USING MOBILE TECHNOLOGY TO DEVELOP UNDERSTANDING OF HEARING RISKS USING AN EXPERIENTIAL APPROACH

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Abstract

Over 10 million people in the UK suffer with a hearing loss, with noise exposure identified as the biggest preventable cause (Bennett, 2007). Young people are particularly at risk, due to the rising level of personal media player (PMP) usage among their age group (Holloway, Green, & Livingstone, 2013). Lack of education results in poor understanding of hearing health, and, therefore, risk taking behaviour, which starts before university age (Barlow, 2011). Current Education is typically didactic in approach and programmes studied have had minimal impact on cohort behaviours (Borchgrevink, 2003; Portnuff, Fligor, & Arehart, 2009). This paper examines the initial stage of an action research project aiming to improve hearing health education by use of an experiential e-learning system.

Keywords: Hearing loss, health education, music listening, noise risk, young adults

Introduction

Hearing loss is a health condition that affects 10 million people in the UK, or one in six (Bennett, 2007) and is the third most prevalent chronic disability in the United States, affecting 29 million Americans between 20-69 years (Prell, Henderson, Fay, & Popper, 2011). Hearing loss also seems to be increasing among the younger demographic, with 8.5% showing a hearing loss between 20-29 years in the American NHANES (National Health And Nutrition Examination Survey), although more contemporary large scale data is now needed due to the age of the study (Agrawal, Platz, & Niparko, 2008).

While hearing loss seems like an easily diagnosed and managed condition, there are links to a wide variety of social and personal health conditions. The most commonly associated symptom of hearing loss is a significant reduction to the communication capabilities of the sufferer. As a result of this, those suffering from a hearing loss condition can be categorised as a high risk of increased social isolation (Arlinger, 2003), which has a separate set of personal and social issues in itself.

There are factors within hearing loss which go beyond the loss of sound perception and begin to affect a wider range of personal and social issues – for instance increased levels of unemployment, increased risk of falls and higher mortality rates. The economic cost is an estimated £1,800 per person with hearing loss per annum as found in Australia in 2005 (Cooperative Research Centre for Cochlear Implant & Hearing Aid Innovation, 2006; Mostafapour, Lahargoue, & Gates, 1998). The UK spent an estimated £450 million as direct costs to the health service according to the NHS (National Health Service) themselves, though undiagnosed individuals are thought to have the power to double this cost (Harker, 2011). When considering that the overall cost: benefit ratio for a national hearing screening programme is considered to be 8:1 (Action on Hearing Loss, 2010), it is fairly obvious that hearing health represents a substantial global cost burden and that the value of prevention outweighs the value of subsequent treatment dramatically.

Hearing loss is a complex condition – there are various reasons that have been shown to cause damage to hearing. The most common reasons, however, are age (presbycusis) and exposure to loud noise (Noise induced hearing disorder). Noise exposure is identified as the single biggest preventable cause of hearing loss. It is estimated that ~25% (estimates range from 23.5-29.9%) of cases of hearing loss in the US are attributable to noise induced hearing loss alone (Agrawal et al., 2008; Stanbury, Rafferty, & Rosenman, 2008).

There is some risk of mild hearing damage to people who are regularly exposed to average levels (L_{EQ}) exceeding 80 dBA (Decibel A-weighted to human hearing), while most people will suffer some degree of hearing loss if regularly exposed to average levels exceeding 85 dBA (Barlow, 2011). The guidelines suggest a dose exchange system as levels increase beyond the 85 dBA average level, whereby an increase of 3 dB reduces the time taken to exceed a *safe* dose by half (Health & Safety Executive, 2005).

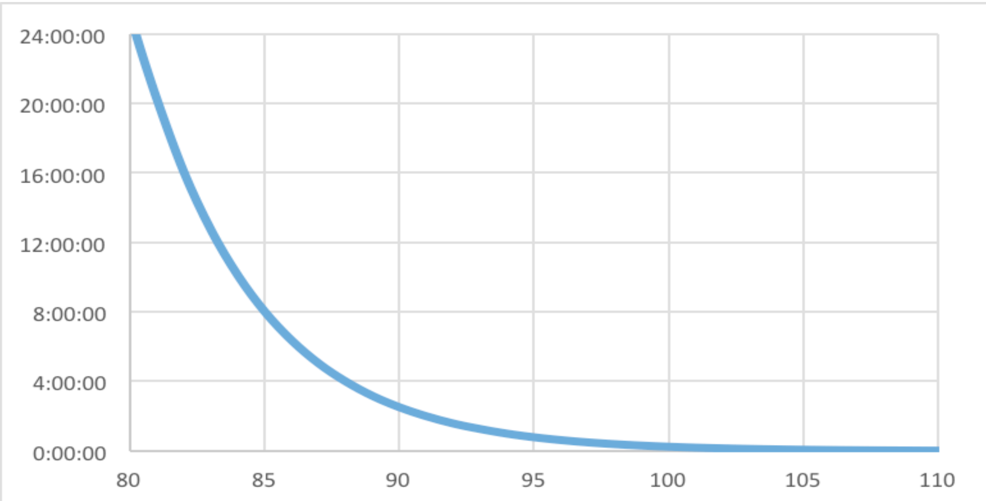

Figure 1. Maximum recommended exposure thresholds of noise.

Over the past few decades, the primary risks to hearing have been occupational, where workers are exposed to high noise levels as part of their job. However, the regulation of noise exposure in the workplace has reduced this risk significantly, while leisure based noise exposure has become an increasing issue.

Loud music has been identified as one of the two recreational noise sources most likely to be harmful (Clark & Bohne, 1999), with the other being shooting. By the 1990s, concern for hearing loss and research was turned toward assessing potential risk by the use of personal (cassette, at the time) music players. A study in a community in Hong Kong showed that risk factor was low in most cases, but measured some hearing damage likely to have been caused by negligent listening patterns and suggested increased education on the subject (Wong, Van Hasselt, Tang, & Yiu, 1990).

Thirty years later, and personal media player usage has greatly increased, with up to 100 million people using personal media players in the European Union on a daily basis (European Commission: Scientific Committee on emerging and newly identified health risks 2012). The technology in music players has also advanced changing the potential listening habits of consumers. The advances are that the devices are capable of high music storage capabilities, longer battery lives, and outputting very high sound pressure levels (Portnuff & Fligor, 2006). This leaves young people very susceptible to hearing loss due to the prolonged listening to high sound levels that can be attributed to that particular age group (Holloway et al., 2013).

As leisure noise exposure is voluntary, rather than inflicted on the person by an occupational environment, there is minimal legislative control over noise exposure, and reducing risk becomes instead an educational issue.

Young people have also shown a negligent attitude to hearing safety, taking easily preventable hearing risks (Widen, Holmes, Johnson, Bohlin, & Erlandsson, 2009). This behaviour seems to be common both during and before university age (Barlow, 2011). Although there is extensive research in this area, the information does not seem to be reaching the young people who are at risk. According to The World Health Organisation (2015) states that 1.1 billion teenagers and young adults are at risk of hearing loss due to recreational noise exposure.

A web-based survey in 2004 revealed some of the listening patterns of young adults and showed that a majority of them had experienced hearing loss and / or tinnitus after listening to loud music, with many of these people open to wearing hearing protection after learning the risks (Chung, Des Roches, Meunier, & Eavey, 2005). Shargorodsky, Curhan, Curhan, and Eavey (2010) reported that the compound effect of a lack of education and increasing potential for risk has led to an increase in hearing loss among adolescents in the US, from 14.9% to 19.5% of the demographic.

Education that does take place is commonly didactic in nature, which has been shown to be ineffective in changing cohort behaviour (Borchgrevink, 2003). Various campaigns have used educators, medical professionals or older students to present information to student groups, or have used *informational websites*, while some have used museum or web resources to explore aspects of hearing with interactive demonstrations (Gilliver, Beach, & Williams, 2013; Martin, Griest, Sobel, & Howarth, 2013).

Studies in recent years have shown a negative reaction to the didactic approach, in which increased peer pressure to turn music levels down has actually resulted in the opposite behaviour amongst teenage students (Portnuff et al., 2009).

There are also issues with the assessment of noise exposure of young people, as the majority of studies of noise risk in this population have been based on self-reporting questionnaires, and there are serious concerns about the level of potential under-reporting of noise exposure (Portnuff et al., 2009).

There are therefore a number of key questions to ask:

- What is the actual noise risk posed to students by recreational music listening?
- What are student's views and current understanding of noise risk and hearing conservation?
- Is it possible to quantify the noise risk from music listening more accurately than using self-reporting?
- How can young people best be engaged with education on noise risk and hearing loss?
- What are the most effective tools for providing young people with education regarding noise risk and hearing loss?

This paper examines the early stages of an action research project on developing an educational system capable of aiding teaching of hearing health to children and young adults.

There has been a shift in recent years away from the traditional music player to *smart* devices including mobile phones and tablet computers. According to a recent study, 65% of children internationally over the age of 8 have access to a mobile phone (GSM Association & NTT DOCOMO, 2009), while in the UK 62% of children aged 12-15 own a smartphone, and the same proportion of 5-15 year olds use a tablet computer at home (OFCOM, 2014).

As the smart phone or tablet is now the primary medium for listening to music, and is also capable of running web browsers and dedicated software, so the mobile device was chosen as the ideal tool for both gathering the required data on listening habits, and also for providing access to appropriate educational material to young people regarding noise risk.

Method

An action research project was devised as the most appropriate methodology for the overall study. Action research is a cyclical approach to the improvement of practice, in a participatory and often collaborative way. It allows the researcher to participate in the research process in a much more holistic way, allowing a deeper understanding of the problem that a cohort is facing. In this case, action research methodology was used to obtain observational data on how students respond to the use of the learning system, and what improvements could be made for the next iteration. The main advantage of this approach in these circumstances is it allows the full emphasis of the research to land on the changes to the method in question, rather than understanding the complex system of learning in people. This methodology pertains to the idea that the complex systems by which people learn cannot be reduced to a simple model.

The first stage of the action research cycle is to gain initial data and use this for the system's further development. As the core underlying issues are an understanding of the noise risk posed to students and their understanding of hearing conservation, a preliminary system was designed that allowed collection of quantifiable data regarding listening behaviours. A core element of the project is to allow students to use their own music devices and headphones to test levels of their preferred music at a level at which they would generally listen, providing direct feedback to the students regarding their own music listening.

The system designed includes both hardware and software elements. Its basic premise is for the users to set some music (using the students' own player and headphones combinations, or a unit provided) to the normal level of their listening, according to their own estimation. They would do this by using their headphones in the normal manner and listening to the normal level, and typically on music that they listen to regularly. The subjects were instructed to "set the volume to your normal maximum listening level" to ensure that all were finding the same volume parameter for themselves. The headphones were then removed from the subjects, and placed on measurement hardware, where the measurement procedure took place. The system was also explained to the students by the use of a large pop-up banner poster, which gave an overview of the subject, with details on the theory underpinning it.

The system's most complex part is an artificial ear designed as an analogue to the human ear to simulate the sound pressure that someone would be exposed to if wearing the same equipment at the same level. In this case, this artificial ear was 3D modelled and physically constructed via the use of a 3D printer. The principle behind this was to develop a system that was capable of being produced cheaply for educational use, as artificial ear systems are typically precision stainless steel and expensive. This serves to increase its availability to educational facilities with lower budgets, and overall increase the propagation of the idea. The ear is designed to mimic the acoustic performance of an average human ear canal when using insert type earphones (British Standards Institution, 2010). A mounting mechanism for the ear pinnae was made by use of a silicone formed ear model, appropriated from a headphone storage product. This allows the earphones to be mounted to fire into the ear canal, and provides realistic external mounting for over the ear (circum-aural) and on the ear (supra-aural) type headphones.

The calibrated measurements are provided by the use of an NTi XL2 sound level meter. This is connected to a calibrated microphone, inserted into the artificial ear, which was then mounted into a polystyrene hat mannequin, so that headphones can be easily mounted. This is the extent of the custom hardware, and aside from the calibrated microphone and sound level meter in use, the cost is negligible for a test with good repeatability.

The hardware was connected via USB to a Windows tablet via standard serial port emulation on the XL2 sound level meter. This allowed the computer to run some software specifically developed for this purpose, using visual programming language within National Instruments' LabView. The software queries the XL2 over the serial interface and receives the sound pressure level that is measured, which is then used to work out exposure time on the computer. While the system is currently running on a Windows device, it is planned to port the software onto the iOS and Android platforms in order to maximise the access to students in later project stages.

The system is designed to draw heavily on the constructivist philosophy of education, specifically for science pedagogy. Constructivism is a theory that proposes that students "construct" their own understanding of a subject or concept (Gray, 1997). This structure of learning suggests by its nature that learning is an interactive process, where actions from the students help them construct understanding, and contextualise it with their own experiences (Boudourides, 2003). It is this interactivity that the teaching tool seeks to exploit. By using the context provided by prior experiences of listening to loud music and previous thought into the matter of hearing safety, it provides a strong contextual correlation for the student to construct understanding. The intent is that use of the system will "effect conceptual change" (Cakir, 2008) in the way that students view the nature of decibels and how hearing safety is affected by changes in their listening habits.

This interaction is also strongly experiential, as the experiential method and the constructivist philosophy are closely linked. As both the didactic approach and blended *information delivery* approaches have proved ineffective in changing the behaviours of young people with regards to noise, an experiential approach was considered appropriate, in which students would be able to understand the issues through experimentation and experience using a range of tools. American psychologist David Kolb developed the experiential learning model in the early 1970s. The central theme of Kolb's work is an experiential learning cycle (Figure 2):

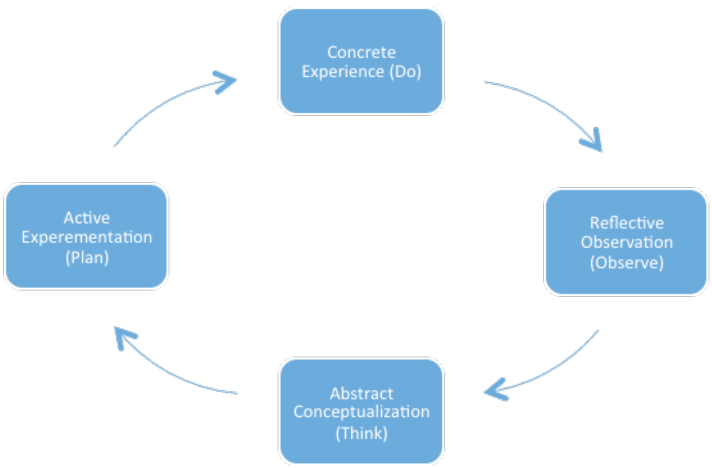

Figure 2. Kolb's experiential learning cycle (Kolb, 1984).

Kolb's theory has been shown to be effective in increasing student participation and assimilation of information (Jiusto & DiBiasio, 2006; Rocha, 2000). It has also been identified that learning technologies are extremely useful in fulfilling the goals of experiential learning, and especially mobile technology (Lai, Yang, Chen, Ho, & Chan, 2007), as it gives an easily distributable and versatile platform for interaction.

Figures 3, 4, and 5 illustrate components of the hardware and software elements of the learning system.

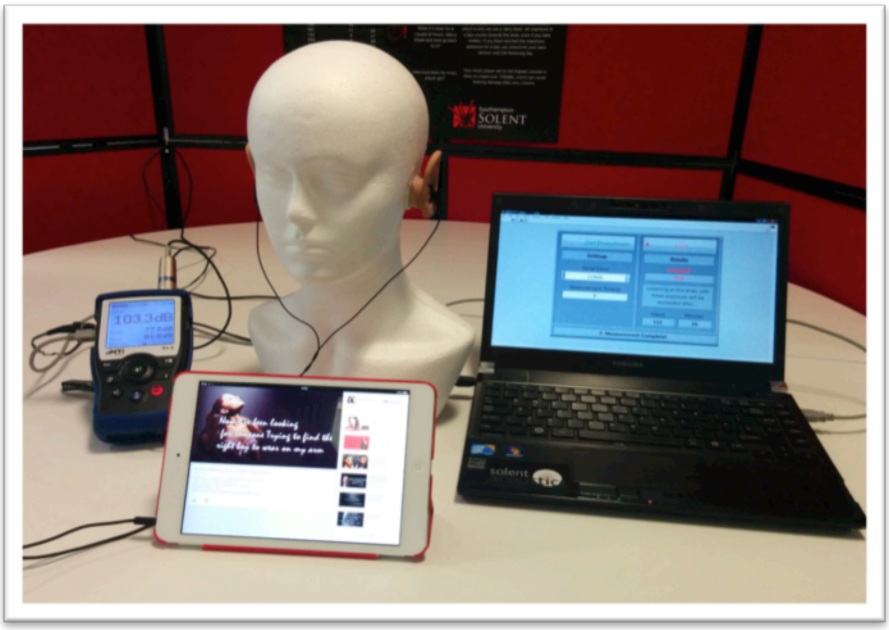

Figure 3: The complete noise exposure education system.

Figure 4: The 3D printed ear simulation.

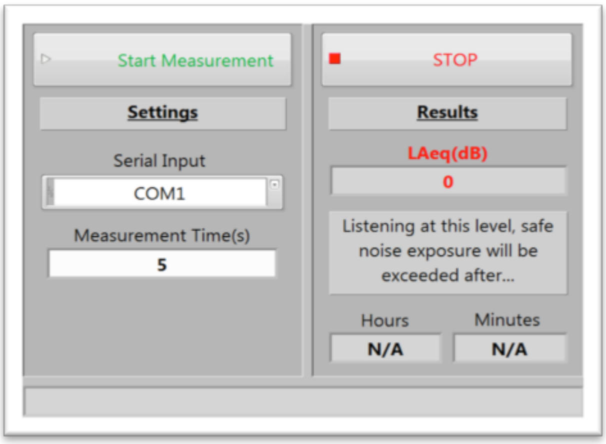

Figure 5: The user interface of the learning system.

Results

In total, 82 participants took part in using the learning tool, over three consecutive weekly events. Participants were typically male (84%), with an age range of 18-50, and a mean age of 25.7. The median age was 22, showing a skew in the distribution. As participation was on a voluntary basis, this showed that in this case males were either more interested, or easier to attract to the study.

Sound pressure levels measured varied considerably from person to person. As can be seen from Figure 6, the highest concentration of sound pressures measured fell into the 80-95 dBA range. The distribution is slightly skewed, with gradually decreasing numbers of people, as the risk gets higher.

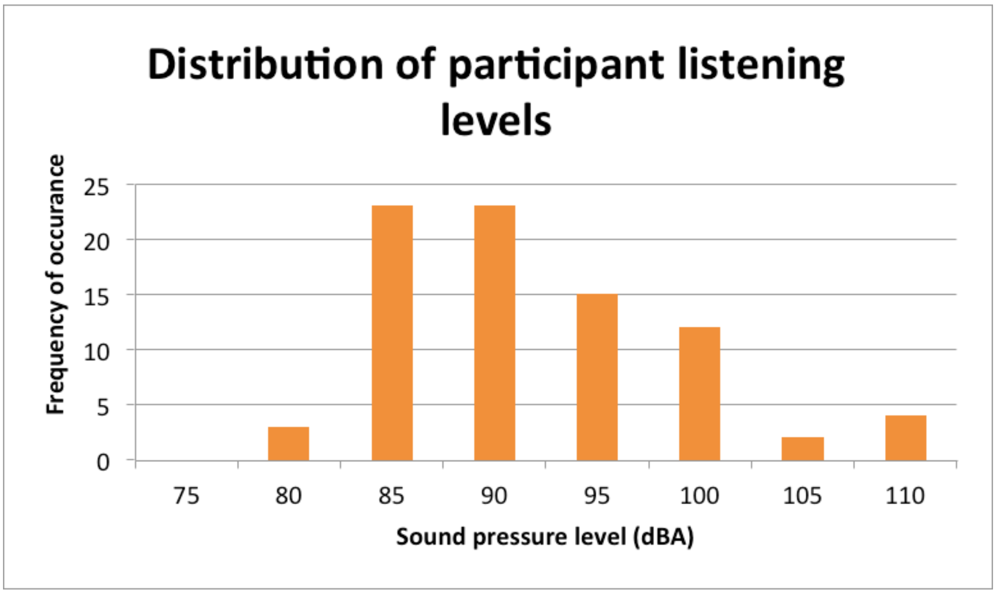

Figure 6. The distribution of sound pressure levels recorded from participants, in dBA.

Discussion

It is clear from this study that there is a wide range of listening levels amongst the initial cohort measured. However, from the initial data alone, it is clear that a high proportion of the sample were putting themselves at risk. Thirty three (39%) of the sample had an average listening level of 95 dBA or above. According to ISO guidelines, an average level of 95 dB gives a *safe* listening time of around 48 minutes, while 110 dB gives a safe listening time of around 1 minute.

This data was analysed in light of a previous survey in which students self-reported their durations of music listening. In that case 58% reported listening to a personal music player for more than 1 hour per day, and 41% listening for more than 2 hours (Barlow, 2010). These results would suggest that a significant proportion of the students whose devices were measured are putting themselves significantly at risk and either did not understand noise risk or chose to ignore it. This reinforces the evidence that an educational approach to this problem is key.

Although there was a general decrease in the proportion of students listening to higher levels, Figure 6 also shows an interesting increase in numbers at the 110 dBA value of the sound pressure level scale. This is attributable to those students who admitted to turning the sound level up to maximum on whatever device they were playing music on. This is evidence of a significant lack of understanding of noise risk.

Informal discussions were held with participants to gain their feedback on the system, and interaction with the device was generally positive; most students stated that they had learned about hearing risk from using the pilot system. Students showed a good level of interest in their hearing health, and from experience over the events it is clear that students are keen to find out how loud they are listening to music themselves.

Conclusion

Results of the pilot study show that there is a considerable requirement for increasing student education regarding hearing risk and indicate that a more interactive/experiential approach in which the student actively participates in a way which relates directly to his/her own activities may be more effective than previous approaches.

As this is an action research project, the next task is to iterate the project to improve the application currently in place, and adapt to the feedback from the data given. The goals of the project are to lower cost and make the hardware as available to schools, colleges and universities as possible. This means that the next project iteration will be focussed on moving towards a cheaper and more sustainable measurement system. While the hardware is currently of reasonable design, it is not robust enough to support a large-scale distribution, due to the fragility of the head.

The next step will also involve porting the design to a dedicated mobile platform. Windows laptops and tablets are typically expensive, and over specified for this particular task. Porting the software to a mobile platform such as Android or iOS will allow a cheaper and more specific system. Porting will also allow a more user friendly interface by using touch screen technology and potentially increase participation. There is also a potential for the system to be implemented onto students' own devices, allowing them to plug into the hardware to measure a result. This will allow students to save their own data, and thereby track their own noise exposure over time, and provide themselves with meaningful data.

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