistive listening devices help to improve communication with others by making it easier to hear (ASHA, 2015a). Variables to consider when implementing an ALD include the classroom noise level, reverberation tendencies, average distance between the speaker and user, and appropriate modes of transmission and configuration (Brackett, 1997). The configuration of an ALD refers to the way in which the device is set up (i.e., personal amplification, single speaker, or sound-field) while the transmission of an ALD refers to the way in which the sound in transmitted to the user (i.e., frequency modulation system, infrared, or induction loop), (ASHA, 2015a). Frequency modulation (FM) systems are the most popular type of HATS used in the classroom settings (Crandell & Smaldino, 1999). This type of HATS uses a microphone to pick up the speaker's voice and convert the acoustic signal to an electrical signal, which is then transmitted to the amplification system via FM signal and is presented to the listener in an amplified manner (Crandell & Smaldino, 1999). FM systems can transmit signals to a personal speaker located on a student's desk (i.e., personal amplification), a single speaker placed strategically in a classroom, or a sound-field system with multiple amplification systems placed strategically throughout the classroom (Crandell & Smaldino, 1999). In the same way as an FM system, infrared systems use a microphone to pick up the speaker's voice and convert the acoustic signal to an electrical signal; however, it is then at this point transmitted to the speaker via light wave and is presented to the listener in an amplified manner (Crandell & Smaldino, 1999). Lastly, an induction loop system uses a wire loop which is placed around the classroom and creates a magnetic field when electrical current flows through it (Crandell & Smaldino, 1999). This is referred to as telecoil technology and requires the listener to have some type of compatible device such as a hearing aid to increase amplification (Crandell & Smaldino, 1999).

Scope of Practice for team members

Members of a collaborative team when working with students with hearing loss must include a speech-language pathologist, audiologist, and general education teacher, especially when working to maximize the effectiveness of assistive technology (Thibodeau & Johnson, 2005). Additional members of the collaborative team could include a psychologist, interpreter, and/or itinerant teacher (Tye-Murray, 2009).

Speech-language pathologist. By law and scope of practice, a speech-language pathologist may play a role in the aural rehabilitation assessment and intervention process (ASHA, 2004a). The SLP can make recommendations for intervention to appropriate professionals, evaluate the intervention methods for effectiveness, and make referrals to other professionals when necessary (ASHA, 2004a).

SLPs provide services necessary to improve communication of clients, including those with hearing loss (ASHA, 2004a). SLPs can offer necessary accommodations and supports to enhance the facilitation of successful communication by altering appropriate variables to reduce barriers and providing information and offer guidance to all relevant personnel and team members (ASHA, 2004a).

Audiologist. Audiologists direct the prevention, identification, assessment, and treatment of hearing loss (ASHA, 2004c). They are responsible for the fitting and dispensing of all hearing assistive technology devices, including the measurement of noise levels and selection of devices to be installed. Audiologists play a significant role in advocating for the communication needs of their clients (ASHA, 2004c). They should collaborate with and provide training to other professionals as needed (ASHA, 2004c).

General Education Teacher. The general education teacher plays a significant role in the assessment, diagnosis, and evaluation process of an individual with hearing loss (Tye-Murray, 2009). The job of the general education teacher is to provide access to the curriculum, and doing so requires close collaboration with all members of the interdisciplinary team (Tye-Murray, 2009). Per ASHA (2004b), teachers provide education to children in schools that serve children who are deaf and hard of hearing in self-contained classrooms, resource rooms, and general education classrooms, in addition to itinerant, home, and community-based settings. The general education teacher is involved in modifying the physical learning environment of the classroom, if needed, in addition to helping with any behavioral management or social skill intervention (Tye-Murray, 2009).

Psychologist. The role of the psychologist is to perform a psychoeducational assessment (Tye-Murray, 2009). The purpose of this assessment is to evaluate the intelligence of the individual with hearing loss, in addition to measuring additional school related strengths and areas of weakness (Tye-Murray, 2009). Behavioral and emotional concerns are also addressed in conjunction with the psychologist (Tye-Murray, 2009).

Interpreter. The interpreter presents the ongoing discourse within the classroom to the student using the student's preferred mode of communication. It is most common to involve an interpreter as a part of the interdisciplinary team when the student utilizes a mode of communication, such as sign language, that the teacher does not (Tye-Murray, 2009).

Itinerant Teacher. The final member of the interdisciplinary team could include an itinerant, or resource teacher. The role of the itinerant teacher is to provide support to the general education teacher by providing one-on-one services to the student to reinforce the classroom rules and curriculum. Additionally, the itinerant teacher may provide speechreading or sign language training to the student (Tye-Murray, 2009).

Historical Review of HATS

HATS were heavily studied in the mid to late 1900's, specifically frequency modulation systems. The earliest of studies identified addressed the efficacy of hearing aids, followed by studies that outlined the definition of various types of HATS, as described below. It was not until the late 1900's that studies appeared to address the efficacy of HATS, and even still the data was limited. Articles were organized chronologically by year, and further by level of evidence based on ASHA's adaptation of the Scottish Intercollegiate Guidelines Network (2015) (see Table 2).

Table 2

ASHA's adaptation of the Scottish Intercollegiate Guidelines Network

Level	Description
Ia	Well-designed meta-analysis of >1 randomized controlled trial; systematic review
Ib	Well-designed randomized controlled study
IIa	Well-designed controlled study without randomization
IIb	Well-designed quasi-experimental study
III	Well-designed non-experimental studies, (i.e., correlational and case studies)
IV	Respected authority report, consensus conference, clinical experience of respected authorities

Sung, Sung, Hodgson, and Angelelli (1976) conducted a level IIb well-designed quasi experimental study that measured the intelligibility of speech via frequency modulation systems versus induction loop systems. Participants included 36 individuals with normal hearing who had a mean age of 24.2 years. No participants were school aged, but results were determined to be relevant based on methodology. The participants were presented a recording of monosyllabic words that were degraded by the presentation of background noise, while their ability to discriminate between the words was measured. When using the frequency modulation system, participants earned a mean score of 54.8% which decreased to 48.1% when using the induction loop system. The researchers stated that the results indicated that the use of frequency modulation systems provided greater benefit to the user than induction loop systems (Sung et al., 1976).

In a different study, Sung, Sung, Hodgson, and Angelelli (1976b) conducted a well-designed controlled study without randomization to measure the performance of hearing aids when used with an induction loop amplification system, in both the classroom and laboratory.

Included in the study were 10 hearing-aids selected from the inventory in the Audiology Clinic of Mercy Hospital. No live subjects participated in this study, and a computerized system was used to measure sound instead. A frequency response was collected for each hearing aid in the lab without the use of the induction loop, and then with the induction loop system. Next, the same measurements were collected in the classroom setting. When the induction loop was not used, the mean frequency range in the laboratory was 250-3,555 Hz, which improved to 264-3,675 Hz. When the induction loop was used in the laboratory, the mean frequency range was 155-3,360 Hz, which decreased to 199-2,720 Hz in the classroom. Sung et al. noted that a significant outcome of this study was the distinguished decrease in frequency range when the induction loop was used in the classroom. The researchers stated that it was due to a notch found in the induction loop, and mentioned that many other reports of defective induction loops had been made. The researchers made it clear that induction loop systems, when used, needed to be checked regularly by the teachers to detect malfunction (Sung et al., 1976b).

Logan and Bess (1985) authored a level IV respected authority report that described important components of amplification for individuals with hearing loss in the primary and secondary educational settings. Logan and Bess stated that most individuals with hearing loss participated in a mainstream classroom, making them more prone to acoustically poor learning environments. The authors explained that high noise and reverberation levels in the classroom were detrimental to speech recognition abilities of the listeners. Like other studies, the researchers outlined the technicalities of HATS (i.e., personal frequency modulation, sound-field frequency modulation, and, infrared). In addition, they stated that classroom amplification was common in the classroom setting, although very few studies examining their effectiveness were conducted (Logan & Bess, 1985).

Maxon, Brackett, and Van den Berg (1991) conducted a level III well-designed non-experimental long-term study that collected data on the national use of frequency modulation systems. The researchers stated that their goals were to identify procedures used to select frequency modulation systems in the school, collect data on the attitude of special education teachers regarding the use of frequency modulated amplification, describe how the use of the device affected individuals with hearing loss, and explore any changes in the previous goals over time (Maxon et al., 1991). A questionnaire was completed by 165 participants across 15 different states in 1981 (e.g., Sample 1), and again in 1988 by 136 participants (e.g., Sample 2). All participants were working with, or had worked with school-aged children who were hearing-impaired and used frequency modulation systems. All participants were reached via polling directors who provided contact information for speech, language, and hearing service providers in the United States. Results from the first questionnaire administered in 1981 indicated that 37% of parents reported being involved in the decision-making process when selecting amplification, while results from 1988 indicated similar results (e.g., 39%). The researchers noted the importance of parent involvement throughout the selection process to facilitate buy in and promote support for the student. Results also indicated that a trial period prior to the selection of classroom amplification did not occur for 30% of respondents in Sample 1 and 51% in the Sample 2. In both Sample 1 and Sample 2, 93% of respondents agreed that the use of classroom amplification was good to use with students with severe hearing loss. In sample 1, 87% agreed that is was good to use with students who had moderate hearing loss, while 88% in sample 2 agreed the same. These numbers decreased to 50% and 77%, respectively, for children with mild hearing loss. Few respondents believed that elementary students would refuse to use classroom amplification, but 68% and 72% felt that high schoolers would be likely to refuse. The same trend was noted with the belief that social problems would arise. Few believed that classroom amplification would create social problems in elementary school, 62% and 51% agreed that it would cause social problems in junior high school, and 60% and 55% agreed that it would cause social problems in high school. Additionally, researchers discovered that 81% of respondents used their frequency modulation system full-time at the time of the 1981 survey, while only 73% used it full time at the time of the 1988 survey. This indicated that fewer students used their frequency modulation system full-time in 1988 than in 1981 (Maxon et al., 1991).

Leavitt (1991) authored a peer reviewed level IV respected authority report that addressed various assumptions that governed the use of sound-field amplification in the classroom setting. Leavitt stated that although certain modifications made to the classroom reduced overall reverberation, they were detrimental to the transmission of high-frequency sounds in the classroom. He stated that the distance between the speaker and the listener were still just as important in an acoustically ideal classroom as in a less ideal classroom. It was noted that the enhancement of auditory signals did not a guarantee adequate levels of support, and many students needed or preferred visual reinforcements in addition to the auditory stimuli. Additionally, Leavitt compared desirable qualities of various modes of transmission including induction loop, frequency modulation, and infrared systems. Leavitt noted 21 desirable qualities of classroom amplification. Some examples of desirable qualities included the following: accessible, inexpensive, durable, free of sanitary problems, high quality perceived by users, functioned over long distance, easy to repair, and easy to install. He labeled each mode of transmission with either a yes or no regarding the presence of each desirable quality. Of the twenty-one listed desirable qualities, induction loop systems had thirteen, frequency modulation systems had nine, and infrared systems had four (Leavitt, 1991).

Allen (1994) conducted a level III well-designed non-experimental study that surveyed teachers and students to collect feedback on the use of classroom sound-field systems. The students were in grades 1-6 and all attended a general education classroom in Dubuque Public Schools. No further information was provided regarding hearing abilities of participants so it was inferred they were students with normal hearing. While the study did not focus on students with hearing loss, it provided valuable information on the use of sound-field amplification in the classroom. Allen stated that many professionals and parents questioned the benefits of sound-field amplification systems in the classroom, so to eliminate uncertainty, she administered a survey to 15 teachers and 334 elementary students throughout eight classrooms that used sound-field amplification. The 15 teachers were asked to respond to 15 questions on a Likert Scale, with 1 indicating that they strongly agreed and 6 indicating that they strongly disagreed. All teachers agreed that the use of a sound-field amplification system improved their classroom environment and wanted it to remain in their rooms permanently. The teachers stated that they felt comfortable using the equipment and that it improved the participation of their students. The 334 students were asked if they either agreed or disagreed via eight questions on a different survey. Of the students who were administered the survey, 93% agreed that they liked when their teacher used the amplification system, 84% agreed that it made the voice of their teacher sound clearer, 95% agreed that it was easier to hear the teacher when she wore the microphone, 88% of the students agreed that they liked getting to use the microphone in class, and 33% of students reported that the speakers were too loud at times (Allen, 1994).

Berg, Blair, and Benson (1996) authored a peer reviewed level IV respected authority report respected authority report that explored the problems, impacts, and solutions of classroom acoustics. The researchers stated that excessive noise in the classroom setting masked the teacher's voice and made it difficult for the students to hear the teacher. They declared that this problem impacted speech-recognition for both children with normal hearing, and children who had hearing loss. For example, they stated that students with normal hearing scored an average of 30% to 80% on word recognition evaluations, while students with hearing loss scored an average of 15% to 60%. The researchers determined that the solution to improving speech-recognition abilities in the classroom was to utilize amplification in the classroom, including personal frequency modulation systems, loop systems, and infrared systems. The researchers mentioned the importance of carefully selecting a device for each student based on his/her needs, but did not specify what that process entailed (Berg et al., 1996).

McSporran, Butterworth, and Rowson (1997) conducted a level IIa well-designed controlled study without randomization that was designed to measure the listening and attending skills of targeted children in the classroom, both before and after installing a sound-field amplification system. The participants in this study were not previously diagnosed with hearing loss and were in the third grade. The researchers selected two classrooms, one from two different schools, for inclusion in the study based on classroom reverberation levels. Classroom A contained 35 children while classroom B contained 30 children, all between the ages of 7.3 and 8.2 years of age. The researchers used the Screening Instrument for Targeting Educational Risk (SIFTER) to select target students within each classroom. Following the administration of the SIFTER, researchers determined that 10 students in classroom A and 15 students in classroom B failed, thus putting them at risk for academic failure. These 25 students were included in the study, and administered the Children's Auditory Processing Performance Scale (CHAPPS), a test that examines the listening behaviors of children. The CHAPP was re-administered at the end of the trial period which resulted in scores that indicated an overall improvement for most total students; however, the level of improvement did not result in a statistically significant difference. The researchers stated that the use of sound-field amplification had the potential to improve overall listening behaviors of hearing students in the classroom but, like Logan and Bess (1985), further research was warranted to determine their efficacy (McSporran et al., 1997).

Nelson and Nelson, (1997) conducted a level III well-designed non-experimental study that measured the satisfaction of teachers' and students' use of sound-field amplification systems in the classroom setting. Participants included twenty-three classroom teachers who taught grades 2-6, and sixty-six students in four fifth- and sixth-grade classrooms. Each classroom had up to two children with a diagnosed slight to mild hearing loss. The remaining children were assumed to have normal hearing, but could have had undiagnosed hearing loss. The survey administered to the teachers was comprised of 13 questions, most of which were multiple-choice. Of the 23 teachers, 18 returned the completed survey. When asked to rate personal satisfaction of device use, 89% of the teachers rated it above 5 on a Likert Scale (i.e., 1 was the lowest rating while 10 was the highest), and 72% rated it to be an 8 or higher. Of the 18 teachers who responded to the survey, 94% stated that they would recommend the use of a sound-field system to their coworkers, and 83% stated that their satisfaction remained the same, or improved over time. The teachers identified the most notable benefits of the sound-field system to be that their students could hear each other better, the room acoustics appeared to be better, and the students listened to the teacher better (Nelson & Nelson, 1997). A group of 66 fifth- and sixth-grade students were asked to respond to a separate survey comprised of five multiple choice questions. Of the 66 students who completed the survey, 72% believed that using the sound-field system helped them hear their teacher better, 81% stated that it helped them understand their classmates, 58% found it helpful when they sat in the back of the classroom, 21% thought that it was helpful regardless of seat positioning, 82% enjoyed when their teacher used it, 14% were impartial, 78% wanted to keep the sound-field system, and 19% remained neutral. Overall, results from Nelson and Nelson's research indicated a strong acceptance of the use of sound-field amplification systems by both teachers and students in the classroom setting, which correlated with results from research conducted by Sapienza, Crandell, and Curtis (1999) that suggested that in addition to offering benefits to student users, sound-field amplification systems could provide benefits to teachers as well.

Flexer (1997) authored a peer reviewed level IV respected authority report that outlined personal and sound-field frequency modulation systems. The author described the technicalities of both configurations, and mentioned that at the time of the study desktop or single speaker systems were a new option. Flexer stated that the populations most in need of this technology were children with fluctuating conductive hearing loss caused by ear infections, wax buildup, or who had chronic otitis media; children with unilateral hearing loss; children with slight permanent hearing loss; children who had normal hearing but attended the special-education classroom; children who wore hearing-aids; children with normal hearing who had difficulty attending to the speaker, processing auditory stimuli, or problems staying focused; children who spoke English as a second language, and children with cochlear implants. He also mentioned that individuals with more severe levels of hearing loss or central processing disorders were a better fit for personal amplification options versus the sound-field choice (Flexer, 1997).

Boothroyd and Iglehart (1998) conducted a level IIb well-designed quasi-experimental study to quantify the effects of frequency modulation amplification for individuals with severe to profound hearing loss, to compare any differences between body-worn and behind-the-ear frequency modulation systems, and to measure the effects of reducing frequency modulation microphone sensitivity to hearing aid sensitivity. Participants included 13 teenaged students with a mean age of 15.7 years who had been diagnosed with sensorineural hearing loss. Etiologies of hearing loss were unknown for eight participants, meningitis for two, genetic for two, and ototoxicity for one. The remaining participant acquired a hearing loss diagnosis at 8.5 while the others had been born with or acquired their hearing loss prior to age 1. Phoneme recognition via lists of consonant-vowel-consonant words were measured per student under each of the conditions outlined above. The results indicated that excessive classroom noise interfered with phoneme recognition regardless of use of amplification, and vowels were recognized more easily than consonants (Boothroyd & Iglehart, 1998).

Arnold and Canning (1999) authored a level Ib well-designed randomized controlled study that measured the effect that classroom amplification had on comprehension. Participants included 49 school aged children with a mean age of 9.92 years old who were in the top two classes of a mainstreamed public school. Information on the hearing abilities of the participants was not provided by the authors so it was assumed the participants had normal hearing. The participants were randomly assigned to one of two groups. The researchers presented a passage from the Neale Analysis of Reading Ability: Revised British Edition. The passage included two corresponding versions of stories that increased from level 1 to level 6. The passages were presented in the following order: level 1 story presentation with no amplification, level 2 with amplification, level 3 with no amplification, level 1 with amplification, level 2 with no amplification, and level 3 with amplification. Half of the students completed Form 1 comprehension questionnaire during the first three levels while the other half completed form 2 questionnaires during the first three levels for counterbalancing purposes. Initial results indicated that there were no between-group differences, so the counterbalancing of the forms was effective. The mean scores of level 1 were 3.62 out of a possible 4 with sound-field amplification and 3.53 without, level 2 were 5.02 out of a possible 8 with sound-field amplification and 4.54 without, and level 3 were 2.6 out of a possible 8 with sound-field amplification and 1.77 without. The researchers stated that the overall negative trend in scores as levels increased was due to the increased difficulty of each level of comprehension questionnaires. Reading comprehension improved with use of the sound-field amplification system in the classroom, and the benefits became greater with increased complexity of questionnaires. The results indicated that the use of sound-field amplification in the classroom setting could improve the academic performance of the students. However, the improvement did not correlate with age, seating position, auditory memory results, or non-verbal intelligence scores from pretest results. A questionnaire completed by the students indicated that 54% of students perceived an improvement in their abilities when amplification was used, and 71% agreed that noise was a notable problem in their classroom (Arnold & Canning, 1999).

Crandell and Smaldino (1999) authored a peer reviewed level IV respected authority committee report that examined technological and rehabilitative resolutions for the improvement of the acoustics in the classroom. The researchers found that appropriate acoustical conditions were rarely achieved via classroom modification. Therefore, the use of technological solutions such as HATS were warranted. The researchers stated that personal frequency modulation systems were most commonly used for students with hearing loss, while sound-field frequency modulated systems were used as a supplement for children with normal hearing within the classroom. Like Logan and Bess (1985), the researchers outlined the technicalities of HATS (i.e., personal frequency modulation, sound-field frequency modulation, induction loop, infrared, and hard-wired systems) in the classroom, but like McSporran et al., (1997) stated that there was very limited empirical data regarding their effectiveness (Crandell & Smaldino, 1999).

Rationale for Additional Research in This Area

SLPs require readily available evidence-based information when implementing assistive listening devices in primary and secondary educational settings to apply evidence-based practice (EBP). Evidence-based practice is a technique that integrates scientific evidence, clinical expertise, and client/patient/caregiver values (ASHA, 2005). ASHA requires SLP's to implement EBP into treatment (ASHA, 2005). Specifically, ASHA states that SLPs must, "acquire and maintain the knowledge and skills that are necessary to provide high quality professional services, including knowledge and skills related to evidence-based practice" (2005, p. 6). This position statement released by ASHA made it clear that an SLP should understand the evidence supporting the implementation of ALDs in primary and secondary educational settings if he/she is going to promote their use. Search results did not identify a clear resource compiling more recent scientific evidence to support use of communication options for individuals with hearing loss in primary or secondary education settings. There was not a Practice Portal available by ASHA that addressed HATS, like there was for many other areas within the scope of practice of speech-language pathologists such as aphasia, voice disorders, selective mutism, spoken language disorders, autism spectrum disorder, and dementia. However, a preliminary search of the literature revealed there were recently published individual studies available on the use of ALDs in the classroom setting. For example, Anderson, Goldstein, Colodzin, and Iglehart (2005) conducted a level IIa well-designed controlled study without randomization to measure the perceived loudness, speech-recognition, and opinions of participants regarding ALDs. Odelius and Johansson (2010) conducted a level III well-designed non-experimental study that analyzed preferences regarding ALDs in the classroom, and Alterovitz (2004) conducted a Level IIb well-designed quasi experimental study that analyzed the engineering of induction loop systems. It would be beneficial to have a compilation of data from multiple studies relevant to the use of ALDs in the classroom. Therefore, additional research appears warranted to provide an accessible resource to professionals working with this population so they may evaluate current scientific evidence during application of evidence-based practice principles.

Chapter 3

Methodology

A systematic review is a research design used to critically evaluate the literature on a specific topic (Pan, 2004). It is an original document that coherently synthesizes all available literature that have met the inclusion criteria (Pan, 2004). Approval was not required from the Minnesota State University Institutional Review Board due to the nonexperimental nature of this design.

Purpose of the Study

The purpose of this study was to systematically review the available literature on ALDs. It was designed to serve as a resource for SLPs when implementing communication options for individuals with hearing loss in primary and secondary educational settings.

Systematic Review of Scientific Evidence to Support the Use of Assistive Listening Devices

Search strategy. Databases including, PUBMed, ComDisDome, ERIC, and EBSCO Academic Search Complete were used to access journal articles in a systematized manner. The following search terms were used to access the journal articles: assistive listening devices; hearing assistive technology; and hearing loss combined with specific intervention terms: (a) frequency modulation systems, (b) infrared systems (c) induction loops systems. A thesaurus provided by each database was used to determine relevant search terms (i.e., hearing loss versus hearing impaired).

Inclusion Criterion. Once the journal articles were located, they were screened for selection criteria to determine eligibility for inclusion in the study. Each journal article was published in a peer reviewed journal between the years of 2000 and 2018, written in the English language, and comprised of scientific information relevant to the research question proposed.

Primary preference was given to relevant articles of higher evidence, as identified by ASHA's adaptation of the Scottish Intercollegiate Guidelines Network (SIGN) hierarchy. Attempts were made to include a minimum of five studies per subcategory (i.e., frequency modulation, infrared, or induction loop, personal, single speaker, and sound-field) identified on the results table; however, ten to fifteen studies per subcategory would have been optimal for synthesis.

The initial search resulted in few journal articles that met criteria. When searching ComDisDome database, combined search terms resulted in fourteen peer reviewed articles that met search criteria based on date of publication and language. Of those fourteen articles, one article was judged to be relevant to the research question. When combined search terms were not utilized, twenty-six additional peer reviewed articles that met search criteria based on date of publication and language were located. Of those twenty-six articles, no articles were judged to be relevant to the research question. When searching PubMed database, combined search terms resulted in six peer reviewed articles that met search criteria based on date of publication and language. Of those six articles, no articles were judged to be relevant to the research question. ERIC and EBSCO Academic Search Complete were searched simultaneously through a comprehensive search engine provided by Minnesota State University Moorhead and powered by EBSCO*host*. This search engine utilized databases including but not limited to ERIC, EBSCO, Health Source, CINAHL, and ScienceDirect. Combined search terms within this comprehensive database resulted in two hundred and fifty peer reviewed articles that met search criteria based on date of publication and language. Of those two hundred and fifty articles, nine articles were judged to be relevant to the research question. A rigorous study by conducted Lewis (2008) that thoroughly reviewed the literature was included, despite not being peer-reviewed since few studies were located overall. When additional attempts to locate relevant articles were made using a combination of relevant search terms combined with defined search criteria, an additional five articles were located. During this process, the author worked with a research librarian to locate additional articles; however, the search resulted in only two new sources since many were either duplicates or not relevant to the research question. Further attempts were made to locate additional sources by carefully reviewing reference lists from articles that met inclusion criteria. This resulted in locating many relevant articles that did not meet inclusion criteria based on year of publication which were included in the historical review of the literature in chapter two after consultation with chair member and audiologist on the committee.

Parameters to be synthesized. Following the screening, the articles deemed eligible to be considered for the study were analyzed. The literature was systematically categorized and presented horizontally on a table based on its relevance to either (a) transmission, or (b) configuration. It was then further subcategorized based on the method of transmission (i.e., frequency modulation, infrared, or induction loop) or configuration (i.e., personal, single speaker, or sound-field).

Tab over Each article was systematically reviewed to determine the following: author; year; type of study design; level of evidence based on ASHA's adaptation of the Scottish Intercollegiate Guidelines Network (see Table); participants including the number of participants, gender, age, and control group; dependent variable if experimental/quasi-experimental; what was being measured if nonexperimental; and the outcome of the study. These results were displayed in Table 3 and expanded via narrative within the results.

Chapter 4

Results

Search Results

Levels of evidence. A total of fifteen peer reviewed journal articles met search criteria based on date of publication, language, and relevance to the proposed research question (see Table 3 for display of results in table format). Of those fifteen articles, none were identified as well-designed meta-analyses or systematic reviews (i.e., level Ia). There was one article identified as a well-designed randomized controlled study (i.e., level Ib), four articles identified as well-designed controlled studies without randomization (i.e., level IIa), three articles identified as well-designed quasi-experimental studies (i.e., level IIb), two identified as well-designed non-experimental studies (i.e., level III), and four respected authority reports (i.e., level IV). Levels of evidence were determined based on ASHA's adaptation of the SIGN hierarchy, as shown in Table 2. Multiple studies included more than one method of transmission and configuration, so those studies were cited in more than one portion of Table 3.

Summary of the Literature

All methods of transmission (i.e., frequency modulation, induction loop, and infrared) and configuration (i.e., sound-field, personal amplification, and single speaker) were explored within the compilation of research articles collected. However, sound-field systems was the most frequently studied method of configuration, while frequency modulation systems was the most frequently studied method of transmission.

Transmission.

Frequency modulation. Anderson, Goldstein, Colodzin, and Iglehart (2005) conducted a level IIa well-designed controlled study without randomization that included three experiments. Two single subject designs with alternating treatments, and one with randomized listening environments were used to compare the effects that listening environments had on speech-recognition abilities. Twenty-eight students between the ages of eight and fourteen years old who were experienced amplification users were included in the study. Students had hearing abilities ranging from normal to moderate-severe, and were identified as having normal intelligence and language, and had comprehensible speech. Anderson et al. measured the following: (a) perceived loudness, (b) the speech-recognition abilities of children using hearing aids or cochlear implants, and (c) the opinions of participants regarding ALDs for varying levels of hearing loss. Based on results of the study, the researchers supported the use of frequency modulation systems in primary and secondary educational settings because there was an increase in the dependent variables when paired with each mode of configuration. However, although the study included a control group, the mode of transmission was not an independent variable and therefore, the study did not compare it against any other types of transmission. The results supported the use of frequency modulation systems in classrooms with high levels of noise and reverberation (Anderson et al., 2005). Further expansion on research conducted by Anderson et al. (2005) will be discussed within each specific mode of configuration studied.

Anderson and Goldstein (2004) conducted a level IIa well-designed controlled study without randomization. They included single subjects with alternating treatments in their study, and compared the effects of three different types of amplification systems against the effectiveness of hearing aids alone. The study was conducted under typical classroom conditions and collected parent opinions regarding preferred amplification systems. Participants included eight children between nine and twelve years old (i.e., four boys and four girls), with mild to severe hearing loss. Participants were primarily auditory communicators and attended a large school. All participants had normal intelligence, no other identified disabilities, and spoke English as a primary language. The use of the following was compared: (a) a classroom infrared sound-field system with two speakers adjacent to the ceiling, (b) a personal sound-field system, and (c) a personal frequency modulation system. Dependent variables were as follows: (a) perceived loudness of sound, (b) word recognition performance, and (c) social validation. The results of the subjective loudness assessment indicated the classroom sound-field amplification system to be the second loudest option. Researchers stated that the results indicated there was no increase in word recognition abilities with the use of infrared sound-field amplification systems over the use of hearing aids in isolation. The sound-field and single speaker amplification systems provided more benefit than hearing aids used in isolation. However, the mode of transmission was not an independent variable in this study, and was therefore not compared against other modes of transmission (Anderson & Goldstein, 2004). Further expansion on this research conducted by Anderson and Goldstein will be discussed within each specific mode of configuration.

Iglehart (2004) conducted a level IIa well-designed controlled study without randomization to measure the speech perception abilities of students with cochlear implants in the classroom setting. The design was a two-factor within-subjects study that contained two levels of classroom acoustics, which were combined with no sound-field system, a wall-mounted frequency modulated sound-field system, and a frequency modulated desktop sound-field system. The study included ten males and four females, ages six to sixteen years of age with bilateral hearing loss ranging from severe to profound. All participants were enrolled in an auditory education program, utilized cochlear implants, retained normal language abilities, and could attend to auditory tasks for an extended amount of time. Results suggested that frequency modulation receivers helped to increase speech perception by reducing levels of reverberation and refining sound-to-noise ratios. However, like previous studies, the mode of transmission was not an independent variable in this study, and was therefore not compared against the other modes of transmission (Iglehart, 2004). Further expansion on this research conducted by Iglehart will be discussed within each specific mode of configuration.

Lewis (2008) authored a level IV respected authority report outlining the most frequently used options for classroom amplification: frequency modulation and sound-field. Lewis stated that microphones (i.e., transmitters) used with frequency modulations systems offered a much more significant comfortability factor when compared to older versions. This factor, combined with their small size, was believed to make the use of the transmitter more socially acceptable in the school setting. Additionally, Lewis outlined the idea of a handheld transmitter to be used as an available option for older students who may wish to personally control their transmitter. This option would allow each student to point it towards the sound source of choice. Many parents and children reported that they experienced benefits from the use of frequency modulation systems, but none selected them as a most preferred source of amplification. A notable advantage of frequency modulation systems was the ability to be easily paired with personal hearing instruments, or to have it built into a behind the ear hearing aid. In addition to reviewing the effectiveness of the commonly used classroom amplification choices, Lewis discussed the clinical practice guidelines for implementation. He compared the preferred practice patterns of the American Academy of Audiology (AAA) against ASHA, and found that they varied notably.

The newest guidelines provided by AAA addressed listening needs combined with regulatory considerations; personnel qualifications; equipment and space requirements; candidacy; and fitting, verification, implementation, and validation procedures. However, the guidelines provided by ASHA recommended a verification approach that focused strictly on sound output, which did not apply to more recent technology that was being evaluated by Lewis. He stated that when ASHA's guidelines were developed, they were concurrent; however, at the time of this review they had fallen behind the more recent advances in technology (Lewis, 2008).

McKay, Gravel, and Tharpe (2008) authored a level IV respected authority report that examined articles regarding considerations that guide the clinical decision-making process when selecting amplification options for children with minimal or mild bilateral, or unilateral hearing loss. Auditory considerations, hearing aid technology, hearing technology, nonconventional hearing technology, and other management considerations were explored in the literature and addressed in this study. Frequency modulation technology for children diagnosed with minimal or moderate bilateral and unilateral hearing loss was explored under hearing technology. The researchers stated that frequency modulation technology significantly improved the ability to perceive speech. Additionally, it was declared that for certain children diagnosed with minimal or moderate bilateral and unilateral hearing loss, frequency modulation technology may be the only option for an increased signal-to-noise ratio within the classroom setting (McKay et al., 2008).

Rosenberg (2005) authored a level IV respected authority report that reviewed all relevant research regarding the history of sound-field amplification efficacy and revealed the validity of listening enhancement technology. Rosenberg included over 40 studies on high interest topics such as sound-field amplification system options, literacy and academic achievement, speech-recognition abilities, attending skills, learning behaviors, and teacher responses. Rosenberg stated that overall, the studies included in the review demonstrated an increase in literacy development, academic achievements, speech-recognition abilities, attending skills, and learning behaviors of students in classrooms with sound-field amplification systems. As mentioned before, frequency modulation systems are the most common type of HATS used in the classrooms setting (Crandell & Smaldino, 1999). They use a microphone to pick up the speaker's voice and transmit it to an audio system for amplified presentation to the listener (Crandell & Smaldino, 1999). The researcher found that the use of sound-field systems transmitted via frequency modulation increased the speech-recognition abilities in children with normal hearing at an average of 45%, and children with hearing loss who were using a hearing aid at an average of 12% (Rosenberg, 2005). The author concluded that the use of sound-field systems was cost effective and has resulted in a reduction in special education referrals in school systems (Rosenberg, 2005).

Induction loop. Alterovitz (2004) conducted a level IIb well-designed quasi experimental study to analyze the engineering and nontechnical issues of using induction loop systems. An induction loop amplification system requires a speaker to talk into a microphone which then sends a signal to a long loop of wire. The wire receives the signal by inducing a magnetic current around the wire and transmits it to the listener. This type of technology has been utilized since the 1950s. Alterovitz measured the available level of sound input to the ear to analyze the engineering and nontechnical issues when using an induction loop system while two loops and amplifiers were taped to the floor of a gymnasium. Outputs were measured at various frequencies across three phases during the study. An individual loop was used in isolation during the first phase, while both loops were tested to examine any interference during the second phase. In the third and final phase, the loops were placed in opposite directions. The data led Alterovitz to results that indicated normal audibility to the listener when inside of a loop system, regardless of setup and positioning. Additionally, Alterovitz stated that the use of multiple smaller loop systems in a larger area was the most preferred option when compared to the alternative option of using one large loop system. The larger loop systems were noted as being less portable. The smaller loop systems were portable and composed of fewer parts than most comparable systems which made them ideal for a classroom setting and less likely to fail. Induction loop amplification systems were beneficial and convenient since they eliminated the need for a costly receiver attached to a hearing aid, if the hearing aid included a telephone coil. Some disadvantages to using multiple loop systems included the amplification of noise generated by fluorescent lights, and the effect that the orientation of the receiver had on the signals being picked up. In a classroom where students were moving around often, the orientation factor could be problematic (Alterovitz, 2004).

Odelius and Johansson (2010) conducted a level III well-designed non-experimental study that analyzed the use and preference of ALDs via self-assessments completed by twenty-five students. These participants used bilateral hearing aid amplification and were between ten and twenty years old. Audibility and awareness were measured using the Speech, Spatial and Qualities of Hearing Scale, in addition to a word recognition test. One participant stated that noises transmitted via induction loop systems sounded mechanical, while another stated that the sound was perceived as robot-like. Researchers stated the results indicated that the induction loop transmission option received the overall highest rating for speech-recognition and an overall lowest rating for spatial hearing abilities (Odelius & Johansson, 2010). Further expansion of research conducted by Odelius and Johansson will be discussed as a specific mode of configuration within the sound-field subheading.

Tao (2013) authored a level IV respected authority report which was published in a peer reviewed journal. Tao's report discussed the advantages and disadvantages of using induction loops versus digital wireless hearing aid accessories to improve hearing across multiple environments. Tao stated that specific benefits of using induction loops included an improvement in the signal to noise ratio, the absence of required pairing that is associated with many alternatives, and optimal use with telephones. Noted disadvantages of using induction loops were that telecoils are expensive to install, less portable than alternative options, and may distort music (Tao, 2013).

Yanz and Preves (2003) authored a level IV respected authority report that reviewed the process of coupling hearing aids with induction loop systems. They utilized past issues with induction loop systems such as electromagnetic noise, frequency response, positioning and orientation, and user dexterity limitations to address recent issues with approaching solutions, and to determine current concerns requiring a solution. Yanz and Preves stated that telecoil technology had the advantage of reduced acoustic feedback when compared to alternative options. However, the use of induction loop systems was also noted to have resulted in noise interference that was difficult to eliminate. The researchers alluded to the futuristic concept of using Bluetooth technology to pair students' devices to their amplification system, thus eliminating issues noted in the study (Yanz & Preves, 2003).

Infrared. In Lewis' (2008) level IV respected authority report that outlined the most commonly used options for classroom amplification, he stated that infrared technology had become popular in the school setting. Lewis said that this was true due to radio frequency and other types of interference, such as electromagnetic, decreasing the effectiveness of frequency modulation and induction loop systems in the classroom. When using infrared technology to transmit sounds, there was no possibility of the infrared light transmitting through walls, which eliminated the ability for signals to transfer between classrooms. However, the light wave necessary for the use of infrared technology could be interrupted by a physical obstruction if it prevented the light from connecting to the receiver. Another possible negative concern regarding the use of infrared light technology was the possibility of outside light interfering with the signal, which would make this a poor choice for sports or outdoor activities (Lewis, 2008). Further expansion of Lewis' results will be discussed within each specific mode of configuration.

As previously mentioned, Anderson and Goldstein (2004) compared the effects of three different types of amplification systems against the effectiveness of hearing aids alone for eight participants between nine and twelve years old with mild to severe hearing loss. The variable relevant to infrared technology as a mode of transmission included a classroom infrared sound-field system with two speakers adjacent to the ceiling. The dependent variables were as follows: (a) perceived loudness of sound, (b) word recognition performance, and (c) social validation. When word recognition performance was measured, the researchers found there to be no significant difference between the use of hearing aids alone versus the infrared sound-field system. However, like before, the study included a control group, but the mode of transmission was not a true independent variable and therefore was not compared against other modes of transmission (Anderson & Goldstein, 2004). Further expansion on research conducted by Anderson and Goldstein will be discussed within each specific mode of configuration.

Configuration.

Sound-field amplification system. Wilson, Marinac, Pitty, and Burrows (2011) conducted a level IIa well-designed controlled study without randomization to determine if sound-field amplification influenced the performance of students in a variety of classroom settings. Wilson et al. conducted a repeated measures study which included the use of pre- and post-assessments on each student. The study was controlled via matching of classrooms assessed based on use of a sound-field amplification system versus classrooms without a sound-field amplification system. The study included 147 children ages 7;9 to 8;7 years of age in their second trimester of third grade. Of the 147 participants, 52 had diagnoses ranging widely (e.g., fine motor complications or ADHD), and/or received support services from at least one healthcare or educational support professional such as an audiologist or speech-language pathologist. Specific data regarding hearing abilities of each participant was not noted. Participants involved in the studies were comprised of 77 males and 70 females. Dependent variables included the following: (a) literacy and listening, (b) regular word spelling, (c) sight word spelling, and (d) reading comprehension. The type of classrooms selected for use in this study were stated to be structurally typical of a standard classroom setting. Scores on listening tests were higher in the control classroom than in the test classroom, while scores on sight word spelling tests were higher in the test classroom than in the control classroom. Overall results indicated that the use of sound-field amplification systems in classrooms resulted in small but significant improvements in listening skills of children, but only in the classroom that was made of brick walls and had low background noise measures (Wilson et al., 2011).

As noted earlier, Anderson et al., (2005) conducted three experiments. Participants had hearing abilities ranging from normal to moderate-severe, and were identified as having normal intelligence, language, and comprehensible speech. Anderson et al. measured the following: (a) perceived loudness, (b) the speech-recognition abilities of children using hearing aids or cochlear implants, and (c) the opinions of participants regarding ALDs for varying levels of hearing loss. The first experiment utilized all data from Anderson and Goldstein's previous research. The researchers measured perceived loudness with a seven-point Likert Scale, with a value of one representing the quietest and seven representing the loudest perceived noise. The researchers noted that a response of four was considered to be the most comfortable. Participants judged the sound-field amplification system to be an average of 4.4 on the Likert Scale. This data suggested that sound-field amplification systems provided a comfortable level of amplification for students in the classroom. When measuring word recognition performance during the second experiment, participants scored an average of 87.3% when using only a hearing aid, which improved to only 88% with use of the sound-field amplification system. These results coincided with the results from Anderson and Goldstein's (2004) research. In the third and final experiment, participants scored an average of 78% for those using a hearing aid and 77.5% for those using a cochlear implant. Participants who used hearing aids scored an average of 76%, and cochlear implant users scored an average of 65% when using a sound-field amplification system (Anderson et al., 2005). The results of the third and final experiment indicated a decrease in word recognition ability when using a sound-field system, especially for individuals who utilized cochlear implants. Social validation perceptions were measured for the use of a sound-field system. One out of the twenty-eight participants selected sound-field amplification as the easiest to listen to, eight believed it to be most preferred by their teacher, seven felt that it was the most accepted option by their peers, two selected it as their most desired device, and fifteen chose it as their least desired option (Anderson et al., 2005).

As mentioned earlier, Anderson and Goldstein (2004) included single subjects with alternating treatments to compare the effects of three different types of amplification systems against the effectiveness of hearing aids alone under typical classroom conditions, and parent opinions regarding a preferred amplification system. The participants included eight children between nine and twelve years old (e.g., four boys and four girls) with mild to severe hearing loss who were primarily auditory communicators and attended a large school. All participants had normal intelligence, no other identified disabilities, and spoke English as a primary language. The variable relevant to sound-field technology as a mode of transmission included a personal sound-field system. The dependent variables were as follows: (a) perceived loudness of sound, (b) word recognition performance, and (c) social validation. The participants' results on the perceived loudness assessment rated sound-field amplification as being the second loudest selection. When word recognition performance was measured, the researchers found there to be no significant difference in the use of a sound-field system versus hearing aids in isolation. Participants scored an average of 82.4% when using hearing aids alone, which improved only to a level of 83.1% when using a sound-field amplification system. Social validation procedures led researchers to believe that sound-field systems were not a preferred choice by students for classroom use. One out of the six students rated sound-field amplification as being the easiest to listen to, two perceived it to be their teachers' most preferred option, one identified it as being most accepted by their peers, one rated it as a most preferred option for classroom use, and five students labeled it as an option that they did not want to use in class (Anderson & Goldstein, 2004).

As mentioned above, Iglehart (2004) measured the speech perception abilities of students with cochlear implants within the classroom setting. The design was a two-factor within-subjects study that contained two levels of classroom acoustics and combined each with various modes of configuration, including a wall-mounted frequency modulated sound-field system. The study included ten males and four females, ages six to sixteen years, with bilateral hearing loss ranging from severe to profound. All participants were enrolled in an auditory education program, utilized cochlear implants, retained normal language abilities, and could attend to auditory tasks for an extended amount of time. Mean phoneme and word recognition data were collected prior to utilizing a sound-field amplification system in both an acoustically poor and ideal classroom. The acoustically poor classroom had hard walls, ceilings and floors, while the acoustically ideal classroom had walls covered in acoustic fabric, fiberboard ceiling tiles, and a carpeted floor. In the acoustically poor classroom, participants scored a mean phoneme recognition score of 12.8% using no amplification system. This increased to 25.2% when using a sound-field amplification system. In the acoustically ideal classroom, participants' mean phoneme recognition score was 40.5% when using no form of amplification, which improved to 50.3% when using a sound-field amplification system. These results indicated that speech perception improved with the use of sound-field amplification regardless of classroom acoustics; however, a slightly greater increase in phoneme recognition was noted in the acoustically poor classroom (Iglehart, 2004).

Da Cruz et al. (2016) conducted a level Ib, well-designed randomized controlled study that evaluated the effectiveness of sound-field amplification systems in the classroom. This prospective study with participants divided into two groups, a control and an experimental group, evaluated the academic performance of the students. The teacher participated and assessed the students using standardized tests and questionnaires to evaluate the effectiveness of a dynamic sound-field system within the classroom. Both the experimental and nonexperimental groups included ten children with a mean age of eight years old. No children included in this study had a hearing impairment. All children attended the same private school, were in the third grade, and did not have a cognitive impairment. The various academic performance tests measured aptitudes related to reading, writing, arithmetic, and reading comprehension. However, both groups were close to reaching ceiling scores on all tests prior to the implementation of a sound-field amplification system. The experimental group performed significantly better for the academic performance tests when using the sound-field system. Overall, the researchers concluded that the use of sound-field amplification systems improved the sound-to-noise ratio and enhanced the overall attention of the students in the classroom. Statistically significant differences were noted between the two groups (Da Cruz et al., 2016).

Larsen and Blair (2008) conducted a level IIb well-designed quasi-experimental study that measured the signal-to-noise ratios in the classroom setting. Measurements were taken when class was in session and when student-teacher interaction was present. Measurements of noise and reverberation were collected and reported on for four classrooms while unoccupied, and then again while occupied. Classrooms included in this study were four fourth grade classrooms that were similar in size, met the American National Standards Institute requirements for reverberation, and had been built within the last ten years. The mean noise level in the classrooms when unoccupied was as follows: 34 dBA, 31 dBA, 35 dBA, and 31 dBA. The mean noise level in the classrooms when class was in session was as follows: 58 dBA, 58 dBA, 59 dBA, and 60 dBA. When using no form of amplification, the teachers' mean speech intensity was as follows: 61 dBA, 62 dBA, 65 dBA, and 65 dBA. When amplified, and using a sound-field system, the teachers' mean speech intensity increased to the following: 71 dBA, 71 dBA, 70 dBA, and 79 dBA. These results indicated that the use of sound-field amplification systems improved the signal-to-noise at an average of thirteen decibels (Larsen & Blair, 2008). Larsen and Blair's research did not utilize the participants as dependent variables, so their perceived loudness of stimuli was not measured. However, the quantitative data collected was considered relevant to the research question proposed.

Rekkedall (2012) conducted a level III well-designed non-experimental study in the form of a survey to determine factors that promoted satisfaction among students with hearing impairments who used assistive hearing technology. More specifically to the research question at hand, this study addressed the user's satisfaction with the use of sound-field amplification systems in the classroom setting. Participants included 153 children with mild to profound hearing loss between 10 and 16 years old. Of the 153 respondents, 59% could hear speech without using a hearing aid, 32% could hear speech with a hearing aid or cochlear implant, and 9% could not always hear speech when using a hearing aid or cochlear implant. The students identified that 29.4% used no personal amplification, 46.9% used a loudspeaker, 24.6% used an FM system with or without a loudspeaker, and 28.5% used an induction loop system. Results were presented via multiple regression analysis and indicated that males were generally more satisfied with the use of teacher microphones for sound-field amplification than females. Additionally, the students who had more optimistic views of school and experienced fewer technological issues were more satisfied with sound-field amplification than those who did not. These results and preferences were paralleled in the survey of use of student microphones for sound-field amplification in the classroom setting (Rekkedal, 2012).

DiSarno, Schowalter, and Grassa (2002) conducted a level IIb well-designed quasi-experimental study to assess the use of classroom amplification for enhancement of the performance of students. Pre- and post-listening, and academic behavior scores were recorded as observed by two classroom teachers to judge the effectiveness of the use of classroom sound-field amplification systems. The hearing abilities of students in the test classrooms were not specified, but the teachers taught in a mainstream classroom. The listening and learning behaviors of students were measured. Both teachers noted an improvement in listening and academic skills when a classroom sound-field system was used. Overall, the participating teachers reported that the amplification system was rewarding and useful when used in the classroom, especially for students with learning disabilities (DiSarno, Schowalter, & Grassa, 2002).

As stated earlier, Lewis (2008) outlined the most commonly used options for classroom amplification: frequency modulation and sound-field. Studies included in the review included school aged participants with both normal and impaired hearing. Lewis mentioned in his review of trends in classroom amplification systems, that the goal was oftentimes to increase sound stimuli by ten to fifteen decibels to improve the overall signal-to-noise ratio when implementing sound-field amplification systems. In addition to improving signal-to-noise ratios, the presence of sound-field amplification systems reduced the likelihood of vocal strain on teachers and other users. Significant and rapid improvements in academic abilities were noted for children who were in an amplified classroom. Lewis indicated that although small, a significant benefit was observed in the performance of children using a sound-field system versus a hearing instrument in isolation (Lewis, 2008).

As previously mentioned, McKay et al. (2008) reviewed articles regarding considerations that guided the clinical decision-making process when selecting amplification options for children with minimal or mild bilateral, or unilateral hearing loss. The researchers stated that children who attended school in a classroom with sound-field amplification systems were more likely to experience less distractions, a stronger ability to focus, and less maladaptive behavior.

The researchers additionally noted a potential negative consequence of the likability of sound-field systems in the school, which was that a misconception could evolve that would lead professionals to believe that sound-field amplification was enough to meet the needs of all individuals with a hearing loss. However, the researchers noted that this was not true (McKay et al., 2008).

As previously mentioned, Rosenberg (2005) authored a level IV respected authority report that evaluated the history of sound-field amplification efficacy and revealed the validity of listening enhancement technology. Rosenberg included over 40 studies on high interest topics such as sound-field amplification system options, literacy and academic achievement, speech-recognition, attending skills, learning behaviors, and teacher responses. Rosenberg stated that overall, the studies that were included demonstrated an improvement in the literacy development, academic achievement, speech-recognition abilities, attending skills, and learning behaviors of students in classrooms with sound-field amplification. Rosenberg found that the use of sound-field amplification systems, transmitted via frequency modulation, increased speech-recognition abilities in children with normal hearing at an average of 45%, and children with hearing loss who utilized a hearing aid at an average of 12%. These results led the researcher to believe that sound-field amplification was a viable option. In addition to benefiting the students the researcher stated that the use of sound-field amplification benefited the teachers by minimizing vocal strain, which coincided with research conducted by Lewis (2008) (Rosenberg, 2005).

Personal amplification system. As previously stated, Anderson et al. (2005) conducted three experiments that included twenty-eight students between the ages of eight and fourteen. The researchers measured the following: (a) perceived loudness, (b) the speech-recognition abilities of children using hearing aids or cochlear implants, and (c) the opinions of participants regarding ALDs for varying levels of hearing loss. The first experiment utilized all data from Anderson and Goldstein's (2004) previous research. Researchers measured perceived loudness with a seven-point Likert Scale, with one representing the quietest and seven representing the loudest perceived noise level (Anderson et al., 2005). Participants labeled hearing aids at an average of 3.9 on the Likert Scale, which improved to an average of 4.2 with the use of a personal amplification system. This data suggested that personal amplification systems provided a comfortable level of amplification for students in the classroom. When measuring word recognition performance during the second experiment, participants scored an average of 87.3% when using only a hearing aid, which improved to 92.6% when using a personal amplification system. In the third and final experiment, participants scored an average of 78% when using a hearing aid, and 77.5% when using a cochlear implant. Hearing aid users scored an average of 93.2%, and cochlear implant users scores an average of 90.7% with use of personal amplification. The results of the third and final experiment indicated a substantial increase in word recognition ability when using a personal amplification system, especially for hearing aid users. Social validation perceptions were measured for the use of personal amplification as well. Eighteen of the twenty-eight participants selected personal amplification as being the easiest to listen to, ten selected it as being most accepted by their peers, fifteen believed it to be the most preferred by teachers, and twenty-one students selected it as being their overall most preferred amplification choice (Anderson et al., 2005).

As mentioned previously, Anderson and Goldstein (2004) included eight children between the ages of nine and twelve (i.e., four boys and four girls), with mild to severe hearing loss in their study that was designed to compare the effects of three different types of amplification systems against the effectiveness of hearing aids alone under typical classroom conditions, and parent opinions regarding a preferred amplification system. The variable relevant to personal amplification as a mode of transmission included a personal frequency modulation system. As stated before, the dependent variables were as follows: (a) perceived loudness of sound, (b) word recognition performance, and (c) social validation. The participants perceived the intensity of the sound when using a personal amplification system to be the second quietest option, with the quietest choice being the use of hearing aids in isolation. When measuring word recognition performance, the researchers found there to be a consistent increase in word recognition. Participants scored an average of 82.4% when using hearing aids alone, which improved to a level of 94.4% when using a personal amplification system. Four of the six students rated personal amplification as being the easiest to listen to, four perceived it to be their teachers' most preferred option, two judged it to be most accepted by their peers, six rated it as a most preferred option for classroom use, and one student identified it as an option that they did not want to use in class (Anderson & Goldstein, 2004).

Odelius and Johansson's (2010) non-experimental study analyzed the use and preference of ALDs via self-assessments completed by twenty-five students who used bilateral hearing aids between the ages of ten and twenty. Audibility and awareness were measured using the Speech, Spatial and Qualities of Hearing Scale, in addition to a word recognition test. Participants compared the use of their hearing aid alone, versus connection to an induction loop system at the personal amplification level. Students' preferences for use in noisy classroom settings varied significantly. Some students preferred the use of their hearing aid alone, while others found it more beneficial to utilize a telecoil induction loop system at the personal amplification level when in noisy environments. Generally, students with less severe hearing loss found it to be just as easy to listen to a speaker using only their hearing aid, while students with severe hearing loss found it easier to utilize the personal amplification option (Odelius & Johansson, 2010).

As previously discussed, Lewis (2008) outlined the most commonly used options for classroom amplification. Lewis noted that personal amplification systems provided significant benefit over hearing aids alone. However, the personal amplification choice was no better or worse than the single speaker system (Lewis, 2008).

As mentioned earlier McKay et al., (2008) explored auditory considerations, hearing aid technology, hearing technology, nonconventional hearing technology, and other management considerations. The researchers discovered that personal amplification systems were commonly a preferred choice by users and offered the greatest signal-to-noise ratio and could be easily coupled with a behind the ear hearing aid (McKay et al., 2008). Specific numerical data regarding the effectiveness of personal amplification systems was not reported in this study.

Single speaker amplification system. As discussed before, Anderson et al. (2005) compared the effects of listening environments on speech-recognition. Participants included twenty-eight students with hearing loss between the ages of eight and fourteen were included. The following was measured: (a) perceived loudness, (b) the speech-recognition abilities of children using hearing aids or cochlear implants, and (c) the opinions of participants regarding ALDs for varying levels of hearing loss. Researchers measured the perceived loudness with a seven-point Likert Scale, with one representing the quietest and seven representing the loudest. Participants labeled hearing aids to be an average of 3.9 on the Likert Scale, which improved to an average of 4.6 with the use of a desktop amplification system. This data suggested that single speaker amplification systems also provided a comfortable level of amplification for students in the classroom. When measuring word recognition performance during the second experiment, participants scored an average of 87.3% when using only a hearing aid, which improved to 93.4% when using a single speaker amplification system. In the third and final experiment, participants scored an average of 78% when using a hearing aid and 77.5% when using a cochlear implant. Students using hearing aids scored an average of 88%, and students using cochlear implants scored an average of 87.3% when using a personal amplification system. The researchers indicated that there was a notable change in word recognition ability when using a personal amplification system and/or single speaker system over hearing aids alone. Nine of the twenty-eight participants selected a single speaker system amplification as being the easiest to listen to, eleven selected it as being the most accepted by their peers, five believed it to be the most preferred by their teachers, and five students selected it as being the most preferred overall. Additionally, students were observed to respond more quickly and with greater ease when using a personal amplification system when compared to alternatives (Anderson, et al., 2005).

As mentioned previously, Anderson and Goldstein (2004) compared the effects of three different types of amplification systems against the effectiveness of hearing aids alone under typical classroom conditions, and parent opinions regarding a preferred amplification system. They included eight children between the ages of nine and twelve years old (i.e., four boys and four girls), with mild to severe hearing loss. The children included in the study were primarily auditory communicators and attended a large school. All participants had normal intelligence, no other identified disabilities, and spoke English as a primary language. The variable relevant to single speaker technology as a mode of transmission included a personal frequency modulation system. Dependent variables were as follows: (a) perceived loudness of sound, (b) word recognition performance, and (c) social validation. The participants perceived the intensity of the sound when using a single speaker amplification option to be the best option, providing the loudest perceived sound. When measuring word recognition performance, the researchers found there to be a notable increase in ability. Participants scored an average of 82.4% when using hearing aids alone, which improved to a level of 93.4% when a single speaker amplification system was used. Two of the six students rated the single speaker amplification system as being the easiest to listen to, two perceived it to be their teachers' most preferred option, five judged it to be most accepted by their peers, one rated it as a most preferred option for classroom use, and two students labeled it as an option that they did not want to use in class (Anderson & Goldstein, 2004).

Iglehart' (2004) measured the speech perception abilities of students with cochlear implants in the classroom setting. The variable relevant to single speaker technology as a mode of transmission included single speaker amplification. The study included ten males and four females, ages six to sixteen years of age with bilateral hearing loss ranging from severe to profound. All participants were enrolled in an auditory education program, utilized cochlear implants, retained good language abilities, and could attend to auditory tasks for an extended amount of time. Mean phoneme and word recognition data were collected with no amplification, and then with a single speaker amplification system in both an acoustically poor and ideal classroom. In the acoustically poor classroom, participants earned a mean phoneme recognition score of 12.8% using no amplification system. This increased to 38% when using a single speaker system. In the acoustically ideal classroom, the mean phoneme recognition score of the participants was 40.5% when using no form of amplification, which improved to 48.2% when using a sound-field system. The results indicated no statistically significant difference between the mean scores when a sound-field amplification system was used, versus personal amplification. These results indicated that the two methods provided equal benefit. Additionally, there was no statistically significant difference between the use of a single speaker in an acoustically poor versus ideal classroom. These results indicated that the classroom acoustics were not a significant variable when using a single speaker. The researcher stated that an acoustically ideal classroom combined with a form of amplification provided the greatest benefit to the students; however, no amplification system could fully compensate for an acoustically poor classroom (Iglehart, 2004).

Per Lewis' (2008) level IV respected authority report that outlined the most commonly used options for classroom amplification, large-area sound-field systems were not the best fit for all children, especially individuals with more severe degrees of hearing loss. Children who experienced severe degrees of hearing loss made better candidates for single speaker systems or personal amplification systems paired with their hearing aids. As mentioned earlier, there was no significant difference between the use of a personal amplification system versus a single speaker system (Lewis, 2008).

As described previously, McKay et al. (2008) reviewed amplification considerations for children with minimal or mild bilateral, or unilateral hearing loss. In addition to single speaker amplification, auditory considerations, hearing aid technology, hearing technology, nonconventional hearing technology, and other management considerations were explored in the literature and addressed in the study. The researchers stated that single speaker amplification systems were not a primary choice for students in the classroom. In fact, only 32% of children chose to use a single speaker; however, an explanation of rationale was not provided (McKay et al., 2008).

Table 2

Display of Results

Analysis of Studies Addressing Mode of Transmission					
Author	SIGN Level	Mode	Participants	Dependent Variable(s)	Study Outcome
(Anderson, Goldstein, Colodzin, & Iglehart, 2005)	IIa	FM	28 students ages 8-14 who were experienced amplification users. Hearing loss ranged from normal to moderate-severe; normal intelligence and language; comprehensible speech	Perceived loudness, speech-recognition, and the opinions of participants regarding ALDs	Researchers supported the use of frequency modulation systems in primary and secondary educational settings
(Anderson & Goldstein, 2004)	IIa	FM and infrared	8 children ages 9-12 with mild to severe hearing loss who were primarily auditory communicators and attended a large school	Perceived loudness of sound, word recognition performance, and social validation	1. FM provided more benefit than hearing aids in isolation 2. No significant difference between the use of hearing versus the infrared sound-field system
(Iglehart, 2004)	IIa	FM	14 participants 6-16 years with bilateral hearing loss from severe to profound. Participants were enrolled in an auditory education program, had cochlear implants, retained good language abilities, and could attend to auditory tasks for an extended period	Number of correctly recognized phonemes	Frequency modulation receivers helped to increase speech perception by reducing levels of reverberation and refining sound-to-noise ratios
(Alterovitz, 2004)	IIb	Induction loop	N/A	Sound output	When inside a loop system, audibility is normal and the listener should have no

					difficulty hearing
(Odelius & Johansson, 2010)	III	Induction loop	25 students ages 10-20 years who used bilateral hearing aids	Audibility, awareness, and word recognition abilities	Induction loop transmission received the overall highest rating for speech-recognition and overall lowest rating for spatial hearing abilities
(Tao, 2013)	IV	Induction loop	N/A	N/A	Improved the signal to noise ratio, no pairing requirement, optimal use with telephones, but expensive to install, less portable than alternative options, and may distort music
(Lewis, 2008)	IV	FM and infrared	N/A	N/A	1. FM were easily paired with personal hearing instruments or built into a behind the ear hearing aid, and no possibility of light transmitting through walls 2. Infrared light wave could be interrupted by a physical obstruction or outside light interference
(McKay, Gravel, & Tharpe, 2008)	IV	FM	Children with minimal or mild bilateral hearing loss and unilateral hearing loss	N/A	Significantly improved the ability to perceive speech
(Rosenberg, 2005)	IV	FM	School aged children with all levels of hearing abilities	N/A	Increased the speech-recognition abilities in children with normal and impaired hearing
(Yanz & Preves, 2003)	IV	Induction loop	N/A	N/A	Offered reduced acoustic feedback and resulted in a noise interference that was difficult to eliminate

Analysis of Studies Addressing Mode of Configuration

Author	SIGN Level	Mode	Participants	Dependent Variable(s)	Study Outcome
(Da Cruz et	Ib	Sound-	20 total children with a mean age	Abilities	Improved the sound-to-noise ratio and

al., 2016)		field	of 8 years who attended the same private school, had normal hearing, were in the third grade, and did not have a cognitive impairment	related to academic performance	enhanced the overall attention of the students in the classroom
(Wilson, Marinac, Pitty, & Burrows, 2011)	IIa	Sound-field	147 children ages 7;9 to 8;7 years in their second trimester of 3rd grade.	Literacy and listening, regular word spelling, sight word spelling, and reading comprehension	Resulted in small but significant improvements in listening skills of children in acoustically ideal classroom
(Anderson, Goldstein, Colodzin, & Iglehart, 2005)	IIa	Sound-field, personal, and single speaker	28 students ages 8-14 who were experienced amplification users. Hearing loss ranged from normal to moderate-severe; normal intelligence and language; comprehensible speech	Perceived loudness, speech-recognition, and the opinions of participants regarding ALDs	1. Decrease in word recognition abilities for individuals with cochlear implants when using sound-field and majority of students selected as least desirable option 2. Personal amplification system and most preferred option by users 3. Notable change in word recognition ability with both personal amplification system and single speaker system over hearing aids alone
(Anderson & Goldstein, 2004)	IIa	Sound-field, personal, and single speaker	8 children ages 9-12 with mild to severe hearing loss who were primarily auditory communicators and attended a large school	Perceived loudness of sound, word recognition performance, and social validation	1. No significant difference in the use of a sound-field system versus hearing aids in isolation and majority of students did not want to use in class 2. Students rated personal system as most preferred 3. Students rated single speaker as the most accepted option by peers
(Iglehart, 2004)	IIa	Sound-field and	14 participants 6-16 years with bilateral hearing loss from severe	Number of correctly	Speech perception improved with the use of amplification regardless of

		single speaker	to profound. Participants were enrolled in an auditory education program, had cochlear implants, retained good language abilities, and could attend to auditory tasks for an extended period	recognized phonemes	classroom acoustics, but indicated no statistically significant difference between sound-field versus personal
(Larsen & Blair, 2008)	IIb	Sound-field	4 fourth grade classrooms similar in size that had been built within the last 10 years	Signal-to-noise ratio	Classroom amplification systems positively influenced the signal-to-noise ratio within the classroom setting
(DiSarno & Schowalter, 2002)	IIb	Sound-field	2 classroom teachers	Listening and learning behaviors of students	Teachers reported that the amplification system was rewarding and useful when used in the classroom, especially for students with learning disabilities
(Rekkedal, 2012)	III	Sound-field	153 children with mild to profound hearing loss between 10 and 16 years old	N/A	Males were generally more satisfied than females and students who had more optimistic views of school and experienced fewer technological issues were more satisfied than those who did not
(Odelius & Johansson, 2010)	III	Personal	25 students ages 10-20 years who used bilateral hearing aids	N/A	Students with less severe hearing loss found it just as easy to listen to a speaker using only their hearing aid, while students with severe hearing loss found it easier to utilize the personal amplification option
(Lewis, 2008)	IV	Sound-field and personal	N/A	N/A	Improvements in academic abilities were noted for children who were in an amplified classroom
(McKay, Gravel, & Tharpe, 2008)	IV	Sound-field, personal, and single	Children with minimal or mild bilateral hearing loss and unilateral hearing loss	N/A	1. Children experienced less distractions, more focus, and less maladaptive behavior with sound-field option 2. Personal amplification systems were a

		speaker			commonly preferred choice by users and offered the greatest signal-to-noise ratio 3. Single speaker amplification systems were not a primary choice for students in the classroom
(Rosenberg, 2005)	IV	Sound-field	School aged children with all hearing abilities	N/A	1. Increased speech-recognition in children with normal and impaired 2. Benefited the teachers by minimizing vocal strain

Chapter 5

Discussion

Principle Findings

Scientific evidence available to support the use of assistive listening devices in primary and secondary education settings was limited. When conducting the search for articles relevant to the research question proposed, many were located that did not meet inclusion criteria based on date of publication (i.e., 2000-2018). These articles oftentimes had publication dates between 1980 and 1999, which eliminated them from inclusion in the study, although some were evaluated in the review of the literature. Although attempts were made to locate 5-15 articles per category, only fifteen total articles located met inclusion criteria, none of which were well-designed meta-analyses or systematic reviews (level Ia), and only one was a well-designed randomized controlled study (level Ib). Many older studies relevant to the research topic outlined different types of HATS, and noted that classroom acoustics created a need for classroom amplification (Berg et al., 1996; Boothroyd & Iglehart, 1998; Crandell & Smaldino, 1999; Logan & Bess, 1985). However, few evaluated the effectiveness of HATS in the classroom, and only two measured user preferences (Allen, 1994; Nelson & Nelson, 1997).

Clinical Implications

Mode of Transmission. Frequency modulation systems were the most commonly studied mode of transmission throughout this review. They were included in 6 of the 15 total studies. Several researchers indicated that the use of frequency modulation systems in the classroom increased speech perception abilities of children (Iglehart, 2004; McKay et al., 2008; Rosenberg, 2005). Lewis (2008) stated that an advantage of using frequency modulation systems in the classroom was that there was no requirement to pair devices prior to use. Frequency modulation, as a mode of transmission, was not a dependent variable in the studies included. Therefore, no quantitative data was reported on their use, which was a limitation of this systematic review. However, an older study included in the historical review of HATS used frequency modulation and induction loop systems as dependent variables, and determined induction loops to be more effective at transmitting sound than the frequency modulation system (Sung et al., 1976).

Induction loop systems were the second most commonly studied mode of transmission throughout this review. They were included in 4 of the 15 total articles. Alterovitz (2004) found that regardless of setup and positioning, if the user was within the loop's parameters there was no difficulty with audibility of the sound. Like frequency modulation systems, an additional advantage of induction loop systems was that there was no need for device pairing if the device was compatible with this mode of transmission (Tao, 2013). An older study reviewed in the historical outline of HATS stated that induction loops had more desirable qualities than any other mode of transmission (Leavitt, 1991). However, Sung et al., (1985) mentioned the need for induction loops to be checked regularly by a teacher for any structural damage that could cause acoustical distortion. A disadvantage was that it is an expensive option, and large loops are not easily transported (Tao, 2013).

Infrared systems were the least commonly studied mode of transmission throughout this review. They were included in 3 of the 15 total studies. A notable advantage of using infrared technology as a mode of transmission was that it was impossible for infrared lights to transmit sound through the walls of a classroom, and therefore decreased the possibility of interference with other teachers (Lewis, 2008). However, the light wave required for infrared technology to work could therefore be interrupted by physical barriers that prevent the signal from connecting to the receiver (Lewis, 2008).

In summary, frequency modulation systems appeared most frequently throughout the literature. This option offered an inexpensive mode of transmitting sound and was frequently used in the classroom setting (Lewis, 2008). Tao (2013) mentioned that induction loop systems offered the same conveniences as frequency modulation systems; however, they were more expensive and less portable. Infrared technology was not a commonly explored option in the literature and had the noted disadvantage of easy signal interference. Overall, the evidence to support the use of one mode of transmission over another was inconclusive. More research is warranted to address the differences between each type in the classroom setting; however, there was no evidence to support the idea that any of the three options would be detrimental to the listening environment.

Mode of Configuration.

Sound-field amplification systems. Sound-field technology was the most commonly researched mode of configuration within the included articles. It was studied in 11 of the 15 total articles. Researchers found many advantages to using sound-field amplification in the classroom setting, including a decrease in distractibility, less maladaptive behavior, increased literacy development, and improved speech recognition skills (Da Cruz et al., 2016; McKary, Gravel, & Tharpe, 2008; Rosenberg, 2005). These results agreed with studies conducted in earlier years (Allen, 1994; Arnold & Canning, 1999; Berg et al., 1996; Leavitt, 1991; McSporran et al., 1997).

The use of sound-field amplification systems in the classroom setting improved the signal-to-noise ratio at an average of 13 decibels (Larson & Blair, 2008). In Rosenberg's (2005) study, a more significant increase in speech recognition abilities was noted in children with normal hearing than when used in combination with children with hearing loss who were hearing aid users (Rosenberg, 2005). However, in a different study conducted by Anderson and Goldstein (2004), no significant differences were reported in word recognition performance between the use of hearing aids and sound-field. When using sound-field amplification in a classroom with children with cochlear implants, researchers indicated there was a decrease in word recognition abilities (Anderson et al., 2005).

Per the results of a Likert Scale measurement of perceived loudness, using sound-field systems provided comfortable amplification for users (Anderson et al., 2005). However, most students selected sound-field amplification as their least preferred option for classroom use (Anderson & Goldstein, 2004; Anderson et al., 2005). This contrasted with studies conducted in earlier years stating that most students and teachers preferred to use sound-field amplification; however, most students included in these studies had normal hearing (Allen 1994; Nelson & Nelson, 1997).

Wilson et al., (2011) found a small but significant increase in the attention span of students when the sound-field system was used in an acoustically ideal classroom. These results correlated with results from the older study by McSporran et al. (1997) that stated sound-field amplification improved the listening and attending skills of children, but not by a statistically significant amount. Phoneme recognition improved significantly in both acoustically poor and ideal classrooms; however, a greater level of improvement was noted in the acoustically poor classroom when a sound-field system was used (Iglehart, 2004). This conflicted with data from research by Wilson et al., (2011) which indicated the contrary to be true. When interviewed, males were more satisfied with the use of a sound-field system than females (Rekkedal, 2012). Additionally, there appeared to be a positive correlation between positive feelings towards school and preferences for sound-field systems (Rekkedal, 2012). When interviewed, teachers stated that they noticed an increase in listening skills when using a sound-field system in their classroom (DiSarno, et al., 2002).

The use of sound-field amplification systems in the classroom provided acoustical benefits for more than children with hearing loss (Lewis, 2008). They reduced the need for teachers and other users to raise their voices, and thus reduced the chance of vocal strain (Lewis, 2008). Additionally, significant and rapid improvement in learning and listening skills were noted for children with normal hearing in the classroom setting (Lewis, 2008). Overall, sound-field amplification appeared most frequently throughout the literature and was the most commonly explored mode of configuration. Sound-field systems offered benefits to many types of users, not just those with a diagnosed hearing loss. However, it was not a preferred choice for those children who utilized a cochlear implant (Anderson & Goldstein, 2004; Anderson et al., 2005).

Personal amplification systems. Personal amplification systems were the second most commonly researched mode of configuration. They appeared in 5 of the 15 total articles. Older studies outlined in the historical review of HATS did not include personal amplification as dependent variables. Flexer (1997) outlined their use, but stated that they were new options and lacked evidence to support their use. In the more current studies, a personal amplification system was repeatedly a commonly preferred choice and provided a comfortable perceived level of amplification to users (Anderson et al., 2005; Anderson & Goldstein, 2004; McKay et al., 2008). Students with severe degrees of hearing loss preferred to use personal amplification systems over a hearing aid alone, while students with mild hearing loss were content with using only a hearing aid in the classroom (Odelius & Johansson, 2010). Personal amplification systems provided the most significant increase in signal-to-noise ratio and were easily coupled with hearing aids (McKay et al., 2008). The researchers indicated that personal amplification provided significant improvement in word recognition abilities for individuals who utilized both hearing aids and cochlear implants (Anderson et al., 2005).

Single speaker amplification systems. Single speaker systems were the least common mode of configuration within the included articles. They appeared in 4 of the 15 total articles and were not a primary choice for students in the classroom (McKay, et al., 2008). However, they offered a comfortable perceived level of loudness to users, and an increase in word recognition for students who used hearing aids and students with cochlear implants (Anderson et al., 2005). Like the personal amplification option, older studies outlined in the historical review of HATS did not include single speaker amplification as dependent variables. Flexer (1997) outlined their use, but stated that they were new options and lacked evidence to support their use. In a more current study, classroom acoustics were not significant variables when determining the effectiveness of personal amplification (Iglehart, 2004). However, researchers stated that it was impossible to fully compensate for an acoustically poor classroom, so ideal results would be seen in acoustically sound classrooms with appropriately applied amplification (Iglehart, 2004).

Suggestions for Further Research

Many researchers for the studies included agreed that further research was needed on ALDs (Crandell & Smaldino, 1999; Logan & Bess, 1985; McSporran et al., 1997). A meta-analysis of data regarding modes of configuration and their effect on phoneme recognition, word recognition, and other hearing abilities of children in the primary and secondary education setting could serve as a beneficial resource for SLPs. Additionally, modification of methodology, specifically search strategy and inclusion criteria when completing a systematic review of the literature, could be beneficial to this area of research. The researcher found the chronologically organized outline of studies included in the historical review of HATS to be a beneficial and efficient method of arranging data, which could be utilized for future research to track the quickly evolving subject.

Strengths and Weaknesses of the Study

Current literature available was limited, potentially because previous research is just now becoming outdated as classroom listening environments evolve. A limited number of studies were accessed and identified as a high-level source, which was a limitation of this study. Although a thorough search of the literature was conducted, a finite number of databases were searched with limited search terms. The search criteria both strengthened and weakened the study by providing replicable methodology, but potentially limiting the total number of studies accessed. As previously mentioned, a more thorough review of historical studies was added in the review of the literature to counteract that, and did lead to additional valid discussion points. Additionally, ASHA did not publish guidelines for classroom acoustics until 2005, which was recently rescinded in 2015 so that updated information could be added to the ASHA practice portal. It would have been impossible for researchers to have taken the 2005 guidelines into consideration when conducting studies in earlier years, which was also a limitation of the study.

Although this study did not definitively include all research conducted on the use of ALDs in the classroom, it effectively compiled the readily available literature relevant to the research question. The overlap in results between the various studies reviewed was an additional strength and offered a more reliable resource to SLPs. Overall, this study could effectively serve as an evidence based resource for SLPs when implementing communication options for individuals with hearing loss in primary and secondary educational settings.

References

Allen, L. (1994). Student and teacher feedback regarding the use of sound-field classroom amplification. *Educational Audiology Association News-Letter 11*(3). *Cited in* Peters-Johnson, C. (1994). Students and teacher feedback regarding the use of sound-field classroom amplification. *Language, Speech & Hearing Services In Schools*, *25*(4), 279.

Alterovitz, G. (2004). Electrical engineering and nontechnical design variables of multiple inductive loop systems for auditoriums. *Journal of Deaf Studies and Deaf Education*, *9*(2), 202-209.

American Speech-Language-Hearing Association (2004a). *Preferred practice patterns for the profession of speech-language pathology.* Retrieved from https://www.asha.org/policy/PP2004-00191/.

American Speech-Language-Hearing Association. (2004b). *Roles of speech-language pathologists and teachers of children who are deaf and hard of hearing in the development of communicative and linguistic competence* [Guidelines]. Retrieved from www.asha.org/policy.

American Speech-Language-Hearing Association. (2004c). *Scope of Practice in Audiology* [Scope of Practice]. Retrieved from https://www.asha.org/policy/SP2004-00192/.

American Speech-Language-Hearing Association. (2005). *Evidence-based practice in communication disorders* [Position Statement]. Retrieved from https://www.asha.org/policy/PS2005-00221/.

American Speech-Language-Hearing Association (2015a). *Hearing assistive technology*. Retrieved from http://www.asha.org/public/hearing/Hearing-Assistive-Technology/.

American Speech-Language-Hearing Association (2015b). *Type, degree, and configuration of hearing loss*. Retrieved from http://www.asha.org/public/hearing/Types-of-HearingLoss/.

American Speech-Language-Hearing Association (2016). *Scope of practice in speech-language pathology.* Retrieved from https://www.asha.org/uploadedFiles/SP2016-00343.pdf.

Anderson, K., & Goldstein, H. (2004). Speech perception benefits of FM and infrared devices to children with hearing aids in a typical classroom. *Language, Speech & Hearing Services In Schools*, *35*(2), 169-184.

Anderson, K. A., Goldstein, H., Colodzin, L., & Iglehart, F. (2005). Benefit of S/N enhancing devices to speech perception of children listening in a typical classroom with hearing aids or cochlear implant. *Journal of Education Audiology, 12,* 14-28.

Arnold, P., & Channing, D. (1999). Does classroom amplification aid comprehension? *British Journal of Audiology, 33*(3), 171. Retrieved from http://trmproxy.mnpals.net/login?url=https://search-proquest-com.trmproxy.mnpals.net/docview/223203055?accountid=12548

Berg, F., Blair, J., & Benson, P. (1996). Classroom acoustics: The problem, impact, and solution. *Language, Speech & Hearing Services In Schools*, *27*(1), 16-20.

Boothroyd, A., & Iglehart, F. (1998). Experiments with classroom FM amplification. *Ear & Hearing (01960202)*, *19*(3), 202-217.

Bowers, D. (2017). Unilateral hearing loss in children: Impact and solutions. *Audiology Online*, 1-16.

Brackett, D. (1997). Intervention for children with hearing impairment in general education settings. *Language, Speech, and Hearing Sciences in Schools, 28*(4), 355-361.

Carney, A. E., & Moeller, M. P. (1998). Treatment efficacy: Hearing loss in children. *Journal of Speech, Language, and Hearing Research, 41*(1), S61-S84.

Centers for Disease Control and Prevention. (2010). Identifying infants with hearing loss - United States, 1999-2007. *MMWR Morb Mortal Wkly Rep. 59*(8): 220-223. Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5908a2.htm.

Clark, J. G. (1981). Uses and abuses of hearing loss classification. *American Speech-Language Hearing Association, 23*, 493–500.

Crandell, C. C., & Smaldino, J. J. (1999). Improving classroom acoustics: Utilizing hearing-assistive technology and communication strategies in the educational setting. *Volta Review*, *101*(5), 47.

Da Cruz, A. D., Alves Silvério, K. C., Da Costa, A. A., Mortari Moret, A. L., Pereira Lauris, J. R., de Souza Jacob, R. T., & Lauris, J. P. (2016). Evaluating effectiveness of dynamic sound-field system in the classroom. *Noise & Health*, *18*(80), 42. doi:10.4103/1463-1741.174386

DiSarno, N. J., & Schowalter, M. (2002). Classroom amplification to enhance student performance. *Teaching Exceptional Children*, *34*(6), 20.

Dumanch, K. A., Holte, L., O'Hollearn, T., Walker, E., Clark, J., & Oleson, J. (2017). High risk factors associated with early childhood hearing loss: A 3-year review. *American Journal of Audiology*, *26*(2), 129-142. doi:10.1044/2017_AJA-16-0116

Flexer, C. (1997). Individual and sound-field FM systems: Rationale, description, and use. *Volta Review*, *99*(3), 133-162. Retrieved from: https://login.trmproxy.mnpals.net/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107172486&site=eds-live

Hendry, C., Farley, A., & McLafferty, E. (2012). Anatomy and physiology of the senses. *Nursing Standard, 27*(5) 35-42.

Iglehart, F. (2004). Speech perception by students with cochlear implants using sound-field systems in classrooms. *American Journal of Audiology*, *13*(1), 62-72. doi:10.1044/1059-0889(2004/009)

Kuhn, M., Heman-Ackah, S. E., Shaikh, J. A., & Roehm, P. C. (2011). Sudden sensorineural hearing loss: a review of diagnosis, treatment, and prognosis. *Trends in Amplification*, *15*(3), 91–105. doi: 10.1177/1084-713811408349

Larsen, J. B., & Blair, J. C. (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. *Language, Speech & Hearing Services In Schools, 39*(4), 451-460. doi:10.1044/0161-1461(2008/07-0032)

Leavitt, R. J. (1991). Group amplification systems for students with hearing impairment. *Seminars in Hearing*, *12*(4), 380. doi:10.1055/s-0028-1085509

Lewis, D. (2008). Trends in classroom amplification. *Contemporary Issues in Communication Science & Disorders*, *35*122-132.

Lin, F. R., Niparko, J.K., Ferrucci, L. (2011). Hearing loss prevalence in the united states. *Arch Intern Med. 171*(20): 1851-1852.

Logan, S. A., & Bess, F. H. (1985). Amplification for school-age hearing-impaired children. *Seminars In Hearing*, *6*(3), 309. doi:10.1055/s-0028-1092009

Masterson, L., Howard, J., Zi Wei, L., Phillips, J., & Liu, Z. W. (2016). Asymmetrical hearing loss in cases of industrial noise exposure: A systematic review of the literature. *Otology & Neurotology*, *37*(8), 998-1005. doi:10.1097/MAO.0000000000001104

Maxon, A. B., Brackett, D., & Van den Berg, S. A. (1991). Classroom amplification use: A national long-term study. *Language, Speech, and Hearing Services in Schools*, *22*(4), 242-253. doi:10.1044/0161-1461.2204.242

McKay, S., Gravel, J., & Tharpe, A. (2008). Amplification considerations for children with minimal or mild bilateral hearing loss and unilateral hearing loss. *Trends in Amplification*, *12*(1), 43-54.

McSporran, E., Yvonne Butterworth, Y., & Rowson, V. J. (1997). Sound-field amplification and listening behaviour in the classroom. *British Educational Research Journal*, (1), 81.

Nelson, D. G., & Nelson, D. K. (1997). Teacher and student satisfaction with freefield FM amplification systems. *Volta Review*, *99*(3), 163.

Niskar, A. S., Kieszak, S. M., Holmes, A., Esteban, E., Rubin, C., & Brody, D. J. (1998). Prevalence of hearing loss among children 6 to 19 years of age. *American Medical Association, 279*(14) 1071-1075.

Nosrati-Zarenoe, R., Arlinger, S., & Hultcrantz, E. (2007). Idiopathic sudden sensorineural hearing loss: results drawn from the Swedish national database. *Acta Oto-Laryngologica*, *127*(11), 1168-1175.

Odelius, J., & Johansson, Ö. (2010). Self-assessment of classroom assistive listening devices. *International Journal of Audiology*, *49*(7), 508-517. doi:10.3109/14992021003645886

Pan, M. L. (2004). *Preparing literature reviews.* Glendale, CA: Pyrczak Publishing.

Peters, K. (2017). Considering the classroom. *Audiology Today*, *29*(1), 20-30.

Rekkedal, A. M. (2012). Assistive hearing technologies among students with hearing impairment: Factors that promote satisfaction. *Journal of Deaf Studies & Deaf Education*, *17*(4), 499.

Rosenberg, G. (2005). Sound-field amplification: A comprehensive literature review. In C. Crandell, J. Smaldino, & C. Flexer (Eds.), *Sound-field amplification: Applications to speech perception and classroom acoustics* (2nd ed., pp. 72-111). Clifton Park, NY: Thompson Delmar Learning.

Sapienza, C. M., Crandell, C. C., & Curtis, B. (1999). Effects of sound-field frequency modulation amplification on reducing teachers' sound pressure level in the classroom. *Journal of Voice*, *13*375-381. doi:10.1016/S0892-1997(99)80042-3

Scottish Intercollegiate Guidelines Network (SIGN). *SIGN 50: A guideline developer's handbook*. Edinburgh: SIGN; 2015. (SIGN publication no. 50). [November 2015]. Retrieved from: http://www.sign.ac.uk

Seiker, A. J., King, D. W., & Drumright, D. G. (2010). *Anatomy & physiology for speech, language, and hearing*. Clifton Park, New York: Delmar.

Shin-ichi, U., Ryosuke, K., Hideaki, M., Shin-ya, N., Tomohiro, K., Masafumi, K., & ... Kizuki, W. (2017). Etiology of single-sided deafness and asymmetrical hearing loss. *Acta Oto-Laryngologica (Supplement)*, S2-S7. doi:10.1080/00016489.2017.1300321

Sung, G. S., Sung, R. J., Hodgson, W. R., & Angelelli, R. M. (1976a). Intelligibility of speech transduced via classroom-installed fm and conventional audio induction loop amplification systems. *Audiology: Journal of Auditory Communication*, *15*(3), 257. doi:10.3109/00206097609071784

Sung, R. J., Sung, G. S., Hodgson, W. R., & Angelelli, R. M. (1976b). Performance of hearing aids with an induction loop amplification system: Laboratory versus classroom setting. *Audiology: Journal of Auditory Communication*, *15*(3), 249. doi:10.3109/00206097609071783

Tao, C. (2013). Advantages and disadvantages of using induction loops. Audiology Online.

Thibodeau, L. M., & Johnson, C. D. (2005). Serving children with hearing loss in public school settings. *The ASHA Leader*, *10*, 6-38. doi:10.1044/leader.FTR2.10132005.6

Tye-Murray, N. (2009). Foundations of aural rehabilitation: Children, adults, and their family members. In S. Dickinson & M. Bellegarde (Eds.), *School-age children who have hearing loss* (pp. 599-665). Clifton Park, NY: Delmar, Cenage Learning.

Wilson, W. J., Marinac, J., Pitty, K., & Burrows, C. (2011). The use of sound-field amplification devices in different types of classrooms. *Language, Speech & Hearing Services In Schools*, *42*(4), 395-407. doi:10.1044/0161-1461(2011/09-0080)

Yanz, J. L., & Preves, D. (2003). Telecoils: Principles, pitfalls, fixes, and the future. *Seminars In Hearing*, *24*(1), 029. doi:10.1055/s-2003-37907