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Perceived Harm Level of Personal Listening Devices and Effects on Task Performance

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Perceived Harm Level of Personal Listening Devices and Effects on Task Performance

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Abstract

This study aimed to examine if people know what intensity level of white noise or music will harm hearing with prolonged exposure. Each of the 25 college students were surveyed to find their perceived harm level in white noise and music, then completed a comprehension test while listening to each sound at that intensity level. The participants did not have perceived harm levels above the NIOSH-recommended 85 dB-A and there were no significant differences between the sound conditions. This showed that using personal listening devices while completing daily tasks is highly variable and may not cause harm.

Literature Review

Students are using personal listening devices during their everyday life at intensity levels which can be harmful to hearing (CDC 2020). Personal listening devices are technologies used with earbuds or headphones that output sound for an individual user, and are often used while studying, exercising, and sleeping. As a result, there have been investigations into the effects that listening to music with personal listening devices has on differing aspects of cognition and hearing loss. Students listen to music and white noise for many reasons while they study, but it is possible that they listen to these sounds at high enough intensity levels that it leads to long-term noise-induced hearing loss.

Peng, Tao, and Huang (2007) found that long-term use of personal listening devices can cause significant hearing loss in users, especially in higher frequencies. One hundred twenty young adults between the ages of 19 and 23 who listened to personal listening devices for at least 1 hour a day underwent an otoscopic examination, tympanometry, conventional audiometry, and extended high-frequency audiometry between 10,000 and 20,000 Hz. Peng et al. (2007) split the participants into three subgroups based on their duration of use and gathered a control group of 30 typically hearing adults who did not use personal listening devices. Peng et al. (2007) found significant differences in the hearing thresholds between the control group and the three personal listening device subgroups, especially at 3000, 4000, 6000, and 8000 Hz, although there was no significant difference between the three subgroups. The subgroup with the longest duration of 5 or more years device use also presented with a significant difference in hearing loss at 1000 and 2000 Hz. With extended high-frequency audiometry, the researchers found that the participants with and without a hearing loss from 1000 to 8000 Hz had higher thresholds than the control group. This study revealed that long-term exposure from personal listening devices can cause hearing loss, and extended high-frequency audiometry has greater sensitivity to hearing loss than traditional audiometry.

Like Peng et al., Kumar, Mathew, Alexander, and Kiran (2009) analyzed the output intensity levels of personal music systems and the effect on hearing. Seventy graduate students ranging from 17 to 24 years old completed the study. The researchers asked the participants to set their preferred and maximum volume control settings in a quiet room and on a bus with 65 dB SPL of background noise. Afterwards, the researchers used a probe microphone in the ear canal to measure the intensity of the preferred volume settings. They found that, on average, the participants preferred their music to be 73 dBA regardless of background noise. Since the National Institute for

Occupational Safety and Health (NIOSH) sets the safety limits for volume level at 85 dBA on average for 8 hours, the subjects were not putting themselves at risk for a hearing loss by listening at 73 dBA for 1 to 3 hours a day. Kumar et al. (2009) demonstrated that people often avoid the volume level that will harm their hearing.

Tufts and Skoe (2018) researched the difference in noise exposure between musician and non-musician college students at the University of Connecticut. They had the 22 musicians and 40 non-musicians wear a dosimeter continuously for a week and record in a journal their activities. The researchers found that the musicians were much more likely to reach 100% exposure in a day, which is 85 dBA on average for more than 8 hours. The musicians were more likely to be exposed to loud noise in general and engaged in more high noise-level activities outside of class. Most of the non-musicians were never at full exposure (i.e., 8 hours at 85 dBA) and only five of the 40 non-musicians experienced 100% exposure for three days of the week. This study reveals some interesting information about how even students who do not regularly expose themselves to loud music during practice still may encounter dangerous levels of sound.

Wolfe (1983) tested college-aged students on their ability to complete a task while listening to varying music intensity levels. Participants were non-music major volunteers who were taking an introductory music course and received extra credit for completing the study. The four music pieces played during testing were instrumentals that would be recognizable to the experimental population. Four different groups listened to them at 0, 60-70, 70-80, or 80-90 dB-C. The participants completed an arithmetic test while the music played. After analyzing the results, the researchers found that the music volume had no significant impact on the arithmetic test scores, although the subjects in the 80-90 dBC group did report that the music was distracting. In conclusion, music loudness did not affect task performance, but it did create a distraction for the subjects when played at a significantly loud volume.

In an effort to learn more about judgement of learning, which is how much a student believes they have memorized, Barnes and Dougherty (2007) had students read a list of words one by one, guess how many they could recall overall, and recall them while dividing their attention at different stages of the process. The secondary action was to listen to spoken words on a headset while completing the other actions. Barnes and Dougherty found that divided attention caused the most trouble in recall when done during the studying and recall stages. Since there was not as much of an effect on the judgement of learning stage, this could suggest that subjects did not retrieve the information when determining their judgement of learning. This study provides relevant information about how dividing attention can affect one’s focus and recall, which is important when analyzing the effect of auditory distraction on completing a task.

Although these studies examined the effects of recreational noise exposure on hearing loss, focus, and memory, the perceived level of harm and its effect on task performance have not yet been measured. Peng et al. (2007) demonstrated that the high intensity output of personal listening devices may not have an impact on hearing health currently, however those devices are surely a threat to future hearing ability (Peng et al. 2007). Kumar et al. (2009) helped show at what intensity level students prefer their music, but that preferred level was close to the 85 dBA limit set by the NIOSH and might surpass this limit when students are asked to set their maximum listening level. Wolfe (1983) showed that high intensity music and white noise can distract subjects while they complete a math-based task, but the distraction did not factor into the task performance scores. Tufts and Skoe (2018) demonstrated that many college students are regularly exposing themselves to a dangerous noise level. Finally, Barnes and Dougherty (2007) revealed that students who listen to music or white noise while studying may have inaccurate estimations about how much material they learned, or may recall less information. Together, these studies lead to the following research questions.

Research Questions and Hypotheses

When subjects are allowed to pick the intensity level where they perceive that the sound is harmful, will they exceed 85 dB HL? Will they still be able to complete a cognitive task while they listen to music and white noise at that intensity level? Will there be a difference if the music presented includes lyrics or is only instrumental? Based on previously conducted studies, it may be expected that the participants will allow the music and white noise to escalate to an unsafe intensity level and that task performance will be impaired when using a personal listening device to listen to sound at that level. Also, when students complete a task in quiet or during a passive listening experience such as listening to white noise and instrumental music, they will perform better than when they listen to music with lyrics.

Methodology

Participants. The participants were 25 Butler University students with typical hearing who use personal listening devices regularly to listen to music and/or white noise. The subjects were recruited using flyers and advertisements around campus. The sample was diverse and included participants from all genders, races and ethnicities, academic grades, and colleges of the university to ensure there was equal representation.

Stimuli and Procedure. Data were collected using predetermined decibel levels for the lyrical music, instrumental music, and white noise samples and a perception scale that allowed the subject to rate the decibel level based on how harmful to the ear it might be. The lyrical and instrumental music selected was widely recognizable and the sound clip chosen was from a section of the song with consistent volume. The sound clips were saved onto a CD and played through a GSI-61 audiometer using an attached DVD player. The white noise was also presented at consistent sound levels during the study using the preexisting white noise options on the audiometer. The decibel levels were set at 60, 70, 80, 85, 90, and 95 dB HL for testing, although the white noise only went up to 90 dB because the audiometer limits higher decibel levels for that noise.

Upon arrival, the participants filled out consent forms and history forms to ascertain their current hearing health as well as how often they use personal listening devices. Participants self-reported their estimated hours per day of use, time since most recent use, and duration of most recent use. They also shared in which settings they usually use their personal listening devices, as well as if others have expressed concern about the volume of their device. Each participant was assigned a random participant code that determined which order they would set their perceived harm levels as well as which order they would listen to the music clips or white noise as they completed the reading comprehension and math test.

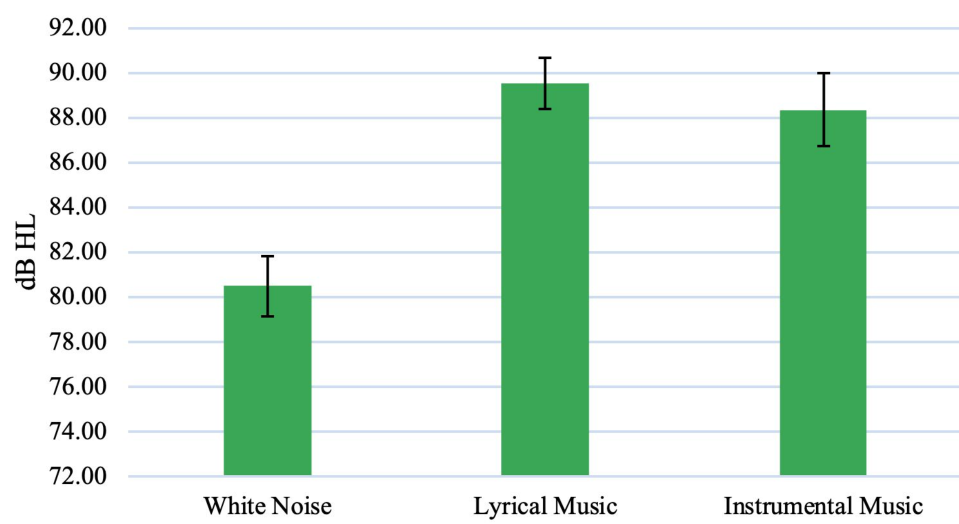
All the participants first had their hearing tested using traditional otoscopy and audiometry to ensure all participants had hearing within normal limits (hearing thresholds <20 dB HL). If the participant was found to have a hearing impairment, they were excluded from the study. Two participants had cerumen occlusion in one or both ears, and two participants had mild hearing loss, so those participants were excluded. The subjects were presented with either lyrical music, instrumental music, or white noise, at 60 dB HL. They rated how damaging they thought the sound was to their hearing on a 7-point interval scale from “not damaging at all” to “extremely damaging.” In succession, the researcher presented the sound at 70, 80, 85, 90, and 95 dB HL, until the participant indicated the noise was “extremely damaging.” The process was then repeated with the other sounds.

Subjects then completed a reading comprehension and math test both in quiet and while listening to white noise, lyrical music, and instrumental music at 5 dB less than their perceived harm level. The reading comprehension and math test was compiled from ACCUPLACER practice tests created by CollegeBoard (Practice 2019). Each subtest contained five reading comprehension questions and five math questions. Participants were asked to complete the four subtests to the best of their ability as quickly as possible. Each subtest was completed with a different sound condition and was timed separately. The quiet round served as the control condition. After the participant completed all listening and cognitive tasks, the researchers presented the participants with their audiogram and a set of earplugs for their participation.

Results

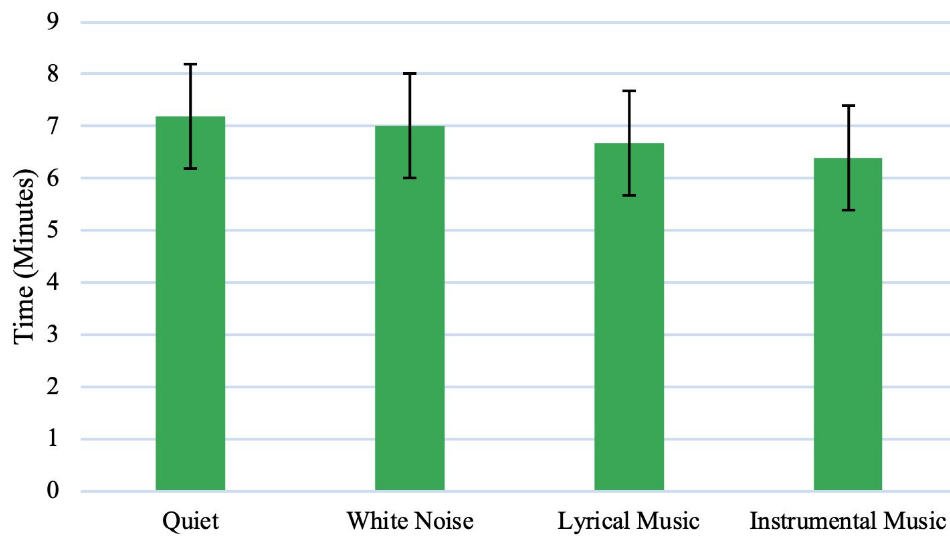
In the history survey completed at the beginning of the study, all of the subjects reported that they use earbuds to connect to personal listening devices, with only 28% using headphones. Most of the subjects used personal listening devices while studying (88%), for recreational use (84%), and while working out (72%), with only a few using them while sleeping (12%). Six of the 25 participants reported that they had someone express concern about the volume of their device. When asked about their hearing, three participants described it as excellent, fifteen described it as good, seven described it as fair, and no one described their hearing as poor. After otoscopy and audiometric testing, four participants were dismissed for having hearing loss. Those four subjects did not seem to be aware of their hearing loss, as three of them described their hearing as good and one described their hearing as fair.

Figure 1: Perceived Harm Level



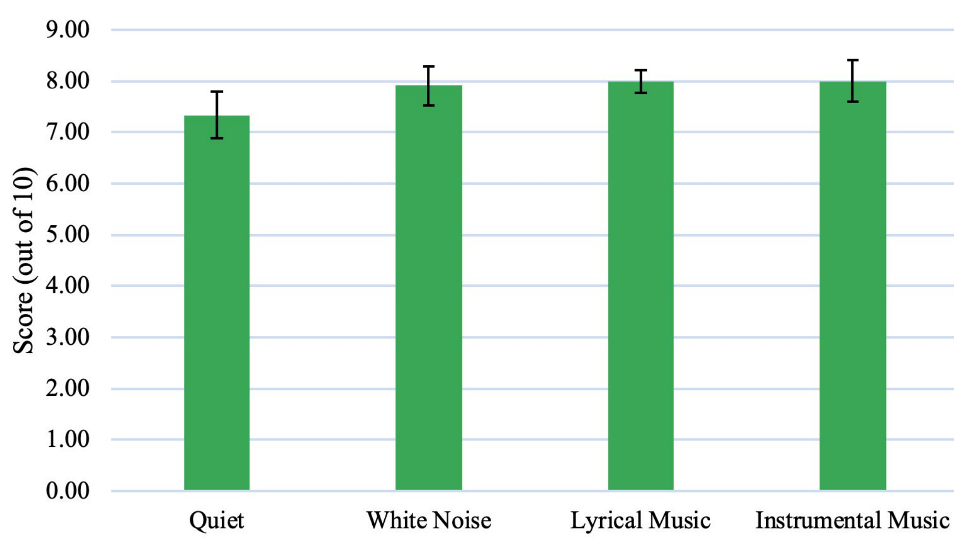
As shown in Figure 1, the perceived harm level was the highest for lyrical music (89.52 dB HL), followed by instrumental music (88.33 dB HL), then white noise (80.48 dB HL). A repeated-measures ANOVA did not reveal any statistically significant differences across condition, *p* = ns.

Figure 2: Time Per Subtest

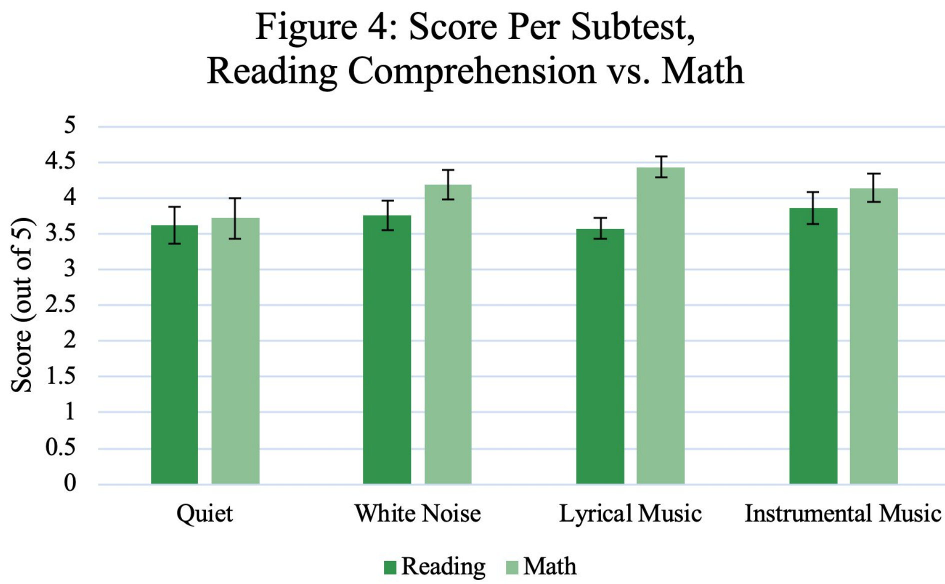


In Figure 2, the time to complete each subtest was the highest in quiet (7.20 minutes), followed by white noise (7.02 minutes), lyrical music (6.68 minutes), then instrumental music (6.39 minutes). A repeated-measures ANOVA did not reveal any statistically significant differences across condition, $F(2, 40) = .852$, $p = .43$.

Figure 3: Score Per Subtest



In addition, in Figure 3, the score on each subtest out of ten was the highest in lyrical music (8.00) and instrumental music (8.00), followed by white noise (7.90), then in quiet (7.33). A repeated-measures ANOVA did not reveal any statistically significant differences across condition, F(2, 40) = .037, p = .956.



Finally, in Figure 4, the score on reading comprehension for each subtest out of five was the highest in instrumental music (3.86), followed by white noise (3.76), quiet (3.62), then lyrical music (3.57). The score on the math portion for each subtest out of five was the highest in lyrical music (4.43), followed by white noise (4.19), instrumental music (4.14), then quiet (3.71). Scores on the math section were consistently higher than the scores from the reading comprehension portion. The difference between the reading comprehension and math portions was highest in lyrical music (0.86), followed by white noise (0.43), instrumental music (0.29), then quiet (0.10). A repeated-measures ANOVA did not reveal any statistically significant differences across condition, p = ns.

Discussion

This study examined if students are aware of the intensity with which white noise or music will harm their hearing over time, as well as if listening to loud sound effects performance while completing academic tasks. When subjects are allowed to pick the intensity level where they perceive that the sound is harmful, will they exceed 85 dB HL? Will they still be able to complete a cognitive task while they listen to music and white noise at that intensity level? Will there be a substantial difference if the music presented includes lyrics or is only instrumental?

In reference to the first research question, on average the participants did set their perceived harm level at a higher value than 85 dB HL for the music conditions and not the white noise condition, but the difference between listening conditions was not statistically significant (Figure 1). Participants seemed more adverse to the white noise than either music sample, as shown by the fact that, on average, the perceived harm level for white noise was 7-10 dB HL less than the perceived harm level for lyrical music or instrumental music. It is worth noting that the 85 dB HL limit is set for 8 hours of exposure per day, and none of the participants reported listening to their personal listening devices to that extent. However, with each increase in volume, it takes less time for the sound to affect hearing.

Moving on to the second research question, there was no significant difference in performance between completing the test in quiet versus while listening to sounds, either white noise or one of the music samples. On average, it seems that the participants actually scored higher and completed the test more efficiently while listening to something (Figure 2, 3). This could be because even though the participants were in a soundproof booth, there are still random noises that can be distracting, while music and white noise is regulated and consistent. It may be easier to focus when there is less variability in the surroundings. There was some difference in the amount of time for the lyrical music and instrumental music subtests. In Hillard and Tolin's (1979) study of the effect of music familiarity on test performance, they found that participants scored higher on a test while listening to familiar music compared to unknown music. This is then surprising that the scores for lyrical and instrumental music were so similar. The lyrical music was more popular than the instrumental music, although perhaps since the subjects had heard the same sound clip repeatedly during testing it affected how familiar the music was to the participant.

Despite the lack of significant difference between the overall scores in the test, there could still be a difference in the reading comprehension questions compared to the math questions (Figure 4) within conditions. In general, the participants scored slightly higher on the math portions compared to the reading comprehension questions, especially with lyrical music. This could be due to the lyrics of the music interfering with the participant reading the passage to themselves. The contradictory signals could impair the ability to comprehend the passage correctly. Since the differences were not significantly different, this is an open question that future studies could explore.

Although there was no statistical significance to the findings, it is interesting to see the individual variability with regards to the volume and type of sound subjects prefer. Some participants set their perceived harm level as low as 70 dB HL, while others only ranked 95 dB HL as "somewhat damaging," indicating that their perceived harm level would be much higher than 95 dB HL. During the reading comprehension and algebra test, some of the participants scored as low as 3/10 on the quiet subtest while scoring as high as 9/10 in other subtests, whereas others scored consistently across different sound settings.

Future Considerations

In the future, this study could be improved with a larger sample size, as some of the individual variability may be due to the fact that we only tested twenty-one students. If the participant pool is large enough, they could be separated into groups based on how they prefer to study, as many students have preferences on their sound setting while studying. In Etaugh and Michals (1975) study of reading comprehension in quiet versus while listening to preferred music, they found that the more a student reports listening to music, the less it impairs their performance on a reading comprehension test. Perhaps as personal listening devices became easier to utilize in daily life, more students listened to music frequently. Moving forward, personal listening devices may become even more prevalent as new wireless headphones are easier to wear in all settings.

There were limitations of the study due to lack of equipment, as we used traditional clinic equipment instead of specialized tools. Other studies used couplers to determine the exact decibel level of the music their subjects listened to, and that could be useful in improving this study. It could be beneficial to use the subject’s own headphones or earbuds so that they have a more realistic sense of their own volume levels.

An additional improvement would be a longitudinal study design to determine how these preferences change with age. It might be that these current college students have a lower tolerance to loud music as they age, as more mature listeners tend to be conscientious about their risk of hearing loss and take more precautions to stay away from loud noise. There may also be a correlation between those with high perceived harm levels and those who lose their hearing later in life due to noise exposure. In Mostafapour et al.'s (2009) study of the effect of leisure noise on noise-induced hearing loss, they found that young people tend to be at a low risk for noise-induced hearing loss, but that risk can vary based on the additive effects of hearing loss and continued exposure. Since personal listening devices are still fairly new, it is unclear what the long term effects of this sort of access to loud music and sounds will be.

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