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Noise-Induced Hearing Loss in Young Adults

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Introduction

An 18-year-old high school senior comes into an audiology clinic complaining of ringing in her ears and occasional difficulty understanding her friends, parents, and others in conversation. The audiologist performs an otoscopic examination and observes no abnormalities in the outer ear, including a clear external auditory meatus and an intact, healthy tympanic membrane. The audiologist administers a hearing test to the student and finds a slight to mild sensorineural hearing loss in the high frequencies in both ears. During case history, the student reports that the ringing in her ears is occasional and is worse after listening to her music. The audiologist informs the student that she has experienced a noise-induced hearing loss. The audiologist explains how listening to music at loud levels for long periods of time has damaged her hearing, causing a permanent hearing loss. In addition, listening to loud music has also caused the ringing or tinnitus that often fluctuates or worsens with increased noise exposure. As detailed in this case, noise-induced hearing loss is a danger to young adults, as well as all individuals, and is a significant cause for concern.

In the United States, there are about 48 million people with hearing loss in at least on ear (Martin & Clark, 2015). Hearing loss affects day-to-day living in multiple ways. In children and young adults, hearing loss could hinder their academic performance at school, leading to poorer scholastic achievement in areas such as reading and mathematics. Hearing loss can lead to social problems, social isolation, and even depression because individuals who are diagnosed with a hearing loss often withdraw from social situations due to their inability to communicate with others. When a hearing loss is left untreated, it could lead to neurological changes overtime because the auditory

nerve fibers that connect to the cochlea or inner ear to the auditory cortex become damaged.

Considering the damage that may occur because of noise-induced hearing loss, it is important to review the anatomy of the ear. First, sound is collected by the pinna and funneled into the external auditory meatus. Here, sound travels to the tympanic membrane that vibrates in response to sound waves and causes the ossicles in the middle ear to also vibrate. Vibration of the ossicles sets the fluid in the cochlea into motion, causing the basilar membrane and the hair cells on top of the membrane to move in a wave-like motion. The stereocilia positioned on top of the hair cells are activated by the movement of the fluid surrounding the basilar membrane that results in depolarization of the hair cells to create an action potential or electrical signal. Finally, the auditory nerve carries the electrical signal to the brain that codes and further processes the auditory signal (Noise induced hearing loss, 2015). When one part of the auditory pathway is damaged or not working properly, this results in a hearing loss.

There are three types of hearing loss: a) conductive (damage to the outer or middle ear), b) sensorineural (damage to the inner ear or auditory nerve), and c) mixed hearing loss (damage to both outer, middle and inner ear structures). We will focus on sensorineural hearing loss as it applies to this paper. Recall that the cochlea is lined with hair cells called inner and outer hair cells that are vital to hearing. Most sensorineural hearing losses are due to the dying of these hair cells that are often classified as having a pre- or post-natal cause. Pre-natal causes of sensorineural hearing loss refer to damage to the cochlea prior to birth. The most common types of pre-natal causes are anoxia, a lack of oxygen to the body, prematurity, underdevelopment caused by premature birth, and

lastly, trauma to the fetal head during childbirth. Postnatal causes of sensorineural hearing loss occur in childhood or adulthood and include presbycusis (age-related hearing loss), head trauma (results in injury to the cochlear structures), diseases such as Meniere's (causes tinnitus, hearing loss, and vertigo), and noise-induced hearing loss (Martin & Clark, 2015). Noise-induced hearing loss is damage to the inner ear or the cochlea due to loud and repeated noise exposure.

Noise-induced hearing loss affects about 23 million Americans (Noise induced hearing loss, 2015). Some populations that see increased incidence of noise-induced hearing loss include Veterans who have served in war and been exposed to extremely loud noises, hunters who have repeatedly shot guns without use of hearing protection, and young adults and teenagers who use their personal listening devices at dangerously loud levels. Sound levels that are greater than 85 dB SPL[A] are damaging to the hearing mechanism (Noise induced hearing loss, 2015). To put that number into perspective, the average blow dryer is 80 dB SPL[A]. A personal listening device can easily surpass 100dB SPL[A] (Mostafapour, Lahargoue, & Gates, 1998).

Temporary side effects of noise-induced hearing loss are tinnitus and temporary threshold shift. Tinnitus is the perception of a sound in the absence of an external sound. It can be constant or sporadic, soft or loud, high pitched or low pitched. By comparison, temporary threshold shift is the temporary loss of hearing due to the exposure of loud noise. Eventually, hearing can be restored if it is temporary, unlike in permanent threshold shift where a permanent loss of hearing results. Other long-term effects of noise-induced hearing loss associated with a permanent hearing loss are loss of the high frequency sounds and decreased sound intelligibility. In the cochlea, the hair cells at the

base of the cochlea are often the first to get damaged and die when repeatedly exposed to loud noises. These hair cells code the high frequencies and, when looking at the audiogram of someone with noise-induced hearing loss, an acoustic notch (Martin & Clark, 2015) is often observed. This notch is a large dip in the audiogram indicating hearing loss for high frequency sounds, specifically at 4000 Hz. For individuals exposed to loud sounds, such as Veterans and hunters, one of the best ways to prevent noise-induced hearing loss is by wearing hearing protection.

Related to personal device use, listening to music and videos on a personal device has become increasingly popular with millions of Americans, including young adults, who own personal listening devices. In fact, one study reported approximately 85% of all adults 18 and older own a personal listening device (Zickuhr, 2011). Young adults often use their personal listening devices an excessive amount of time. A study done at Miami University in Ohio reported that more than 77% of students used their personal listening devices for an average of 10-12 years for about 6.93 hours a week. The study found that the subjects' average listening level approached dangerous levels that are greater than 80 dB A, but did not exceed the level (Hutchinson et al., 2015). The reason for this saturation in level is likely that new headphones now limit the overall sound output of the device.

There are several types of headphones that are used with personal listening devices, such as over-the-ear, in-the-ear and behind-the-ear headphones. Also, there are noise-canceling headphones that block out all the outside sounds. This causes additional concern because young adults turn the music up louder to block out the sound around them. Even when the outside sound is canceled using noise-canceling headphones, often

times, wearers increase the volume of the music excessively to experience a feeling of stereo surround sound. In this way, listening to personal devices too loud and too long could lead to noise-induced hearing loss.

The purpose of this paper is to research noise-induced hearing loss in young adults.

1) How is the hearing mechanism affected by noise exposure?

2) What is the impact of personal device use on the hearing of young adults?

3) Why are young adults avoiding hearing protection, and what recommendations can be made to promote use of hearing protection?

Summary of Findings

The Effect of Noise-Induced Hearing Loss on the Hearing Mechanism

When exposed to loud noises, there are many ways in which the hearing mechanism is altered and affected that either temporarily or permanently change how we hear. A number of research studies have explored these causes of noise-induced hearing loss, and several studies have investigated ways to prevent it. Here, we will examine the effect of noise exposure on the hearing mechanism, specifically determining what structures are impacted, and explore treatments to improve hearing function following noise exposure.

First, one natural mechanism that our ear uses to prevent damage from noise exposure is the acoustic reflex. The acoustic or stapedial reflex is active when the ossicles in the middle ear stiffen to protect the inner ear in response to a loud sound. However, it is important to recognize that the acoustic reflex is not constantly active and does not protect against all types of sounds. More specifically, the acoustic reflex is activated for frequencies of 500 to 4000 Hz and for sound intensities above 80 dB A. Although it only takes one second to activate the acoustic reflex, constant exposure to loud noises exceeding 80 dB A will cause damage to the inner ear because the acoustic reflex does not protect against constant levels of noise (Martin & Clark, 2015). If, for example, a construction worker works in a loud setting and is exposed to more than 90 dB A for 8 hours, they will need to wear hearing protection to protect their ears from damage. For every 3 dB of increase in sound level, the time that one can be exposed to the noise

decreases (Levey, Levey & Fligor, 2011; Martin, 2015). When the acoustic reflex does not protect the inner, there is damage to multiple mechanisms of the ear.

One of the first structures to be damaged by excessive noise is the basilar membrane, situated in the cochlea that contains the 12,000 outer hair cells and 3,000 inner hair cells and their attached stereocilia. The cochlea is organized tonotopically, meaning the high frequency hair cells are located near the base and the low frequency hair cells are located near the apex (Martin & Clark, 2015). The stereocilia from adjacent hair cells are connected by cross-links and open up to allow ions pass through that causes the cell to be active and produce an action potential. When the basilar membrane moves in a wave-like motion, this causes the perilymph and endolymph fluid surrounding the membrane and hair cells to become displaced and the hair cells move up and down. The excessive vibration of the basilar membrane with exposure to loud sounds causes the stereocilia to break, bend or buckle (Adelman, Perez, Nazariam, Freeman, Weinberger & Sohmer, 2010). The hair cell damage can be seen within minutes after the ear is exposed to loud noise. With sustained duration of excessive noise exposure, hair cell death occurs (Kujawa & Liberaman, 2009). When the cochlea is exposed to extreme loudness, it disrupts the stereocilia on the hair cells such that the cilia separate at the tip links and actin filaments are depolymerized, causing a disruption in the signal transduction (Hyun, Hun, Joon, & Jong, 2009). This causes the cochlea to not function properly. There is more likely to be damage to the high frequencies in the case of noise-induced hearing loss because the base of the cochlea is where the high frequencies are activated.

When there is damage to the organ of Corti following noise exposure that is recoverable, this causes a temporary threshold shift. The bending of the hair cells is called “auditory fatigue” that occurs as the hair cells are bent for a few days and then recover (Henderson, Bielefeld, Harris, & Hu, 2006). There has been controversies related to auditory fatigue and these non-quantitative measures of recovery (Shi et al., 2016) such that researchers have not determined an exact number of days that the hair cells are damaged and exactly how long they take to heal in cases of temporary threshold shift. However, the damage to the ear includes buckling of the supporting cells, temporarily breaking the contact between the outer hair cells, and reversible damage to the base of the stereocilia. In the case of a temporary threshold shift, there is often full recovery to normal hearing thresholds within a few hours (Duan & Canlon, 1996). However, in cases where the damage to the organ of Corti is significant or constant, a permanent threshold shift results.

Permanent threshold shift is when there is damage to the inner ear structures from noise exposure, and the ear does not fully recover before it becomes damaged again. In fact, repeated damage can occur several times with no impact on hearing thresholds (as occurs in temporary threshold shift), but eventually it will result in a permanent threshold change. In many cases of permanent threshold shift, the hair cells die or fuse together due to the excessive vibration. Not only do the hair cells die from the vibration, but the nerve fibers degenerate, causing a complete loss of hair cells and the greatest risk for permanent threshold shift occurs (Holmes, Widén, Erlandsson, Carver & White, 2007). Another cause of permanent threshold shift is decreased blood flow to the cochlea, causing damage to vital tissues in the cochlea (Henderson et al., 2006).

While many people may think that permanent and temporary threshold shifts are caused by the same damages to the same mechanism, this is not actually the case. Permanent threshold shift and temporary threshold shift are caused by different mechanisms (Holmes et al., 2007). The ears vulnerability to noise depends on the recovery or repair process in the cochlea, not only the amount of the initial threshold shift (Holmes et al., 2007). In other words, when the ear is damaged, it needs time to heal. In most cases, the amount of noise that the ear is exposed to at the time of damage does not determine if there is going to be a permanent threshold shift or a temporary one. Instead, during the healing process, if the mechanisms that cause noise-induced hearing loss are damaged repeatedly, there will be a greater risk for a permanent threshold shift instead of a temporary threshold shift.

In temporary and permanent threshold shift, damage occurs to the afferent and efferent auditory nerve fibers that are sending the information to and from the brain. The swelling of these nerves causes ruptures in the dendrites of the auditory nerve fibers. High levels of glutamate excitotoxicity causes the swelling (Kujawa & Liberman, 2009; Henderson et al., 2006). This damage occurs because as the ear is exposed to extremely high levels of sounds, the inner hair cells are very active and release more glutamate than normal into the synpatic junction between the inner hair cells and the nerve fibers. When the dendrites recover, it causes a temporary threshold shift. The hair cells can take a few minutes to recover or as long as several days (Shi et al., 2016). Now that we know all the damage that can be done to the hearing mechanism, how can we protect it?

There have been numerous studies on treatments for mechanisms affected by noise-induced hearing loss. Researchers investigated ways to prevent the structural modifications and biochemical changes that occur in response to a permanent threshold shift (Hyun et al., 2009). In that study, 42 mice were split into six groups. The two control groups received regular food and food with only sesame oil. The other four groups were fed 1 mg/kg of all-trans retinoic acid (ATRA) at different times following noise exposure. An auditory brainstem response was obtained to measure their hearing level. All mice were exposed to white noise continuously at a gradual incline that peaked at 122 dB HL for three hours a day, for three days. The results revealed that the ARTA treatment group had lower hearing thresholds than the two groups who did not receive the ARTA treatment. Inner and outer hair cell survival was significantly higher in the ARTA treatment group in the 1 hour, 1 day, and 2 day exposures, as compared to the control group or a long duration treatment of 3 days. Overall, these results suggest that administering ATRA around the same time as being exposed to loud sounds can help in recovery following noise-induced hearing loss (Hyun et al., 2009). Further research needs to determine the applicability of the ATRA treatment for noise-induced hearing loss in humans.

Other treatments include glutathione that, when injected with 2-oxothiazolidine-4-carboxylate two hours before noise exposure and immediately after noise exposure, reduced noise-induced cochlear damage in guinea pigs (Yamasoba, Nuttall, Harris, Raphael& Miller, 1998). Antioxidants, vitamin A and vitamin E have been shown to also reduce noise-induced cochlear damage (e.g., Le Prell, Yamshita, Minami, Yamasoba, & Miller, 2007). One study examined the blocking of a stress-activated c-Jun N-terminal

kinase. AM-111 was the cell inhibitor that was used (Coleman, Littlesunday, Jackson & Meyer, 2007). The researchers studied chinchillas after administering AM-111 for one hour and four hours following noise exposure. Using the auditory brainstem response test and a cytococoleogram that is a digital image of the cochlea, results revealed that AM-111 provided protection against permanent hearing loss from loud noise exposure (Coleman et al., 2007). Furosemide has also shown positive results in protecting the ear from temporary threshold shift and permanent threshold shift. Researchers found that administering furosemide to mice before and after noise exposure resulted in a greater emission showing that there were more hair cells alive (Adleman et al., 2010). These results suggest that furosemide protected the cochlea from damage by reducing the excessive vibrations within the cochlea and preserving the OAE.

Research into noise-induced hearing loss and the effects on specific anatomical and neurological structures has largely involved animals, specifically mice, chinchillas and guinea pigs. However, scientists and researchers are developing these treatments to apply to human subjects research. One limitation of this work using human subjects rather than animals is that to control variability, researchers induce hearing loss in all animals and then surgically remove the cochlea to examine the effects of these various treatments on the inner ear structures. However, for ethical reasons, these methods are not possible in humans, making this process more complex when working with human subjects. Furthermore, the drugs that produce favorable effects in chinchillas could have different effects in humans, and researchers need to be very careful in their development of these treatments for noise-induced hearing loss.

Impact of Personal Device Usage on Hearing

What is causing the hearing mechanism to become damaged? The simple answer is: loud noises. Historically, noise exposure was observed in humans who worked in noisy environments, operated heavy machinery, or were exposed to loud gunfire during war. In today's modern world, young adults are at risk of hearing loss because of their recreational choices such as loud concerns and their usage of personal listening devices. Here, we will examine the impact of personal device usage on the hearing abilities of young adults.

Personal listening devices have become increasingly popular. Last year, it was estimated that 84% of undergraduate students, 86% of post-graduate students and 72% of community college students own personal listening devices (Jiang, Zhao, Guderley & Manchaiah, 2016). The problem that arises from use of these personal listening devices is that the maximum output is exceedingly too loud, and that the user controls the output, allowing many individuals the ability to induce hearing loss in themselves quite easily overtime. For example, some personal listening devices can have an output as loud as 125 dB A (Levey, Fligor, Ginocchi, & Kagimbi, 2012).

The Occupational Safety and Health Administration (OSHA) publishes guidelines for what constitutes safe listening levels that are based on how long the person is exposed to the noise and the intensity of the noise. Moreover, OSHA recommends that a person be exposed to no more than 85 dB A for eight hours (United States Department of Labor, 2016). There is a 3 dB increase rate, indicating that for every 3 dB that the loudness increases, the time a person should be exposed to that sound should go down. For example, if a person was exposed to 88 dB A for four hours, this is just as dangerous as

being exposed to 91 dB A for two hours (Levey et al., 2011). The negative impact that personal device usage has on young adults is mainly because of their listening habits because many young adults routinely listen to music above these safe levels defined by OSHA.

A study completed by The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) in 2004 recommended that people using personal listening devices reduce their listening time to only one hour a day and set the volume at most 60% of the maximum output level when using over-the-ear headphones. Furthermore, if the individual uses ear buds as opposed to over-the-ear headphones, then the volume should be even less than 60%. Across multiple studies, the average volume for listening to personal devices was between 65 dB A to 93 dB A (Levey et al., 2011;Sulaiman, Husain & Seluakumaran, 2015).

Not only are young adults listening to music too loud, but they might also be listening to music too long. The average listening time for young adults of personal listening devices is anywhere from 1.3 to 3.5 hours a day across studies (Jiang et al., 2016; Levey et al., 2011; Sulaiman et al., 2015). One study found that significantly worse hearing thresholds in people who used personal listening devices than those who did not (Jiang et al., 2016). Another study done by Levey, Levey and Fligor (2011) studied 189 college students and found that the participants listened to their music at an average of 92.3 dB A for 18.3 hours a week. Of their 189 participants, 58.2% exceeded the daily limits of sound exposure, suggesting that they put themselves at an increased risk of noise-induced hearing loss. Moreover, unsafe use of personal listening devices among

young adults as shown here negatively affects one's hearing ability that can have lasting effects (Levey et al., 2011).

How knowledgeable are young adults on hearing devices? A survey was given to 180 young adults ages 17-25 years old by Hutchinson et al. (2015) in 2015. Researchers wanted to determine if personal listening device users were able to accurately report their listening levels and if they were aware of the damage on their hearing from these devices. More than 77% of the personal listening device users reported that they had used personal listening devices for 10 to 12 years and an average of 6.93 hours a week. The majority of the students believed that listening to music for one to two hours could be harmful to their hearing. Researchers found that the majority of the participants were aware of the fact that they were listening at harmful or unsafe levels, such that they were intentionally listening to their device at dangerous levels or being cautious by turning the volume down to a safe level. The study also found that while the young adults are listening to music on their personal listening device at safe volumes, they are listening to the music for long durations at a time that poses additional risks to their hearing. Overall, the results of this study showed that the students were able to accurately report their listening levels (Hutchinson et al., 2015). If young adults are aware of how loud they are listening to music, or how long they are listening to music, why are they doing it even though they know it can damage their hearing?

There are numerous factors that influence personal device usage in young adults. First, background noise is an important consideration as individuals often increase the volume on their device above the background or ambient noise in the environment. One study found that 24.7% of young adults exceeded the daily recommended listening levels

by 100% in the presence of 61 dBA to 80 dBA background noise (Jiang et al., 2016). Meaning that young adults are increasing the volume of their music to sometimes dangerous levels in the presence of background noise. Although they are attempting to drown out the background noise, by turning up the volume of their device, they are further damaging their hearing. This lack of awareness regarding personal devices is dangerous, and ultimately, it poses a major risk to the health of many young individuals.

Social factors may lead listeners to ignore the dangers that personal listening devices possess. In fact, the well-known iPod and iPhone devices have made an impact on society. There is a certain stigma associated with millennials and i-pods, with this generation relying heavily on phones and devices for constant communication and entertainment (Levey et al., 2011). Also, people enjoy the idea that they are able to escape from the sound around them by turning their music on and tuning out outside noises. It gives users a sense of isolation when in public situations, causing them to also ignore the risks involved with personal device usage (Levey et al., 2011).

Another factor that might be influential personal device usage is gender. One study found that males listened to their music 6.1 dB higher than females in the same quiet setting (Hutchinson et al., 2015). Other studies have shown that gender does not have an effect on listening habits, therefore, more research is needed regarding gender and personal device usage. Another area of exploration, but requires more research is the type of music that one enjoys. Certain genres of music (e.g., heavy metal) are listened to at louder levels than others (e.g., classical music) although there is not a lot of research on this factor.

The last influential factor is the type of headphones that the personal device user wears. One study reported that 92% of their participants used ear buds as compared to over-the-ear headphones (Hutchinson et al., 2015). Despite their popularity, insert earphones produce a sound output that is 7 dB A to 9 dB A louder than over-the-ear headphones (SCENIHR, 2004). Over-the-ear headphones are considered to be the standard set of headphones, but insert earphones are now more common because personal listening devices now often include a pair of insert earphones with their purchase. The last type of headphones is a noise-canceling headphone that works to cancel the environmental or ambient noise, limiting the loudness you need to listen to your headphones. The headphones themselves cause no damage to one's hearing, but while using noise-canceling headphones, many young adults turn up the volume that negates their benefit. Some personal device users enjoy the surround sound isolation feeling that goes back to the social aspect of personal listening devices. Noise-canceling headphones such as *Beats* and *Bose* are becoming increasingly popular, but can be detrimental to a young adults hearing if they are not properly educated on their use. This is an area where more research can be done, and researchers can show the differences in headphones.

Young adults who are using personal listening devices for an extended duration and at unsafe volumes have been reporting greater problems with their hearing. Users who listened to their devices at an average of 75 dB A reported tinnitus more often and reported having trouble hearing and understanding others immediately following personal device usage (Sulaiman et al., 2015). Also, personal device users have showed higher hearing thresholds than non-users (Jiang et al., 2015; Levey et al., 2011; Mostafapour, Lahargoue & Gates, 1998; Sulaiman et al., 2015). The longer that young adults use

personal listening devices at unsafe levels or for extended durations, the greater the risks of noise-induced hearing loss. The participants who used personal listening devices had significantly higher hearing thresholds than non-users also those who used their devices for six or more years (Sulaiman et al., 2015).

Hearing Prevention in the Young Adult Population

Now that we know the impact that personal device usage has on young adults, what is stopping them from using hearing protection and proper ways to prevent hearing loss? Throughout this final chapter, we will examine why young adults are avoiding hearing protection and what recommendations can be made to promote a greater usage of hearing protection and prevent hearing loss. Finally, we will investigate the results of a survey administered to young adults regarding noise-induced hearing loss, personal device usage, and prevention of hearing loss

Hearing protection is crucial to the preservation of an individual's hearing. There are several types of hearing protection such as ear-muffs that are placed over the outer ear and earplugs that insert into the ear canal. There are numerous workplaces that require employees such as construction workers, military personnel, pilots, and landscapers, to wear hearing protection for their safety when that job involves exposure to loud noise. Hearing protection is also used to prevent hearing loss for recreational purposes such as attending a concert. Protecting your hearing can come in many different forms, even giving yourself a break from listening to loud music.

There are a lot of different types of hearing protection available that need to be promoted. A common complaint about earplugs is that people who use them feel "plugged up" from the outside world. Currently, there are many new types of earplugs

that eliminate that problem. For example, Alpine Hearing Protection is a company that manufactures and sells hearing protectors. Alpine has produces different types of hearing protectors such as a universal ear plug that has multiple slates of protection in order to fit in the ear better and users report feeling less "plugged up". Additionally, otoplastics is a type of hearing protection that is customized to fit the user's ear and adjustable based on the level of loudness (Roode, 2015). Having all these different types of hearing protection suggests that their lack of use is not a the problem of few options, but rather a problem of awareness and education on hearing loss and the damage of noise exposure..

An online survey was administered to 2,151 college students to determine the students' attitudes towards noise and assess related symptoms due to noise exposure (Balanay & Kearney, 2015).The study found that 39.6% of the 2,151 participants experienced at least one of the hearing symptoms associated with noise-induced hearing loss. Of the 1,780 students who participated in at least one noisy activity (i.e., sporting events, dances, concerts, using firearms and using noisy tools), only 41% reported using some type of hearing protections. The majority of the 41% used hearing protection when using firearms, working with loud tools and playing in a band. Another important factor in this study was young adults' attitudes towards noise (Balanay & Kearney, 2015).

Young adults who have a negative attitude towards noise (meaning they dislike loud noises or feel uncomfortable around loud noises) are more likely to wear hearing protection (Balanay & Kearney, 2015). Also, negative attitudes are also found in young adults who have suffered damage due to noise-induced hearing loss such as tinnitus and difficulty understanding others. This may be because of the impact these symptoms are having on their everyday life (Balanay & Kearney, 2015). Students who are already

showing signs of noise-induced hearing loss are also more likely to use hearing protection. However, the opposite effect is observed when students have positive attitudes towards noise, where they do not feel that their hearing is at risk due to noise, are less likely to wear hearing protection. In this study, if a student reported at least one hearing symptom (such as tinnitus and trouble hearing others), they were more likely to use hearing protection compared to a student who reported no hearing symptoms (Balanay & Kearney, 2015). Overall, this indicates that young adults are not using hearing protection until the symptoms of hearing loss emerge. Often, waiting until symptoms occur is too late, and permanent damage to the ear may have already happened.

Why are the majority of these college students not using hearing protection? When going to a sporting event or concerts, students reported that they do not see the need to use hearing protection (Beach, Gilliver & Williams, 2016). One reason is because young adults feel awkward using earplugs or earmuffs at these types of events because it is not the norm (Balanay & Kearney, 2015). Something needs to be done to promote the use of hearing protection in young adults, there is very little education on noise-induced hearing loss and hearing protection.

More awareness is needed on noise-induced hearing loss and ways to prevent it for young adults in America. Programs need to be implemented to teach young adults about hearing protection (Balanay & Kearney, 2015). If wearing hearing protection were the norm, then young adults would not feel uncomfortable going to concerts and big sporting events wearing earplugs. Programs should start in elementary school where young kids can learn about noise-induced hearing loss, how to prevent noise-induced

hearing loss and the dangers of using their personal listening devices too loudly (Balanay & Kearney, 2015). College campuses and high schools can also raise awareness regarding safe noise levels and promote the use of hearing protection (Balanay & Kearney, 2015).

Survey on NIHL in Young Adults

Participants. To determine the how knowledgeable young adults are on noise-induced hearing loss, a survey was administered to Augustana College and high school students. There were 51 participants, 88.2% were 19-23 years old, 9.8% were 16-18 years old, and 2% were 13-15 years old. The majority of the participants were female (88%). This study was approved by the Institutional Review Board at Augustana College (See Appendix A for form).

Methods/Materials. There were 20 questions on the survey including questions like "wearing hearing protection is important" and "I've been properly educated on the risks involved with my hearing because of listening to loud music." Here, participants rated the statement on how much they agreed with the statement (1=totally disagree to 5= totally agree). Other questions inquired about music habits, for example, "how often do you listen to music" and "how loud do you listen to your music." When asked to report how loud they listened to music, a scale from 1-10 was used where 1 was having the volume on the lowest possible setting and 10 were having the volume turned all the way up. Finally, several questions asked if young adults experienced any symptoms of noise-induced hearing loss like "have you ever experienced ringing in your ears or tinnitus after listening to music or after being exposed to loud noises." These questions were answered by "always", "sometimes" or "never" (See Appendix B for list of all questions).

Procedure. First, the online survey was created using Google Forms and then sent to participants via email through familiar contacts. A letter of consent was included in the email for adults taking the survey (See Appendix C for consent form). A signed consent form was obtained for each participant under the age of 18 (See Appendix D for minor consent form). All results were recorded on a spreadsheet.

Results. Of the 51 participants, 47.1% reportedly listened to their music from an i-pod or an i-phone, whereas 27.5% used a smartphone, 15.7% used a laptop, and 9.8% reported using speakers from either a computer or speaker system. Nearly all of the participants (*n* = 48) used headphones when listening to their personal devices. Of those 48 participants, 42 of them reported using insert headphones and the other six reported using over-the-ear headphones. Of all 51 participants, 80% reportedly did not use noise-canceling headphones. When asked how loud they listened to music, most participants reported listening in a moderate range (5=15.7%, 6=19.6% and 7=27.5%). However, there were some students that reported listening to their personal devices at a volume in the range of 8-10 (8=3.9%, 9= 7.8% and 10=2%).

Figure 1

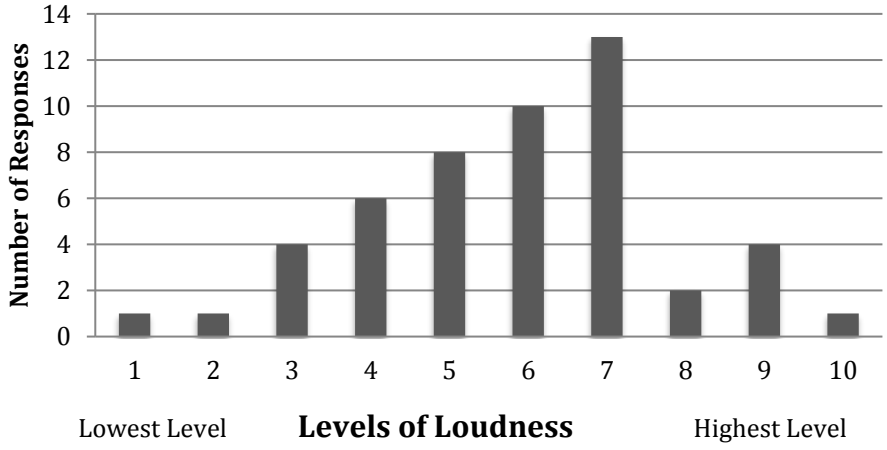

Figure 1. The loudness levels reported by participants in listening to music using a personal listening device. The lowest level is indicated by 1, 5 is the middle setting and 10 is the highest level of loudness. (N=51)

We not only wanted to know how loud young adults reported listening to their music, but how often they listened to their music. The results showed that a majority of young adults (42%) listen to their music for one to two hours a day, but there were 14% that listened to music for over four hours a day, that is dangerous to their hearing.

Figure 2

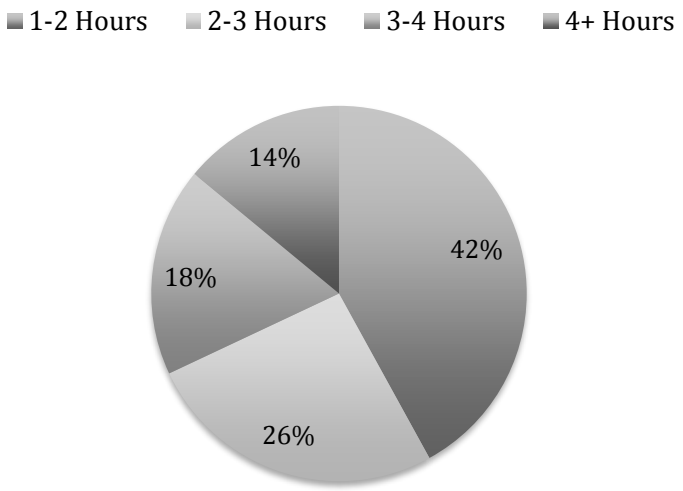

Figure 2. Represents the amount of hours a participant listened to a personal listening device. Responses were categorized by number of hours reported from 1-2, 2-3, 3-4 and over 4 hours.

When asked if participants thought they had a hearing loss, 23.5% reported "yes" and 39.2% reported that they were "not sure." Only 37.3% of participants reported that they did not have a hearing loss. That being said, 51% of the participants reported that they have experienced difficulties understanding others after listening to their personal listening devices. Further, 11.8% of participants reported that they were not sure if they had ever experienced difficulties understanding others after listening to personal listening devices and 37.3% reported they have not experienced any difficulties. Interestingly, most students (58.8%) reportedly had experienced ringing in their ears after listening to music. The majority or 90% of the participants who reported having "ringing in their

ears" sometimes experience, and the remaining10% reported always having tinnitus. This suggests that young adults are showing noise-induced hearing loss symptoms due to their personal listening devices. Also, it should be noted that 98% (n=50) of the participants reported never having been diagnosed with a hearing loss.

Figure 3

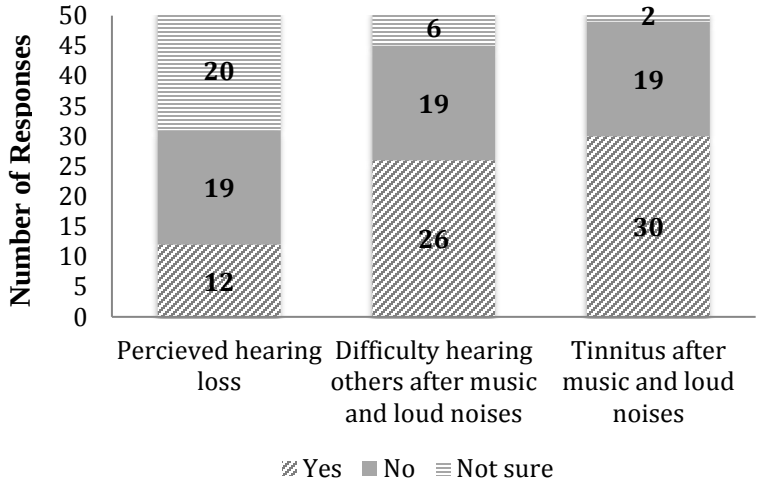

Figure 3. This graph represents participant's perception of their hearing abilities. The questions (from right to left) were: A) Do you think you could have a hearing loss? B) Do you ever have difficulty understanding others after listening to music and loud noises? C) Do you ever experience ringing or tinnitus in your ear after listening to music and loud noise? Results are reported as yes, no and not sure in number per category.

Regarding hearing protection, 90.2% (n=46) of participants reported not using hearing protection. However, 92.2% (47) reported that they thought using hearing protection was important, and 80.4% (41) of those that do not use hearing protection said they would consider using it. Some of the reasons participants said they would want to protect their hearing were "hearing is important for daily function," "It is worth more to invest in hearing protection rather than lose my hearing" and to "save my hearing."

Table 1. Participant's Perceptions on Hearing Protection

	Do you use hearing protection?	Do you think using hearing protection is important?	Would you ever consider using hearing protection?
Yes	9.8% (n=5)	92.2% (n=47)	80.4% (n=41)
No	90.2% (n=46)	7.8% (n=4)	19.6% (n=10)

If young adults are willing to use hearing protection, then why aren't they? Most participants (86.3%) reportedly had never been taught about using hearing protection. The students who were taught to use hearing protection were in band, had parents who informed them about it, or were informed by their physician or Ear Nose and Throat specialist to use hearing protection.

Further, the majority of participants felt as though they had not been properly educated on the risks involved with listening to loud music. The majority of participants also reported that they feel that people need to be more informed on the dangers of hearing loss due to loud noise exposure. Also, most of the participants reported that they "somewhat agreed" with the idea of listening to their music quieter or for less time to better protect their hearing.

Figure 4

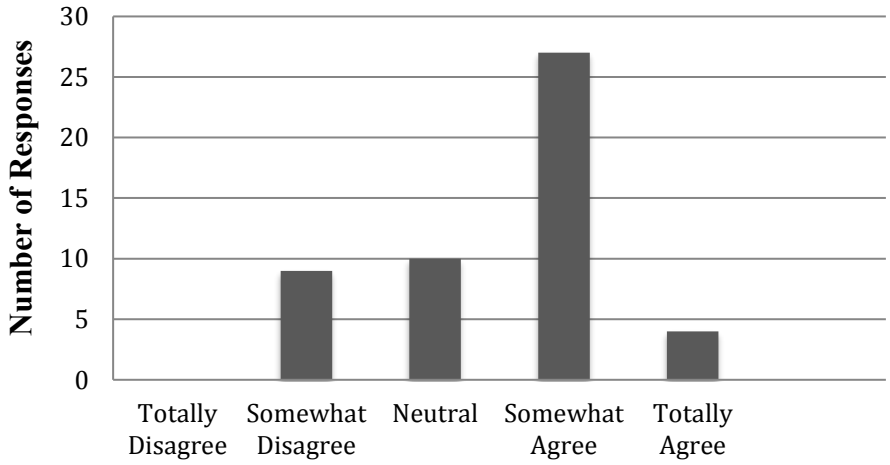

Figure 4. Participants response on the statement of "how damaging is listening to a personal device on your hearing. Responses were gathered on a five point scale from totally disagree to totally agree.

Figure 5

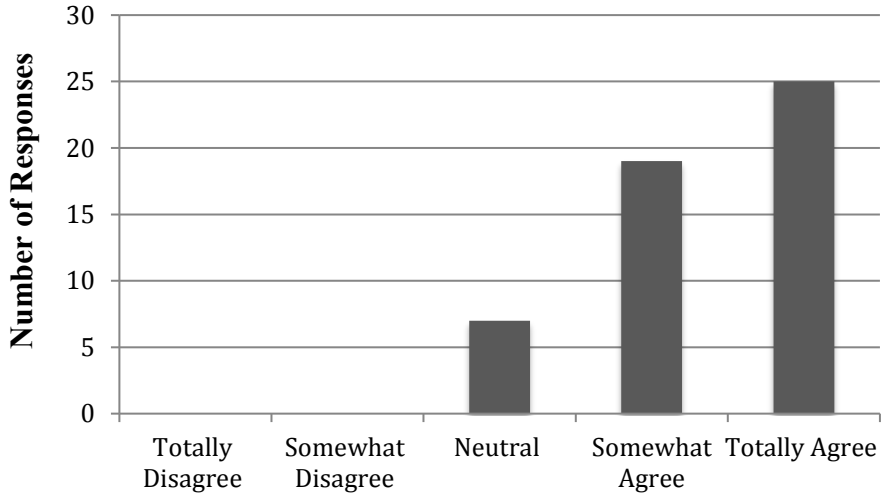

Figure 5. Participants response on the statement of "People need to be more informed on the dangers of hearing loss due to loud noise exposure." Responses were gathered on a five point scale from totally disagree to totally agree.

Figure 6

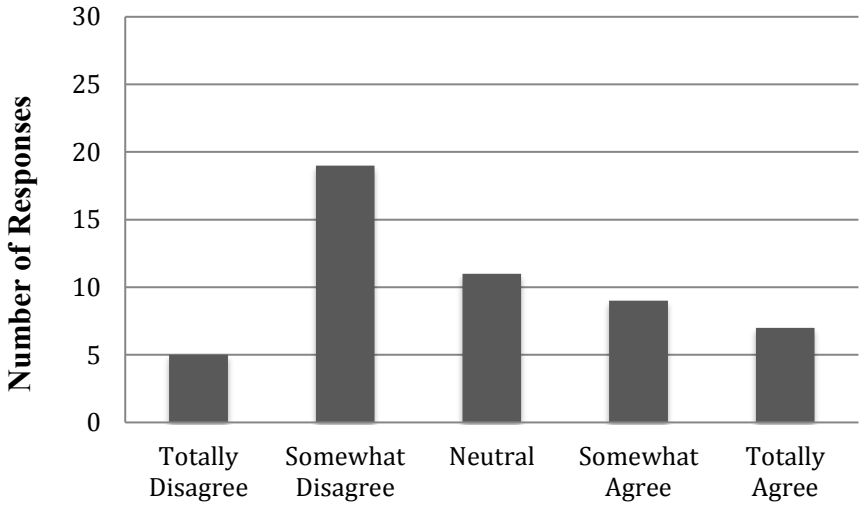

Figure 6. Participant's response on the statement of "I've been properly educated on the risks involved with my hearing because of listening to loud music." Responses were gathered on a five point scale from totally disagree to totally agree.

Figure 7

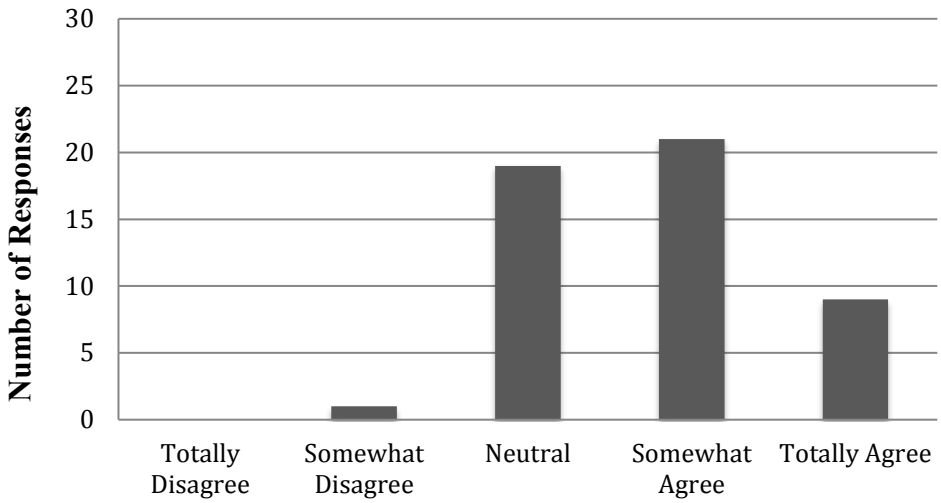

Figure 7. Participant's response on the statement of "Wearing hearing protection is important." Responses were gathered on a five point scale from totally disagree to totally agree.

Figure 8

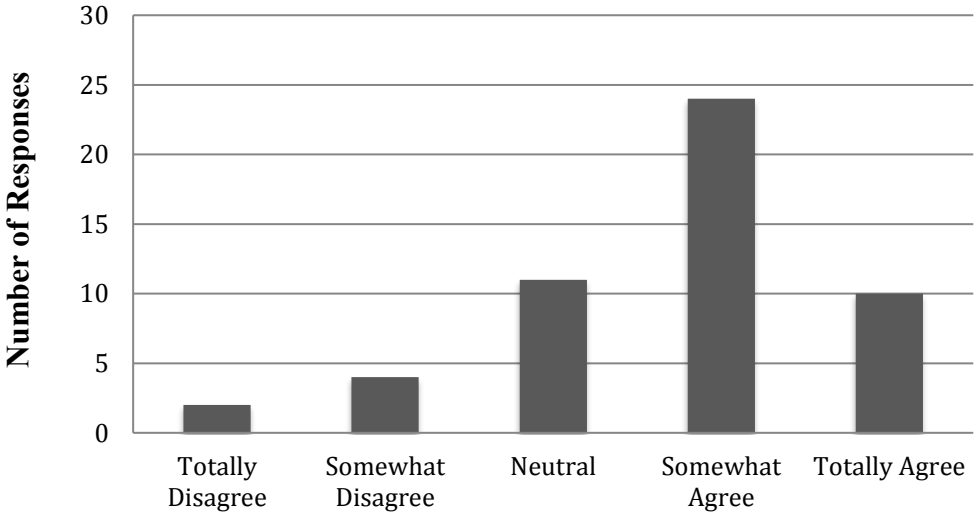

Figure 8. Participants response on the statement of " I would be willing to listen to my music quieter or for less time to better protect my hearing" Responses were gathered on a five point scale from totally disagree to totally agree.

Reflections on Survey Results

Young adults report that they are not aware of the situations of where they need to use hearing protection. Hearing prevent comes in many forms, not just use of hearing protection such as earmuffs or earplugs. Protecting your hearing can be as easy as turning your music down and taking breaks from listening to personal listening devices. Young adults need to be aware of when they need to use hearing protection and what the dangers are of listening to personal listening devices for long hours at high volumes. Most young adults reported that they would be willing to protect their hearing because they do not want to lose it, but they need to be educated on how to protect their hearing. Not only do young adults need to be educated on hearing protection, but also they need to be made aware of the risks of noise-induced hearing loss and be educated on noise-induced hearing loss. As other studies have shown as well as this survey, there is a definite lack in the education regarding noise-induced hearing loss. Many young adults are already experiencing tinnitus and having trouble hearing others. This suggests they are already experiencing noise-induced hearing loss.

Conclusion

This research essay on noise-induced hearing loss examined how the hearing mechanism is changed following noise exposure. New treatments are being studied to protect the inner hair cells in the cochlea and possibly regenerate the damaged hair cells. Currently, these studies are performed on animals. We need to find a way to make them safe and testable on humans.

As many of the studies indicate, young adults are showing signs of tinnitus and having difficulty hearing others because of loud noise exposure because of increased usage of personal listening devices. We know that young adults are at risk for noise-induced hearing loss if they are listening to their personal devices for too long and too loudly. We need educate young adults on the dangers of listening to their personal devices at high levels and for extended periods of time. From these results, we know that most young adults would protect their hearing if they knew about the dangers.

The survey results reported here shows us that there is a significant lack of education when it comes to noise-induced hearing loss and where children and young adults can go to learn about noise-induced hearing loss. Most students know that hunting and going to a loud concert puts them at risk for noise-induced hearing loss. However, they do not know that listening to music above 60% of the volume for more than 1-2 hours a day can also cause hearing damage. Students are not educated on noise-induced hearing loss and hearing protection. Some students are already showing symptoms of noise-induced hearing loss and they are not sure how to prevent it.

Therefore, we need to start educating people on the risks of noise-induced hearing loss. It can not just start when young adults get to college it needs to start sooner. In

middle and high schools, there needs to be some awareness of noise-induced hearing loss and an introduction provided on proper ways to protect hearing. If advocacy for hearing health starts early in elementary and high schools, then young adults will better understand hearing protection and how their hearing is at risk before it is too late. Based on the results of the survey, a good place to begin awareness campaigns on hearing loss and hearing prevention is on college campuses. College students are at a time in their life where they are making decisions for themselves regarding their health, and at the same time, attending extremely loud events or using personal listening devices that may have damaging effects on their long-term hearing health. Because of all the advertising on college campuses about activities and events, why not have one on noise-induced hearing loss? If young adults were educated on the dangers of noise-induced hearing loss, they might be more likely to use hearing protection and protect their hearing before they show signs of noise-induced hearing loss.

Lack of awareness is only part of the problem though. It is not the norm to use hearing protection. People can feel awkward or uncomfortable with wearing ear plugs. Campuses need to make it the norm and better protect their students hearing. Pass out earplugs at football games, limit the noise levels of campus events, and educate students. By doing things like passing out ear plugs at games, young adults are going to be more likely to use them if they understand why they need to. Neither education nor hearing protection can stand on its own, they must be exercised hand-in-hand.

If young adults are not properly educated on noise-induced hearing loss, we are going to see more students present to the audiology clinics with signs of noise-induced hearing loss. The prevalence of noise-induced hearing loss has increased in this

population, and we continue to grow if more awareness of hearing loss and use of hearing protection are not done. Noise-induced hearing loss is preventable, and it starts with protecting your hearing at a young age and limiting your exposure to loud noises. Educating young adults on noise-induced hearing loss is the first course of action.

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Appendix A

Augustana Institutional Review Board
Request for Review of Research Using Human Participants

Principal Investigator and faculty adviser:
Principal Investigator: Maeve Derrig, CSD major
Faculty Advisor: Ann Perreau, Ph.D., CCC-A

Department:
Communication Sciences and Disorders (CSD)

Date Submitted:
February 4, 2017

Project Title:
An investigation of noise-induced hearing loss in young adults

Review of this project is requested on which basis:

__X__ Regular review. Complete all items and attach questionnaires, non-standard tests, consent forms, cover letters, and other supporting documents.

____ To confirm exempt status. Complete items 1 through 7. Under which exempt category, as designated in section D. of the IRB guide, do you think this project qualifies for exemption? (Give paragraph letter/number.)
_____

Please type your responses to items 1-9 below. Add additional space as needed to give sufficient information for the committee to be able to evaluate the risks and benefits of your research project.

1. If any pre-approved departmental or other protocols will be followed for this project, please indicate the name of the protocol.

Not applicable.

2. Brief Project Description – Please write for a lay audience and explain any technical terminology

a. Purpose, hypothesis, or research question:

It is estimated that over 10 million adults in the United States have some degree of noise-induced hearing loss (Martin & Clark, 2000), and that more than 30 million Americans are exposed to hazardous noise on a regular basis (NIDCD, 2002). Personal listening devices (e.g., I-Pods and MP3 players) are very popular among young adults today. When young adults listen to these devices at high decibel levels, they potentially can lead to noise-induced hearing loss overtime. A recent study indicated that half of their college-aged participants did not realize that they have noise-induced hearing loss, when, in fact,

they were found to have hearing loss (Rota-Donahue & Levey, 2016). Many young adults continue to use personal listening devices without knowing the dangers of listening to devices at high levels, or how to practice safe use of these devices. The purpose of this survey is to determine a) the perceptions of young adults regarding the impact of personal listening devices on hearing, b) the use of hearing protection among young adults, and c) why young adults may avoid hearing protection.

References:

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Rota-Donahue, C., & Levey, S. (2016). Noise-induced hearing loss in the campus. *Hearing Journal*,*69*(6), 38-39.

b. Procedures:

The student researcher, Maeve Derrig, is writing a senior inquiry paper on noise-induced hearing loss in young adults. She is also investigating how young adults perceive the dangers of noise exposure and ways to prevent it, specifically with regard to their use of personal listening devices and use of hearing protection. We are seeking permission for her to administer a questionnaire to young adults, including Augustana college students, using an online format via Google Forms. See Appendix A for a list of her questionnaire items to be included on the Google Forms questionnaire.

3. Participants

a. Age, sex, and approximate number: 50-75 young adults ages 13-22, male or female
b. Inclusion/exclusion criteria, if any: Should not be a CSD major
c. Method of recruiting: An e-mail sent to Augustana students and to familiar contacts for students in junior high and high school
d. Inducement for participation: None

4. Are participants at risk? (Describe, if 'yes'.)

There are no foreseeable risks to the participants.

5. Steps taken to minimize any risks identified in #4.

Not applicable.

6. Are illegal activities involved? (Describe, if 'yes'.)

No.

7. Is deception involved (e.g., withholding information, providing misinformation, using confederates)? (If 'yes', please describe. Explain why it is necessary, explain how participants will be debriefed, and, if applicable, attach a copy of the debriefing statement.)

No.

8. Anticipated benefits to participants and/or society?
By gathering experiences and insights directly from young adults, CSD students will better understand how these individuals perceive hearing loss, and the extent to which young adults are willing to protect it.

9. How will prior informed consent be obtained? (Attach copies of consent forms and/or cover letters if they are to be used. Please see Informed Consent Document checklist below.)
By completing the anonymous questionnaire, subjects will be providing their informed consent for participating in this research project. A statement will be provided in the email, stating the informed consent policies as follows:
Informed Consent: This survey is anonymous and you will not be identified in reports or publications that may result from this study. You are asked not to identify yourself or other individuals by name on your anonymous questionnaire. You may refuse to participate in this study without penalty or negative impact on you. You may indicate your refusal simply by not returning the questionnaire.

10. If extra credit is used as an inducement for participation, what alternatives for gaining extra credit are offered to participants?

Not applicable.

11. Describe the procedures relating to the anonymity of participants, if applicable, and procedures for keeping participant data confidential and secure. For example, what documents or databases will contain names or participant numbers, who will have access to these, and how will they be physically or otherwise secured? When will the research materials gathered from or about individual participants be destroyed?
No personally identifying information will be included in the paper. We will secure all responses to the questionnaire on a password protected computer in Brodahl and any data will be kept confidential in the faculty advisor's locked office.

By submitting this RFR to the Augustana IRB, I am agreeing that I have reviewed the Augustana College Policies and Guidebook for Research Involving Human Participants and I agree to adhere to the responsibilities of investigators as specified in Section B. I also agree to report any significant and relevant changes in the procedures or instruments to the Committee for additional review.

Ann Perreau, Ph.D., CCC-A
Assistant Professor, Communication Sciences and Disorders

Appendix B

Questionnaire Items from Survey

1. What is your age in years?
2. What gender do you identify with? (Male, Female)
3. How often do you listen to music or a personal listening device? (Hours a day)
4. What kind of personal device do you use? (i-pod, computer, ipad etc.)
5. Do you use headphones when listening to a personal device or music? (yes/no) If yes, what kind? (insert, over the ear, etc.)
6. How loud do you listen to music? (1=being the softest setting; 10=being the loudest setting)
7. Do you use noise-canceling headphones? (yes/no)
8. Do you think you could have a hearing loss? (yes/no/not sure)
9. Have you ever experienced difficulty hearing others after you listen to music or after being exposed to loud noises? (yes/no/not sure)
10. Have you ever experienced ringing in your ears or tinnitus after listening to music or after being exposed to loud noises? (yes/no/not sure)
    a. If yes, how often? (every time, sometimes etc.)
11. Have you ever been diagnosed with a hearing loss? (yes/no/not sure)
12. Do you use hearing protection? (yes/no) If yes, what kind of hearing protection do you use? If no, what kinds of hearing protection do you know are used to protect your hearing?
13. Why do you think it would be important to use hearing protection?
14. Has anyone ever taught you about hearing protection?
    a. If yes, who?
15. If you don’t use hearing protection, would you ever consider using hearing protection?
    a. If no, why?
    b. If yes, why?

Now, please answer the following questions using a 5-point scale (1=totally agree, 2=somewhat agree, 3- neutral, 4=somewhat disagree, 5=totally disagree)

1. Wearing hearing protection is important.
2. Listening to a personal device is damaging to your hearing.
3. People need to be more informed on the dangers of hearing loss due to loud noise exposure.
4. I would be willing to listen to my music quieter or for less time to better protect my hearing.
5. I've been properly educated on the risks involved with my hearing because of listening to loud music.

Appendix C

Recruitment email to potential participants

An investigation of noise-induced hearing loss in young adults

Hello,

I am currently completing my senior research under the direction of Dr. Perreau on noise-induced hearing loss.

Noise induced hearing loss is damage to your inner ear due repeated exposure to high level sounds. You are being contacted because you are a young adult who may be at risk of noise induced hearing loss due to personal device usage. We invite you to complete the following questionnaire. Your participation in this study is anonymous and it will take approximately 10 minutes to complete. By completing this study, you will help us to learn more about noise-induced hearing loss and your perceptions of hearing protection. This study has been approved by the Institutional Review Board at Augustana College. If you have any further questions about your rights as a participant, please feel free to contact the board at IRB@augustana.edu.

We appreciate your time and participation in this study!

Sincerely,

Maeve Derrig

Appendix D

An investigation of noise-induced hearing loss in young adults

Informed Consent Form - Minors

Your child is being asked to participate in this study because they are between the ages of 13-18 and may be at risk of noise-induced hearing loss due to personal device usage (e.g., I-Pods). Noise-induced hearing loss is damage to the inner ear due repeated exposure to high level sounds. For a senior research project, Ms. Derrig is completing an investigation on noise-induced hearing loss in young adults. Ms. Derrig obtained your email through familiar contacts.

If you decide that your child can participate, Ms. Derrig would like to invite your child to complete a survey on noise-induced hearing loss, personal devices and use of hearing protection. Your child's participation in this study is anonymous and it will take approximately 10 minutes to complete the online survey.

By completing this study, your child will help us to learn more about noise-induced hearing loss in the young adult population and their perceptions of hearing protection. There is no charge, nor is there compensation, for your child's participation in this project.

Information that is obtained in connection with this study and that can be identified with your child will not be disclosed. Your child will never be identified by name in any professional works or presentations, a pseudonym will be used in all written and presented works. Any information obtained will be used for research or teaching purposes only. All survey responses we obtain will be kept confidential and physically secure in the faculty supervisor's lab.

Your decision as to whether or not your child participates will not influence any relations with Augustana College or the student researcher, Ms. Derrig. If you decide for your child to participate, you are free to discontinue their participation at any time and no harm will come to you or your child.

If you have any questions, please contact faculty adviser Dr. Ann Perreau at (309) 794-8935. This research project has been reviewed and approved by the Augustana College Institutional Review Board, which can be reached at (309) 794-7450 or IRB@augustana.edu.

You will be offered a copy of this form to keep.

You are making a decision to authorize your child to participate. Your signature indicates that you have read the information provided above and have decided to allow your child to participate. You may withdraw your child from the study at any time after signing this form, should you choose to discontinue their participation.

_____	_____
Signature of Parent or Legal Guardian	Date
_____	_____
Signature of Student Researcher	Date
_____	_____
Signature of Faculty Adviser	Date