Use of noise cancelling headphones to assist recall of spoken information in noisy environments

Marion Burgess (1) and Brett Molesworth (2)

(1) School of Engineering and Information Technology, The University of New South Wales, Canberra, 2600, ACT, Australia
(2) School of Aviation, The University of New South Wales, 2052, Sydney, Australia

ABSTRACT

The need to hear, comprehend and be able to recall spoken information can exist in less than ideal listening conditions. Such a situation occurs within an aircraft cabin where, despite improvements in modern passenger aircraft, the acoustic properties of the cabin are less than ideal for understanding speech. It is important that passengers, who are untrained and or new to the environment, hear on-board safety announcements such as the preflight safety brief and recall this information in an emergency situation. The benefits of headphones that incorporate active noise control in such environments are the focus of a series of research studies. In this paper, we discuss the techniques developed to investigate if the use of active noise control headphones can improve the recall of speech in a noisy environment similar to that in a commercial aircraft cabin. The initial studies reflected favourably on the use of active noise control headphones under such condition which has led to a series of additional studies investigating their use under different auditory conditions such as with dual masking (i.e., noise and music) and for English second language speakers as well as seeking a comparable marker to demonstrate the effects of such noise on recall.

INTRODUCTION

The need for untrained members of the public to hear, comprehend and be able to recall spoken information occurs in many situations when the message is provided in less than ideal listening conditions. One example is within an aircraft cabin where, despite improvements in modern passenger aircraft, the acoustic properties of the cabin are still less than ideal for understanding speech. It can also occur in other modes of transport such as trains and long distance coaches. For the safety message presented at the outset, as is the case in aeroplanes and coaches it is critical that, should an emergency situation arise, the passengers can recall the message and the actions they need to take. For trains it is not usual to present a safety message at the outset of the journey but the passengers still need, on occasion, hear and recall information provided at the outset of the journey on connections and changes to platform etc.

The obvious means to improve the opportunity for the passengers to hear and understand the spoken information are to have a good quality audio system for relaying the message and a low noise level in the listening area. While there are continuing improvements in both these aspects, it will be some time before all public transport will have ideal listening conditions for the safety message.

One option then is to improve the listening conditions at the ear with the use of headphones incorporating active noise cancelling technology. The series of projects discussed in this paper were initiated from the claim by an airline passenger that the safety message could be better understood when wearing active noise control headphones than without. The dispute was then with the cabin crew as headphones are still considered a Personal Electronic Device (PED) and most countries impose restrictions on the use of certain PEDs (transmitting and non-transmitting) on commercial passenger flights, during certain aircraft operations. In particular, PEDs such as MP3 players, mobile telephones or noise cancelling headphones are not permitted for use from the start of preparation for take-off until airborne or from the start of preparations for landing until on the ground. However, these are the very times when important safety information is presented to the passengers. The prohibited use of noise cancelling headphones during the taxi phase of flight was raised by a concerned member of the voluntary Asia Pacific Flight Cabin Safety Working Group (APCSWG)**.** The first project therefore sought to verify if the use of active noise control headphones, in the active noise cancelling mode and with no conflicting audio could assist with recall of the spoken safety message. The outcome of this first project was interesting and has led to an ongoing series of investigations on the effects of the use of noise cancelling headphones in recall of messages when the listening conditions are non ideal.

SPEECH AND NOISE

Australian Standard, AS 2107 (2000), provides a list of acceptable noise levels for various areas of occupancy within buildings. For a general office where communication is required the recommended range is 40 to 45 dBA. The noise levels in an aircraft cabin vary depending on the mode of operation and are clearly well above this range. There is limited quantitative data in the public domain on the noise levels in the cabins with the predominant information is qualitative comments as part of marketing such as "*Airbus cabins are quietest in the sky*" (Airbus, 2012) and "*cleaner, quieter and more fuel efficient*" (Boeing, 2012). One study by Ozcan and Nemlioglu (2006) does give the noise level of 65 dBA during the taxi mode for Airbus A321 aircraft cabin. So during the presentation of the safety message the in cabin noise level is approximately 20 dB above the upper recommended background noise level in a general office.

The benefits of reducing unwanted or irrelevant noise to minimize interference with a communication or speech signal have been widely studied (for example Miles et al, 1991; Tun et al, 2002; Marsh et al, 2008). It is particularly important to reduce interference when there is the need for encoding the speech signal information in memory, as is the case for recall of information presented in the safety briefing.

Active noise cancellation is more effective in the lower frequencies, ie below the mid and high frequency range for the intelligible parts of speech. However the use of active noise cancellation in communications headsets is widely promoted. According to Bose (2012), for military operations the use of this type of communications headset increased voice intelligibility by 21% as compared to conventional systems.

Over recent decades, the advances in electronics and signal processing have brought active noise cancelling headphones, and even ear plugs, to within the reach of the general public. These are now widely advertised for use when seeking good quality audio signal or even just for rest when there is an annoying/interfering background noise.

In this paper, we discuss the techniques developed to investigate the use of active noise control headphones on the intelligibility and recall of speech generated outside the headphones. The initial studies were directed towards assessing the effects on the recall for safety announcements and the early findings have been summarized by Burgess and Molewsorth (2012 and 2013). These studies have been further extended to investigate the effect if a conflicting audio signal is coming into the headphones or if there are any benefits for those for which English is a second language. An additional study has sought to provide a comparative marker of the effects on performance of background noise levels around 65 dBA.

EXPERIMENTAL PROCEDURE

The main aim of these studies was to examine whether the use of noise cancelling headphones could enhance the cognitive processes of passengers during the presentation of important information, such as a safety briefing, in a noise environment comparable to an aircraft cabin. As the context of the studies was aviation, to create some of the atmosphere of an aircraft, this investigation involved the use of a mock-up aircraft cabin located in a quiet room. A broadband sound signal, with a sound level of 65 dBA at the ear of the subject, provided the simulated in-cabin noise during taxi based on the studies by Ozcan and Nemlioglu, (2006).

Due to widespread familiarity with the content of an aircraft safety briefing, the audio signal used for the investigations consisted of five different audio briefs related to aircraft in general. The sound level of each audio brief was adjusted following advice from a flight attendant on their standard procedure for adjusting the audio level in the cabin.

The specific information in each audio brief was balanced so that each comprised the same number of numerical details and specific words. The audio signal was provided in the manner appropriate for the particular investigation and, immediately following, the task involved a fill-in-the-blanks written test requiring recall of both numerical information and specific words. There were three options presented for each blank, i.e. two words or numbers and “uncertain”, and the test subject had to circle one of these options.

Ethics approval for the studies was granted by the appropriate body within the University and the approved protocol for each investigation was followed carefully. The test subjects were recruited from the University and each group had an average age in the early 20s. A software based audiometric screening procedure, the results revealed all participants had hearing within what is considered the ‘normal’ range (i.e. any loss in either ear at any frequency considerably less than 20 dBA). Over a number of separate studies using a similar methodology, over 200 subjects have been through the screening and it is interesting to note that only 2 have shown to have hearing below the normal range.

The audio signals were presented in a either a balanced or normal Latin square design comprising a single (main) factor with up to five levels. The auditory conditions (independent variables) varied in accord with the particular investigation and were selected from the options of:

- with and without wideband noise in the background;
- with and without headphones,
- noise cancelling headphones active and inactive,
- the audio brief played through the external speaker or the headphone,
- music played through the headphone.

SOME FINDINGS

The first study aimed to examine the effectiveness of noise cancelling headphones (active) in improving individuals’ ability to recall information presented in the presence of broadband noise representative of an aircraft cabin. The findings, reported in Molesworth et al (2013a), suggested that, as long as there was no conflicting audio signal such as music, the use of the noise cancelling headphones during the taxi phase of flight would be beneficial for the user/passenger, in terms of providing them the optimum conditions to hear audio information such as the preflight safety brief. So the outcome of this study supported the claim of the passenger who wished to continue wearing his headphones in the active mode.

For the first study the subject paid full attention to the message and they knew they would be required to recall parts of the content. However in the real situation there can be no assumption that passengers pay full attention to the safety briefing. So a follow up study was undertaken to investigate if the use of noise cancelling headphones would also assist with recall if the person was undertaking a secondary task. The concurrent task was a simple mathematical exercise and the performance in this task was assessed as well as the recall of the audio brief. As expected, the introduction of a concurrent task led to a reduced performance on the primary task, namely the audio brief. However the test procedure was able to identify differences between various conditions and discovered that even with a concurrent task, better performance was achieved when using noise cancelling headphones. So the recall of the audio brief with the use of active noise cancelling headphones plus concurrent task was comparable to the recall when there was no concurrent task and no headphones (Molesworth et al, 2013b).

A confirmation of the first findings was an additional outcome of another study to investigate any differences between price comparable noise cancelling headphones. The results revealed no differences in performance between the use of the two price comparable noise cancelling headphones.

The findings from these studies confirmed that noise loud enough to be annoying, but well below the damage risk level, has the potential to impair cognitive performance in an audio signal recall task. The addition of a secondary task further increased the impairment but that some of this impairment can be offset by the use of noise cancelling headphones. This indicates that the reduction of the external noise, even though the noise is constant and non meaningful, allows for improved embedding in memory. Another concern regarding the safety briefing is the effect of this noise for those who are not native speakers. For non-native speakers, the effect of noise on performance has been shown to be more severe than their native counterparts (for example Shimizu et al, 2002). So a further study aimed to investigate if the use of noise cancelling headphones could mitigate some of the effects of noise on the recall task for non-native speakers. The subjects were again drawn from University students and half the study group were native German speakers who had been regularly speaking in English on average for 13 years. The experimental set up and the analysis followed the same structure as for the previous studies with the same simulated aircraft noise at 65dBA. These studies showed that while the recall was improved for both native and non native speakers, the improvement with the use of noise cancelling headphones was found to be greater for the non-native English speakers.

While the results of these studies show the beneficial effects of noise cancelling headphones to assist recall of audio messages there is the risk that the user will also be listening to their own audio signal, such as their preferred music, at the time of the safety message. A similar approach has been used to investigate the effect on recall when individuals choose to listen to music at low volumes through active noise reduction headphones. This was based on subject assessment of music level when participants were instructed to set the levels at *soft level* defined as 'soft and soothing, similar to elevator music', and to a *loud level* defined as 'loud but comfortable for your pleasure'. The findings (Molesworth et al, 2013c) were that recall performance of an audio brief for low volume music via active noise control headphones plus background noise at 65 dBA was no worse than when no headphones are used, namely the current practice in aircraft.

The studies have provided a statistical comparison of the recall of the audio briefs and thus an indication of the benefits obtained with the use of active noise control headphones. In order to demonstrate the extent of these benefits a further study sought to compare the effects with something that is widely known to affect performance – namely alcohol (Dawson et al, 1997). So this study aimed to compare the effects of alcohol at blood alcohol levels of 0.05 (the common limit for driving) and 0.1 with the effects of noise comparable with in cabin noise of 65 dBA (Molesworth et al, 2013d). The results show that the effect of simulated aircraft noise (wideband noise at 65 dBA) on performance is equivalent to that produced by alcohol intoxication at a BAC of 0.10 for native English speakers and equivalent to 0.05 for non native speakers.

CONCLUDING COMMENTS

These studies have shown that the laboratory arrangement using a mock-up aircraft cabin and a broadband noise to provide background noise to simulate the noise inside a passenger aircraft can be used to investigate differences in recall of a primary auditory listening under a range of situations. The basic findings have been shown to be reproducible across the studies, namely that the use of noise cancelling headphones has been shown to be beneficial in aiding recall of information similar to a safety message, in a background noise level similar to that experienced in an aircraft cabin. The benefits have been shown to be greater for English second language subjects. There have also been benefits when the subject is undertaking a secondary task or is listening to low level music.

The results indicate that, as long as no other risk factors would be introduced, aviation governing authorities should consider the benefits of allowing the use of the use of such noise cancelling headphones during the operational modes when the safety message is being given.

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