Accident-Proof Headphones: An Analytical Research on How Smart Headphones Could Reduce Road Fatalities

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***Abstract*— Headphones are used by most people as a source of entertainment. Many pedestrians, cyclists and joggers like to use headphones while they are on the road even though it can result in extreme sensory deprivation and distraction. The purpose of this paper is to conduct a study on how the use of headphones can reduce the standard limits of human perception. It examines how this increases the vulnerability of one facing road accidents and proposes a possible solution to overcome this issue.**

***Keywords*— Road Safety, Sensory Deprivation, Embedded Systems, Pedestrian Fatalities**

I. INTRODUCTION

Death and injury levels of headphone-wearing pedestrians have risen rapidly over the years with the United States taking the spotlight with the number of injuries and fatalities tripling over the last seven years. A study conducted by Dr. Richard Lichenstein and his colleagues [1] revealed that 70 percent of the accidents which involved pedestrians wearing headphones resulted in the pedestrian's death. The study also proved that more than a third of the fatalities were younger than 18 years and around two-thirds were younger than 30 years. Almost 90 percent of the collisions occurred in urban areas or large cities. It is also a commonly known factor that most youth today prefer to listen to music with extremely high-volume levels. Repeated exposure to sounds over 85 decibels is considered harmful and can even induce hearing loss in most humans [2]. In 2005, Warwick Williams of the National Acoustic Laboratories in Australia [3] conducted a study to compare the sound level of music being played in a headphone of a headphone-wearer with the noise level in various background environments. The results derived from the experiment showed that the volume level used in headphones ranged from 73.7 decibels to 110.2 decibels resulting in an average of 86.1 decibels from the individuals sampled. Meanwhile the typical noise levels in the background environments were in the range of 73.2 decibels. A difference of almost 13 decibels could be seen between the two.

While most studies focus only on pedestrians who are wearing headphones facing accidents, many cyclists and joggers have also faced such situations. Using a pair of headphones and listening to music while cycling or jogging can be very relaxing and help one tune out of this world. This can turn out to be quite dangerous for pedestrians, joggers and cyclists who are deprived from their basic auditory senses. This sort of behaviour especially in busy streets in urban areas can prove to be fatal for the listener. For instance, it might even not always be a head-on collision with a vehicle. One such incident occurred in 2016 when a cyclist using headphones [4] entered a roundabout and suddenly noticed a vehicle exiting the roundabout at the same time. Even though no collision occurred, the victim who was thought be distracted and listening to music panicked at the sudden sight of the vehicle and fell from the cycle to the sidewalk, fracturing her skull and spinal cord on the spot.

When it comes to identifying warning signals for potential danger, the eyes and ears are the most important sensory organs of the human body. There is a much higher chance of a pedestrian wearing headphones facing an accident rather than a person who is not, since such a person will not be able to receive any auditory input of incoming vehicles. Studies have shown that there has been some sort of warning or indication of such an incident been about to occur before most pedestrian fatalities take place. A pedestrian who is not using headphones would have a higher chance of hearing an approaching vehicle, the noise of brakes being applied or the honks from a car. Meanwhile, headphone users might not hear or even see any of these danger cues due to unintentional blindness caused by a sensory overload.

Smartphones play a major role in a person's life today, be it for entertainment, education or business purposes. Many smartphone users also wear headphones for ease of communication and relaxation especially while traveling. As Fig. 1 depicts, the use of headphones or earphones have increased drastically within the last few years and studies indicate it will only increase further with the new improvements being made to them using modern technologies [5].

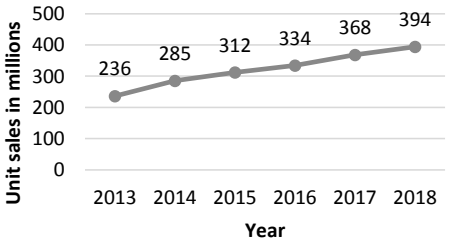


Fig. 1 Global unit sales of headphones

(Source: https://www.statista.com/statistics/327000/worldwide-sales-headphones-headsets/)

Although the usage of headphones keeps on increasing by a large scale each and every year, as shown in Fig. 2 the main purpose of headphones or earphones is still entertainment i.e. to listen to music [6].

The results of a study conducted in China and USA in 2016 among teens and pre-teens regarding distracted walking resulted in 39% of the individuals being distracted due to headphones in the USA and 42% in China [7] [8].

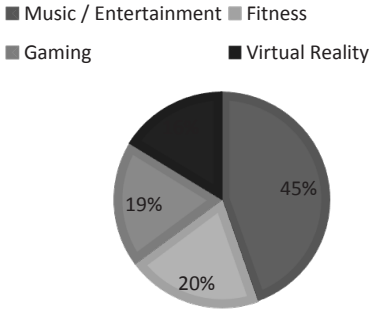


Fig. 2 Headphone Usage in 2019

(Source: https://www.grandviewresearch.com/industry-analysis/earphone-and-headphone-market)

Wearing a pair of headphones will automatically cut off about 15 to 20 decibels of surrounding noise from the listener's ears. An additional noise reduction of around 20 decibels is provided by present-day headphones and data gathered by leading companies in the audio industry prove that most individuals prefer to utilize headphones with these capabilities over normal ones. While these properties such as noise cancellation, custom fitting and in-ear headphones are immensely beneficial for most users in noisy environments, it can lead to devastating repercussions for a pedestrian on a busy road. In the majority of such cases, a warning noise was heard beforehand [9]. Especially in the cases of train accidents where trains have been known to repeatedly blast their horns in order to warn the pedestrians but have been ineffectual.

Although many smart headphones nowadays are equipped with a great list of advanced features such as [10] language translation, audio enhancement, fitness tracking and personal assistants, none of them have been developed to ensure a pedestrian's, cyclist's or jogger's safety when travelling on the road.

A research conducted in 2019 by Audio Analytic, an Artificial Intelligence company focused on sound recognition shows that over the last year, 37 million Americans felt that they were more exposed to danger when wearing headphones or earphones while walking, jogging or cycling [11].

II. Research Questions

1. Do the use of headphones by pedestrians lead to an increase in road accidents?
2. How do noise cancellation features in headphones contribute to this factor?
3. Can an effective solution be implemented to resolve the issue?

III. Methodology

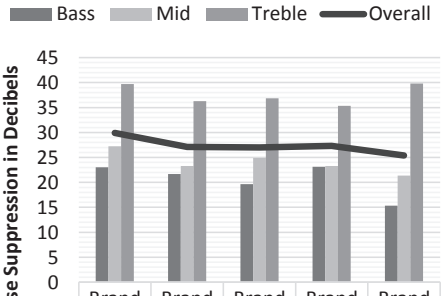
This research was conducted using primary data and quantitative secondary data. Firstly, a study was conducted to analyse data gathered from major companies which manufacture the most in demand headphones with noise isolating attributes. The amount of background noise cut off by each headphone was analysed and compared. In addition, an alternate experiment was conducted to measure the sound intensity of car honks and clarify whether headphones users would be able to hear them in a fairly busy street environment. During the process of data collection and analysis in both studies, the unit of measurement, decibels, was applied to measure sound intensity and the degree of loudness.

IV. Results

Noise isolation through headphones can be classified into two categories, passive isolation and active noise cancellation. Passive isolation is the noise suppression which occurs due to the physical design of the earbuds or the material of the headphones while active noise cancellation occurs from the scientific technology that is used to neutralize the sounds which infiltrate the headphones.

A. Noise Isolation Analysis

Data was gathered to calculate the mean noise isolation for bass, mid and treble ranges separately for five headphones, each from different brands which had the highest ratings for the best noise cancellation features [12]. All statistics and data applied in the study were based on headphones of the over-ear type with closed-back enclosure. The overall noise isolation produced was calculated from these three ranges. Fig. 3 illustrates the results of the study.



	Brand 1	Brand 2	Brand 3	Brand 4	Brand 5
Bass	23.03	21.68	19.65	23.12	15.36
Mid	27.24	23.31	24.92	23.31	21.37
Treble	39.7	36.3	36.85	35.33	39.82
Overall	29.9	27.11	27.01	27.31	25.39

Fig. 3 Noise Isolation in Headphones

The lowest mean noise suppression belonged to the bass-range category at 20.56 decibels. The treble-range had the highest suppression level of 37.60 decibels. Meanwhile, the mid-range had a suppression of 24.03 decibels. Hence, the overall mean noise cancellation produced by a pair of headphones was computed as 27.4 decibels.

B. Sound Intensity Level

A similar study was conducted to measure the noise level made by a vehicle horn at fixed distances. The environment setting of a moderately busy street was stimulated to obtain the best results. The sound was measured using a noise meter app with pre-calibrated measurements to assess the sound pressure level.

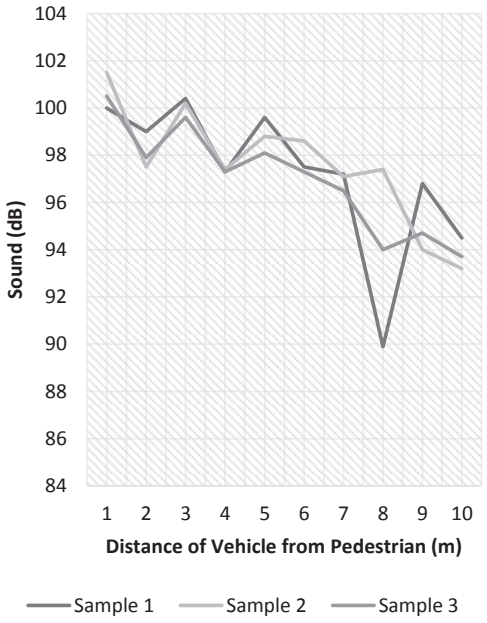


Fig. 4 Sound Intensity of a Car Horn

The tests were performed thrice to achieve the highest possible accuracy level. The vehicle horn was sounded for an average of 3 seconds, but anomalies are visible at certain points in the graph represented in Fig. 4 when this time limit was either incremented or decremented. It could be observed clearly that the intensity increases swiftly the longer the horn is sounded.

TABLE 1
AVERAGE NOISE INTENSITY OF A HONK

Distance (m)	Noise Level (dB)
1	100.5
2	97.9
3	99.6
4	97.3
5	98.1
6	97.3
7	96.5
8	94.0

According to the results of the above experiment, the average sound intensity of a car horn is highest when the pedestrian is away from the vehicle by 1 metre. As shown in Table 1, the intensity gradually decreases as the pedestrian moves further away from the vehicle but still remains above 90 decibels. The average intensity varies from vehicle to vehicle especially since horns used by heavy vehicles have a much larger intensity than of others. The data in the above experiment was gathered from a car horn since cars are considered to be the most popularly used vehicles in the world.

V. DISCUSSION

When comparing the results of the first study of analysing noise isolation properties of headphones and earphones with the results of the car horn sound intensity experiment, it can be observed that there is a very low chance of a pedestrian wearing headphones hearing a noise before an accident is about to occur. The pedestrian might be having 'inattentional blindness', especially if he or she is listening to music at a high-volume level. Inattentional blindness is the inability to notice various objects or events when one's attention is directed elsewhere [13].

A possible solution to overcome this issue would be to develop smart headphones with the technology to alert the wearer of any forewarnings regarding danger using embedded systems. Miniature microphones added to the headset externally could be able to record the noises in the headphone-wearer's environment. The microphones should be placed in such a manner that the noise detected will be balanced on both left and right sides of the headphone. Depending upon the direction of the approaching vehicle or any such imminent danger, the headphone should be equipped to alert the user with a beep or a signal on that specific side of the ear (either left or right). Sensors could also be used to estimate the distance between the pedestrian and an incoming vehicle [16]. The microphones which are situated externally on the pair of headphones will be able to transfer the data to be analysed in real-time. Since almost all pedestrian headphone-wearers, cyclists or joggers use a headphone with the assistance of a smartphone, it would be convenient for the user to have an installable app which can be used to display more information regarding his or her environment. The app can be used to keep the user constantly aware of his or her surroundings. It should also be kept in mind that the solution should be implemented in a cost-effective and user-friendly manner.

As the results of the experiment on car horn intensity demonstrate, it is much more feasible and easier to detect vehicle honks rather than detecting car tire or engine sounds. Even in a busy street environment, car honks can be heard clearly over other noises. Since a noise cancellation of 27.4 decibels is provided by an average pair of headphones, any noises the pedestrian should be able to hear will be clouded or simply unheard. The perception-reaction time of a driver responding to the unexpected sight of a pedestrian in front of the vehicle is of a duration ranging between 2 and 5 seconds [14]. Meanwhile, the median reaction time for a pedestrian is 0.3 seconds [15]. Even though the reaction speed of a normal pedestrian is quite high, there will be a substantial delay in this speed when it comes to a pedestrian wearing headphones. Past research indicates that the sudden reactions of a driver in a

vehicle travelling at a high speed will result in the driver losing control of the vehicle and he or she will most likely be overapplying the brakes. The after-effect usually produces a noise such as the screeching sound of the brakes. A normal bystander would hear such noises even before seeing the vehicle which will in turn provide them a longer time limit to secure themselves. It will not be the case for a pedestrian wearing headphones, especially if his or her back is turned to the vehicle.

VI. Conclusion

In conclusion, modifications must be implemented in headphones in order to resolve this issue so that pedestrians will be able to use them without been in constant danger.

The outcome of this research indicates that pedestrians, joggers and cyclists who utilise headphones while they are on the road, are in more danger of facing a road traffic accident rather than a normal pedestrian. Being able to hear a vehicle horn can actually make the difference between life and death for a person.

The studies conducted in this research prove that the noise suppressing features of present-day headphones contribute to reducing the auditory senses of pedestrians. With the revenue generated by the sale of smart headphones increasing rapidly each year, it would be a smart move to develop headphones which aid in the listener's safety, especially with the modern technological concepts been used in headphones today.

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