The effect on recognition memory of noise cancelling headphones in a noisy environment with native and non-native speakers

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Abstract
Noise has the potential to impair cognitive performance. For nonnative speakers, the effect of noise on performance is more severe than their native counterparts. What remains unknown is the effectiveness of countermeasures such as noise attenuating devices in such circumstances. Therefore, the main aim of the present research was to examine the effectiveness of active noise attenuating countermeasures in the presence of simulated aircraft noise for both native and nonnative English speakers. Thirty-two participants, half native English speakers and half native German speakers completed four recognition (cued) recall tasks presented in English under four different audio conditions, all in the presence of simulated aircraft noise. The results of the research indicated that in simulated aircraft noise at 65 dB(A), performance of nonnative English speakers was poorer than for native English speakers. The beneficial effects of noise cancelling headphones in improving the signal to noise ratio led to an improved performance for nonnative speakers. These results have particular importance for organizations operating in a safety-critical environment such as aviation.

Keywords: Aviation, cabin safety, English as a second language, native language, noise, noise cancelling headphone

Introduction
Commercial aviation has brought many benefits to countries; the most notable includes tourism and commercial trade. For airlines themselves, crossing international borders permits them to expand or even amend the demographics of their workforce. Facilitating this process is the adoption of a common language across aviation, namely English. The outcome is that many, for whom English is a second language (ESL), may have greater difficulty in understanding important speech information presented in the noisy environment of an aircraft. Naturally this problem is not confined to aircrew alone, and extends to commercial airline passengers.

For nonnative English speakers, the presence of noise makes it more difficult to understand speech.[1,2] According to Shimizu et al.[2] this challenge increases as the signal to noise ratio decreases. Unlike an office where typical noise levels, in terms of the A weighted equivalent energy level \(L_{Aeq}\), are between 40 and 45 dB(A),[3] noise in commercial aircraft cabins can range from 65 to 80 dB(A) depending on the phase of flight.[4] The main aim of the present research was to examine the effect on recognition memory of commonly available noise attenuating countermeasures, namely noise cancelling headphones, in the presence of simulated aircraft noise for both native and nonnative English speakers.

Auditory stimuli, man-made or natural are present throughout society. For the normal-hearing listeners, stimuli that don’t require attention (including noise) can act as distractors, or if auditory, as maskers.[5] In a safety critical situation (e.g., safety briefing), where attention to an auditory stimulus is important, failure to attend to the target audio information can have negative implications. For nonnative speakers, the effect of noise on performance is reported to be even higher, compared to their native speaking counterparts, further increasing the risk of error.[6,7]
One method that has shown promise in reducing the negative effects of noise on performance is the use of noise cancelling headphones. Unlike the name suggests, noise cancelling headphones reduce, but do not eliminate unwanted external sounds. They are generally more effective for sounds at the low end of the frequency spectrum,[8] such as generated by machinery and aircraft engines. For passengers in commercial aviation, the use of noise cancelling headphones is promoted for more comfortable listening of audio. The use of these noise cancelling headphones in comparable noise levels has been found to be beneficial by improving recall of a verbal message, similar to a safety message, when compared to situations when no headphones or passive noise attenuation headphones are employed.[9,10] The benefits of noise cancelling technology even extend to situations involving concurrent tasks. To illustrate this, Molesworth et al. asked undergraduate students to complete a listening task with and without noise cancelling headphones while concurrently completing a series of mathematical questions. While there was no difference in performance on the concurrent task exercise between groups, when students were using noise cancelling headphones, they were able to recall more words correctly than when they were not wearing any headphones.[11]

Expanding on these findings, Molesworth et al. investigated the effects of noise cancelling headphones in a dual masking task.[10] Specifically they exposed students simultaneously to constant wideband noise (played through an external speaker) with A weighted Leq of 65 dB(A) as well as music of their choice at Leq, 60s 50 dB(A) and at 70 dB(A) played through the headphones. A baseline condition involved the presentation of wideband noise without music and without the use of noise cancelling headphones. They also had a fourth condition, again without music, but with the target audio (brief) played through the noise cancelling headphones in the presence of wideband noise. Employing the same word recognition task as in the concurrent task study, they found performance in terms of word recognition improved when noise cancelling headphones were used compared to when no headphones were used. However, performance was no worse when listening to music at 50 dB(A) with noise cancelling headphones and wideband noise, than in the baseline condition (no music, no headphones with wideband noise). Not surprisingly, the benefits of noise cancelling headphones were nullified when listening to music at 70 dB(A).

While the benefits of noise cancelling technology in aviation have been repeatedly demonstrated,[9,12] there appears to be limited evidence to suggest if these benefits extend or reduce the detrimental effects of noise on performance for nonnative listeners. However, what is known is that noise adversely affects speech intelligibility and more so for nonnative listeners than their native speaking counterparts.[13-15] In fact, comparing the effect of noise on performance to the effect of alcohol on performance, Molesworth et al. found that simulated aircraft noise at 65 dB(A) degraded performance (recall of information) to a level equivalent to that produced by alcohol intoxication at a blood alcohol concentration (BAC) level of 0.10 for nonnative English speakers. For native English speakers, 65 dB(A) of simulated aircraft noise degraded performance equivalent to a BAC level of 0.05.[16]

The smallest distinguishable acoustic elements of speech are phonemes of which there are two general classes known as vowels and consonants. For both native and nonnative listeners, identifying consonants in spoken words is crucial for word recognition. Hence, test material to quantify speech intelligibility is specifically designed with a balance of consonants and vowels.[17] The importance of consonants in speech intelligibility was illustrated by Broersma and Scharenborg[18] in a study with Dutch and English speakers, where they found out of the 24 consonants tested, eight consonants (/p, t, k, g, m, n,ɲ r/) consistently proved problematic in the presence of noise (e.g., competing talker, speech shaped noise and modulated speech shaped noise), particularly for the nonnative listeners.

Foreign accent has also been cited as a problem for listeners attending to speech not in their native tongue. According to van Wijngaarden et al.,[19] foreign accent is present in all spoken words, which are not in the native language of the listener and is particularly problematic because it is said to change phonemes, and hence word recognition.

The native language advantage is also said to be related to the more efficient use of high level information to compensate for the degraded listening conditions.[14] In a study employing bilingual French/English speakers, Golestani et al.,[19] found that if the prime word was accompanied by a semantically related target word presented in the native tongue, native speakers were more accurate at detecting the prime word than when an unrelated target word followed the prime word. In other words, nonnative listeners require a clear signal, with less noise in order to detect crucial contextual information to facilitate in word recognition.[20] According to Lecumberri et al.[21] for nonnative listeners listening to nonnative speech in the presence of noise with even a modest signal to noise ratio of −4 dB, is twice as difficult when compared with the same task for their native counterparts.

In aviation, and specifically with communication between pilots and air traffic controllers, foreign accent has also been reported as a problem. Moreover, EUROCONTROL (an international organization comprising member states from the European region responsible for the safety of air navigation) identified in a study with over 200 pilots and air traffic controllers, that controller accent was the most cited (34% of respondents cited accent as a problem) contributing factor in communication problems with aircraft call-signs.[22] The same study also found that controller accent was an issue with frequency changes between pilots and controllers (51% of respondents cited accent as a problem). Some of the worst accidents in aviation history such as the collision between
two Boeing B-747 at Tenerife, in the Canary Islands in 1977 and a mid-air collision near Charkhi Dadri in India between an Ilyushin I-76 and a Boeing B-747 in 1996 have also been attributed to deficiencies in aviation English.\cite{23,24} However, the extent to which noise also contributed or played a role in these incidents and accidents remains unknown.

What is known however is that improving the acoustic properties of the environment in which the information is being attended to is one method to improve word recognition, hence communication and ultimately safety. While improvements may be achieved with new aircraft, there is still a need to consider alternative methods for improving the delivery of the audio safety messages and employing noise cancelling headphones is an attractive option as they are widely available for use by aircraft passengers. Therefore, the present research sought to answer the following research question; does the beneficial effect of noise cancelling headphones on speech intelligibility in a safety critical environment extend across native language background?

The present research builds on previous research conducted by Molesworth \textit{et al.} which derived its origins from an applied situation namely involving one airline threatening a passenger with refusal of carriage if he continued to use his noise cancelling headphones during the taxi phase of flight.\cite{9} The headphones were not plugged into any external audio (i.e., noise cancelling active without audio feed), and according to the passenger such a set-up allowed him to hear the preflight safety brief clearer. Hence, such a device has important implications from a safety perspective, namely creating an environment conducive to extracting important information in the unlikely event of an emergency. However, since these headphones fall under the category of a personal electronic device, they are not currently permitted to be used during taxiing, take-off, and landing.

**Methods**

**Participants**

Thirty-two participants (15 male), 16 native English speakers and 16 nonnative English speakers (ESL) were recruited for the study. The mean age of participants was 24 (SD = 4.69; native English = 22, ESL = 25) years. The native language of the ESL speakers was German, and on average the ESL speakers had spoken English for 13 years (SD = 3.61). All participants were screened for hearing loss >20 dB(A) at 11 different frequencies: 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. Each participant was reimbursed for his or her time in the form of either a $20 bookshop gift voucher (Australian participants) or 10 Euros (German participants). The research, including all stimuli, was approved in advance by the University of New South Wales Ethics Panel as well as Technical University of Berlin Ethics Committee.

**Design**

The study comprised a 2 × 4 mixed repeated measures design. The between-groups independent variable (IV) was native language (i.e., English or ESL), and headphones condition, containing four levels was the repeated measures IV. Recall the origin of this study was derived from an applied situation involving a passenger using his noise cancelling headphones without external audio. Hence, this condition featured in the present research along with two other variations and one control. Specifically, they included [Table 1]:

1. No headphones, audio brief played through an external speaker and external wideband noise,
2. Noise cancelling headphones active, audio brief played through headphones and external wideband noise,
3. Noise cancelling headphones active, audio brief played through the speaker and external wideband noise, and
4. Noise cancelling headphones inactive (i.e., ear muffs), audio brief played through the speaker and external wideband noise.

Consistent with previous research,\cite{9,10} and for the purpose of ensuring equal pairing with each condition, the headphones condition variable (four levels) was presented in a balanced Latin square 4 × 4 design, while the audio briefs were systematically varied. This meant that both the native English and the ESL participants were divided into four equal blocks. The order of presentation of the headphones conditions were:

Block 1: 1, 2, 4, 3
Block 2: 2, 3, 1, 4
Block 3: 3, 4, 2, 1
Block 4: 4, 1, 3, 2

Performance, in terms of number of correct responses on each of the four multiple-answer audio tests (maximum possible 12/test) featured as the dependent variable. Finally, and to ensure consistency between the two data collection points (Australia and Germany), the research at each data collection point was conducted by the same researcher.

| Auditory condition | No headphones | Noise cancelling | Source of audio brief | Wideband noise |
|--------------------|---------------|------------------|----------------------|---------------|
|                    |               | Active | Passive | Headphones | Speaker |            |            |
| 1                  | ✓             |        |        |            |         | ✓          | ✓          |
| 2                  | ✓             |        |        |            |         |            | ✓          |
| 3                  | ✓             |        |        | ✓          |         |            | ✓          |
| 4                  |               | ✓      |        |            | ✓        | ✓          |            |
Material

The laboratory equipment comprised: Sennheiser® Noise Cancelling Headphones PXC450, two personal computers (one with internet access), Sennheiser® HD265 linear headphones (solely used for the screening procedure), and one audiometric screening procedure (Digital Audiometer - Screen v6.2). In addition, and unique to the tests in Australia, a Casella sound level meter (model CEL–240) as well as a Logitech 5.1 surround speaker system (stereo mode) were employed. In Germany, a Brüel and Kjaer sound level meter (model 2205) as well as a Dell desktop speaker type 4205 was employed.

The test documentation included: Two information sheets (one in English and one in German), consent form (English only), a demographics questionnaire (English only), four audio briefs and their respective multiple-answer written audio tests (English only). The audio briefs and written audio test were a replication of each other except in the form presented (e.g., audio vs. written). Specifically, each audio brief contained information about a particular aircraft (Airbus A330, Boeing 767, Embraer 190, or Saab 340) that was a mixture of both factual and nonfactual information. Importantly, the audio briefs were designed to reflect, as opposed to replicate, the preflight safety briefs provided by commercial airlines to avoid the possibly confounding effects of prior knowledge on performance. The length of each of the audio briefs was specifically manipulated to coincide with the typical length of a preflight safety brief. The information contained within each audio brief was also manipulated to ensure that each brief contained equal pieces of numerical information, namely 22 pieces. Each multiple-answer written test required recall of three pieces of numerical information and nine words (i.e., non-numerical).

All four audio briefs featured the same narrator, namely a female flight attendant with 16 years flying experience. The flight attendant was native Australian (fourth generation), fluent in English (sole language spoken). Furthermore, the audio files were digitally manipulated to ensure consistency between signal and noise across all four files.

An example (nonnumerical) extracted from the Embraer 190 audio file stated,

“It has a double-bubble fuselage design and according to the manufacturer this provides passengers with an extraordinary amount of personal space”.

The same sentence appeared in the written test except with three options for one word as shown below (option in bold):

“It has a double-bubble fuselage configuration/desig/uncertain and according to the manufacturer this provides passengers with an extraordinary amount of personal space.”

Participants were tasked to choose one of the options and were given the specific instruction “if you do not know the word, circle uncertain”. In the analysis all “uncertain” responses were scored as incorrect.

Procedure

Participants at the University of New South Wales and the Technical University of Berlin were recruited through their respective careers website as well as through the use of flyers placed on notice boards around both campuses. Participants initially read the information sheet (provided in their native language), completed the consent form (provided in English for all participants on both campuses), followed by demographics questionnaire (age, gender, and language background presented only in English), and a computer controlled audiometric screening procedure (Sennheiser® HD265 headphones used). Following this, participants commenced the experimental procedure.

Importantly, participants were reminded that the audio briefs were derived from both factual and nonfactual information. Similarly, when the participants were presented the written test, no conflicting audio was presented nor were the headphones worn.

In both locations, the study was conducted in a quiet research laboratory. The typical noise level inside both rooms without any participants or experimental generated noises (only computers operating) was found to be, in terms of $L_{eq,1min}$ between 38 and 40 dB(A).

Recall the headphone conditions were presented in a balanced Latin square design while the audio briefs were systematically varied to ensure within each audio grouping (e.g., four headphones condition) all audio parings (i.e., headphone condition and audio file) were equal. This meant that for the first participant in each block, the audio briefs (information pertaining to certain aircraft) were presented in the following order - A (Embraer 190), B (Airbus A330), C (Boeing 767), and D (Saab 340), while the second participant in each block received audio briefs in order, B, C, D, and A, and so on to systematically vary the presentation.

Throughout each audio condition, continuous wideband noise was produced from the sound source placed out of view of the participant, to represent the baseline noise condition in an aircraft cabin. Consistent with previous research,[9] the sound level measured in the vicinity of the participant’s head was, in terms of $L_{eq,1min}$ 65 dB(A). This level, as determined by Ozcan and Nemlioglu,[4] is reflective of that during the taxi phase of flight.

In all headphone conditions except condition 2 (i.e., noise cancelling active and brief through headphones), the audio information was played through the external speaker at
This level is consistent with Molesworth and Burgess[9] as originally determined by a subject matter expert (i.e., flight attendant with 16 years’ experience on task). In condition 2, the audio brief was played through the headphones under examination at a level determined by the participant. Specifically, participants were instructed prior to the commencement of the experiment to set the headphone volume at a level that facilitates extracting the most information from the audio file. This was performed with a test audio file (a short segment from the audio file which would be presented to them last) for no more than 5 s in the presence of the wideband noise. Importantly, this condition is reflective of the applied environment where passengers on commercial airlines are free to select their desired audio volume level. Immediately following each audio file, participants were asked to complete the paper and pencil test relating to the audio file they had just heard. At the conclusion of the four audio conditions, participants were thanked for their time and provided their respective reimbursement. The total time taken to complete the experiment for each participant was 35 min (average time).

Results

Since the main aim of the present study was to compare different auditory conditions as a result of native language background and headphone condition, a series of planned comparisons, opposed to a mixed repeated measures analysis of variance were employed. According to Tabachnick and Fidell,[25] this approach maximizes power since it restricts analyses to only those of theoretical interest. For all analyses, the statistical package “PSY” developed by Bird, Hadzi-Pavlovic, and Isaac[26] was employed.

The first analysis sought to determine the effect of noise on performance across native language background. Therefore, a planned comparison between native English speakers and nonnative English speakers under the condition without headphones (condition 1) was performed. With alpha set at 0.05, and assumptions of normality met, the results of the planned comparison revealed a statistically significant difference, \( F(1, 30) = 32.34, P < 0.000, \eta^2 = 0.52 \). As can be seen in Table 2, the effect of noise on performance was significantly greater for nonnative speakers who recalled just over four items compared to their native English speaking counterparts who recalled on average just under eight items correctly.

Having established the negative effects of noise on performance is more profound for nonnative speakers, the next series of analysis sought to determine if this effect could be reduced through the use of noise cancelling headphones. Hence, the following analyses were performed for the nonnative English speakers, starting with comparing scores under the condition where the audio was played through the noise cancelling headphones (condition 2) and the condition where no headphones were employed (condition 1). With alpha set at 0.017 (alpha adjusted accordingly to control for family-wise error-Bonferroni adjusted \( \alpha = 0.05/3 \)), and assumptions of normality met, the results of the first planned comparison with nonnative English speakers revealed a statistically significant difference, \( F(1, 15) = 13.59, P = 0.002, \eta^2 = 0.48 \). As can be seen in Table 2, the nonnative English speakers recalled on average just over four items correctly when they were wearing no headphones. In contrast when they were using noise cancelling headphones with the audio played through the headphones, their performance improved by over 50% (average correct 6.56). In order to determine if this trend was evident with the other two headphone conditions, two further planned comparisons were performed. With alpha set at 0.017, the result of two subsequent planned comparisons failed to reveal a difference between the no headphones condition (condition 1) and when the active feature of the noise cancelling headphones was switched on and the audio was play through the speaker (condition 3), and between the no headphone condition (condition 1) and when the noise cancelling headphones were used as ear muffs (condition 4), largest \( F, F(1, 15) = 0.68, P = 0.42, \eta^2 = 0.04 \).

The final series of analyses were performed for the native English speakers, and like the analysis for the nonnative English speakers, performance under the no headphones condition 1 was compared with the other three audio conditions. With alpha set at 0.017 (alpha adjusted accordingly to control for family-wise error-Bonferroni adjusted \( \alpha = 0.05/3 \)), and assumptions of normality met, the results of the first planned comparison between no headphones (condition 1) and noise cancelling headphones with brief through headphones (condition 2) failed to reveal a statistically significant difference, \( F(1, 15) = 0.46, P = 0.509, \eta^2 = 0.03 \). A similar result was evident between the no headphones condition (condition 1) and when the active feature of the noise cancelling headphones was switched on and the audio was play through the speaker (condition 3), as well as between the no headphone condition (condition 1) and when the noise cancelling headphones were used as ear muffs (condition 4), largest \( F, F(1, 15) = 5.44, P = 0.034, \eta^2 = 0.27 \).

Table 2: Mean number of correct responses and SD on the audio brief exercise distributed across experimental auditory conditions and native language background

| Experimental group (condition) | Native language | Mean score | SD  |
|-------------------------------|----------------|------------|-----|
| No headphones (1)             | English        | 7.88       | 1.31|
|                               | German         | 4.44       | 2.03|
| N/C + brief through headphones (2) | English    | 8.06       | 1.61|
|                               | German         | 6.56       | 2.19|
| N/C + brief through speakers (3) | English    | 7.50       | 1.63|
|                               | German         | 4.19       | 2.54|
| N/C passive + brief through speakers (4) | English | 7.00       | 1.71|
|                               | German         | 4.00       | 2.07|

SD = Standard deviation
Discussion

The effects of noise on performance are well-documented, in particular the detrimental effects of noise for nonnative speakers. Similarly, although to a lesser extent are the beneficial effects of employing noise attenuation methods such as noise cancelling headphones to reduce the effects of noise on performance. What remained unknown was whether the beneficial effects of noise cancelling headphones apply across language background. The results from the present research suggest that in the presence of wideband noise at 65 dB(A), the use of noise cancelling headphones provides little benefit in improving performance in the auditory task for the native English speakers. However for nonnative English speakers the improved listening conditions led to an improved performance. For both native and nonnative English speakers, variations in the use of noise cancelling headphones such as with the noise cancelling active, but without audio feed to the headphones or with the noise cancelling inactive, the beneficial effects of these headphones are lost.

From an applied perspective, and specifically for industries or professions where personnel are required to communicate in a language other than their native language, such as commercial aviation where English is the international language, these results have important implications. Estimates for the number of ESL speakers around the world depends on how literacy is defined, however Crystal calculated the ratio of three to one between nonnative English speakers and native speakers. Assuming this proportion applies to commercial passengers and aircrew, the potential for miscommunication within this domain is significant. The implications of these findings are possibly more far reaching than these results reveal mainly because the typical noise levels within the cabin of a commercial airplane during the majority of the flight (e.g., during cruise) can be 20 dB(A) higher than those tested in the present research and it is widely reported that as the signal to noise ratio decreases, errors in communication increase. These findings support the concerns that miscommunication remains a leading contributing factor in many commercial aviation accidents.

The results from the present research may also explain why attention to the preflight safety announcement on aircraft is regarded as poor. In the passenger cabin, the safety briefing is presented when the cabin noise level is less than ideal for understanding speech. Recall in a typical office, arguably from a safety perspective an environment with a considerably lower level of risk, recommended noise levels are between 40 and 45 dB(A), this is over 20 decibels quieter than in an aircraft cabin during the preflight safety announcement. According to a survey conducted by the National Transportation Safety Board, just over half of the passengers who participated in the survey admitted that they had not watched the entire safety briefing. While the reported reasons varied as to why this occurred (e.g., common knowledge, seen it before, lack of specific information), based on the results from the present research, it is plausible that the conditions (i.e., noisy environment) in which passengers are expected to attend to this important safety related information may affect their ability to understand the audio information.

In relation to the origins of this research, namely a commercial airline passenger using his noise cancelling headphones without audio feed during the taxi phase of flight (similar to condition 3 in the present research), the results suggest that for both native English and nonnative English speakers there appears to be no benefit (compared to condition 1). The headphone seals are further reducing not just the external noise but also external speech. This result is in contrast to that found by Molesworth and Burgess; however, they did employ different headphone styles. The present research employed noise cancelling headphones where the cups of the headphones contact the skull (i.e., completely cover the ear), whereas Molesworth and Burgess used headphones with small cups that sit on the ear. The effect of the style of noise cancelling headphone is an area for future research.

From a theoretical perspective, the results from this study add to the growing body of literature highlighting the beneficial effects of noise cancelling headphones on performance. However, what remains unknown is the reason why noise has a greater negative impact on nonnative English speakers opposed to native English speakers. There are several possible reasons why a listener may have difficulty understanding speech in a noisy environment. Take for example a person engaged in a conversation at a party. In order to listen to the person speaking, the listener divides their attention between the conversations, while attempting to filter out other “unwanted” sound. It is during this filtering that certain stimulus in the “unwanted” sound draws their attention away from the main conversation.

Breadth of vocabulary as well as context is also important in assisting the listener to recognize a word that is difficult to hear. According to Laufer for general reading comprehension where 90-95% of the text could be understood, individuals require a vocabulary of approximately 3,000 word families. However, when the size of an individuals’ vocabulary or the hearing condition (i.e., noise) may be less than ideal, having knowledge about the context of the discussion allows individuals to guess what they failed hear.

The results could also be explained with reference to individuals’ cognitive resources. Moreover, it could be argued that communicating in a language other than an individuals’ native language consumes more of their limited cognitive resources (i.e., is more cognitively demanding). Combined with the known effects of noise on cognition, individuals are left with little or potentially no spare/residual cognitive resources. The result is the same, namely a detriment in performance.
Limitations and Future Research

The present research examined the effects of noise at 65 dB(A) on performance; a situation comparable with the in-cabin noise for twin turbine commercial jet aircraft during taxi. What remains unknown is the beneficial effects of noise cancelling headphones when an aircraft is producing noise in excess of 65 dB(A) such as 80 dB(A) which is common during cruise.[4]

Similarly, what remains unknown is the effect of noise on pilot’s performance at this level; hence, areas for future research.

The present research also failed to examine variation in performance with nonnative English speakers based on years of spoken English, proficiency with the English language and number of languages spoken. Based on the above theorized reasons why noise is more detrimental to nonnative speakers than their native counterparts, it is feasible that a negative relationship may exist between English proficiency and recall performance using noise cancelling headphones under noisy conditions. Arguably the converse could also be true where a positive relationship exists with English proficiency as well as number of languages spoken and performance using noise cancelling headphones under noisy conditions due to the increase in an individual’s vocabulary; another area for future research.

It should also be noted that the present research tested recall performance based on the presentation of information in only one media, namely audio. Whether presenting similar information through two media such as audio and visual, as presently occurs on airplanes during a safety brief, mitigates the effects of noise on performance is another area for future research.

Finally, this research focused on the delivery and testing of material that should have been unfamiliar to all participants. From the applied perspective of the present research, this may not be always the case. Specifically for frequent flyers who may be familiar with the contents of the preflight safety brief, albeit despite having subtle differences based on airline and/or aircraft type, this knowledge may aid in the recall of information irrespective of audio condition.

Conclusion

In summary, the results from the present research suggest that in a noisy environment, increasing the signal to noise ratio through the use of noise cancelling headphones improves recall performance, most notably for nonnative English speakers. These findings have important implications for international organizations such as some commercial airlines which may employ staff from a diverse language background. Similarly, these findings highlight the importance of engaging passengers in a variety of media or presenting important information in a variety of dialects in order to ensure important information such as that contained in the preflight safety brief is effectively communicated.

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