The effect of background noise on speech perception in monolingual and bilingual adults with normal hearing

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Abstract

Background: Previous studies have highlighted that bilingual listeners have a deficit in speech perception in their second language compared with monolingual listeners in noisy listening environments. This deficit may give rise to educational and occupational implications for bilingual speakers who are studying or working in non-native language environments in poor acoustic conditions. Objectives: To compare the speech perception performance of monolingual English speakers and English as a second language (ESL) bilinguals within environments with various levels of background noise and to examine whether bilinguals with an early age of second language acquisition would perform better than those with a late age of acquisition. Study sample: Two groups of adult listeners with normal hearing participated: monolingual British English listeners ($N = 15$) and bilingual Arabic listeners for whom English was their second language and who were proficient in English ($N = 15$). The quick speech-in-noise (QuickSIN) test was used to assess signal-to-noise ratio (SNR) loss and SNR-50 for both groups. Results: The QuickSIN test results indicated that bilingual Arabic listeners with normal hearing displayed a mild SNR loss comparable to that observed for a person with hearing loss, indicating a higher SNR needed for this population to achieve a comparable level of comprehension to their monolingual English peers. Conclusion: Results highlight the importance of measuring SNR loss to obtain accurate diagnosis and potential rehabilitative information that is not available from audiogram studies.

Keywords: Age of acquisition, bilingualism, English as a second language, perception of speech in noise, signal-to-noise ratio, SNR loss

Introduction

Speech perception plays an important role in the maintenance of communication and is defined as a process of extracting acoustic cues and mapping them onto linguistic information.[1] Irrelevant auditory information (e.g., other talkers or environmental noise) can cause listening challenges for all individuals, especially those with hearing loss and cognitive impairment.[2] Various factors affect the ability to understand speech, including: dysfunction of the central auditory system; the acoustics of the listening environment, especially type and level of background noise and amount of reverberation; the predictability of the speech material; and the clarity of the speech regarding elements such as speed and accent. In addition, the listener's understanding of the language in terms of the vocabulary level, ability to identify consonants, words or sentences, understanding of the context, and hearing sensitivity all play a role.[2-4]

It is important to note that individuals use different mechanisms to process speech in quiet and noisy environments.[5] More specifically, noise degrades the speech signal and interferes with important bottom-up processing cues needed for accurate speech perception. The bottom-up process requires the listener to analyse phonetic and phonemic information from the speech signal and piece it together to understand the speech clearly. However, when bottom-up cues, such as phonemes, are not recognizable due to noise, listeners typically use top- down processing to take advantage of other information in the message, which involves more syntactic methods of deconstructing the message; thus, listeners use context and knowledge of the language to fill in any missing information.[2,6]

Listening in adverse conditions is difficult in one's native language, but listening in a foreign language is even more difficult, as non-native listeners must cope with both imperfect signals and imperfect knowledge. Several studies have investigated the speech perception abilities of bilingual (BL) listeners in conditions of quiet and noise.[2,3,7-10] Evidence has suggested that there is a difference between the speech perception performance in noise of monolinguals (MLs) and BLs. Additionally, research has shown that the combination of an increase in speech rate with a shift in acoustic frequency causes the greatest deterioration in BLs' speech perception.[11]

Notably, favourable acoustics are particularly required in classrooms, in which students are exposed to unfamiliar information and vocabulary. The importance of acoustics in school classrooms has been recognized by guidelines and standards established in the United Kingdom and other countries. For example, the World Health Organisation (WHO) has recommended that the signal- to-noise ratio (SNR) in an unoccupied classroom should be at least 15 dB, with a maximum noise level of 35 dBA and a reverberation time of 0.6 seconds to promote good speech communication.[12] Unfortunately, classrooms seldom meet any of these criteria, and many classrooms have high background noise levels ranging from 30 to 47 dBA and reverberation times varying from 0.3 seconds to greater than 1.5 seconds,[13,14] which is far from optimal for listeners still acquiring language skills.[15]

Indeed, evidence has indicated that reduced SNR results in reduced understanding and learning, thereby hindering communication, particularly for children with hearing loss, those not being taught in their first language (L1), or those with attentiondeficits.[16]

In general, the number of BL speakers is increasing considerably. For example, at the time of writing this article, approximately 55 million individuals in the United States speak a language other than English.[17] Furthermore, a 2011 census conducted in the United Kingdom revealed that approximately 1.7 million residents, specifically in London, spoke a language other than English.[18] Therefore, it is important to consider the impact of noise on the speech perception abilities of those with English as a second language (ESL), as any deficit in speech perception might have educational and occupational implications for BL speakers studying in a non-native language under poor acoustic conditions or working in noisy environments.[6,7,19]

However, previous studies have yielded mixed results concerning the impact of environmental conditions and bilingualism on speech perception in noise. These differences could result from methodologic variations across studies, and be due to listeners' linguistic profiles. It is thus difficult to draw conclusions concerning the effect of background noise on speech perception in adult BL speakers.

The aim of this study is to compare the speech perception performance of ML English speakers and ESL BLs at sentence level in the presence of various levels of background noise. In addition, to compare and contrast the impact of background noise on participants with early versuslate acquired bilingualism.

Methods

Participants

In total, 30 adults with normal hearing were recruited from communities in the United Kingdom and Kuwait. The participants were divided into two groups. Group 1 consisted of 15 adult ML UK English listeners (females = 7, males = 8), ranging in age from 22 to 40 years (M = 28), who had acquired English from birth and had no other languages. Group Two comprised 15 adult BL listeners (females = 11, males = 4), aged from 23 to 40 years (*M* = 26), all of whom had been exposed to Arabic (as their native language) from birth and had received more than 7 years of formal education taught in English (L2). The BL group was subdivided into early (EBL) and late (LBL) groups according to the age at which they began learning in English, based on past similar studies. The age range of 5 to 7 years was used as the upper level of inclusion for EBL and the range of 8 to 14 years was used as thelower level of inclusion for LBL.[3,8,20]

None of the participants had previous hearing loss or difficulties; that is, no cochlear or neural lesions in either ear, no history of persistent otitis media with effusion, and no auditory processing disorders as adults. This was important, as these risk factors were expected to result in below average test scores.[21,22] In addition, participants reported no mental or cognitive difficulties, which previous studies have also concluded can have an effect on speech perception.[23]

All BL listeners' English was assessed for fluency, extent, and proficiency of use via a questionnaire adapted from previous studies and English proficiency self-evaluation.[9,20,24] Only participants who had received more than 5 years of formal education in English were considered. Participants self-rated their speaking, understanding, reading, and writing skills in Arabic and English on a 5-point Likert-type scale. All participants were required to self-score at least 3 ("good" competence) or better on speaking and understanding English to be included in the study.

Stimuli

Participants in both groups were tested using the quick speech-in-noise (QuickSIN) test, which quickly and easily measure the ability to hear in noise.[25] It consists of 12 lists of six sentences with five key words (target words) per sentence. The sentences are presented in four-talker babble noise at pre-recorded SNRs, which decrease in 5-dB steps from 25 to 0 dB, delivered through headphones. These SNRs encompass the range of normal to severely impaired performance in noise. The sentences represent a realistic simulation of a social gathering, in which the listener may "tune out" the target talker and "tune in" one or more of the background talkers. The sentences have been recorded by a female speaker with a general American dialect. Standardization data regarding the QuickSIN show that averaging the results from several lists improves the reliability of the score (i.e., increases the number of test items). Thus, six randomly selected lists from the QuickSIN were administeredto each participant in the current study.[25]

Procedure

The experiment was conducted in a quiet listening environment and lasted approximately 30 minutes. Participants signed consent forms and completed the hearing, language, and English fluency questionnaire. Then they were given written and verbal instructions regarding the QuickSIN test. Each participant completed one practice list for familiarization with the test protocol. The presentation levels used were as recommended by the test manual and presented for all participants at 70 dB HL. The participants were instructed to repeat the sentence heard via the headphones immediately, and their verbal responses were scored based on how many key words were repeated correctly. This was done "live"; that is, immediately after they responded. Speech perception in noise was assessed using lists 1, 2, 3, 4, 5, and 6 of the QuickSIN, and no lists were repeated for any of the participants throughout the studyto minimize learning and practice effects.

Scoring

The SNR at which 50% of the stimuli were repeated correctly (SNR-50) was calculated for each list administered. To do this, the standard recommended procedure for the test was followed carefully: the total number of key words repeated correctly was determined and then the SNR-50 values calculated per list using the formula 27.5 minus the total number of words repeated correctly (see Ref. [25] for the derivation of this formula). These were then averaged across the number of lists presented for the test (i.e., six) to give an average SNR-50 per participant. The participants did not know which words were the target words. An exact repetition of a target word was worth one point; any error was considered failure (zero points).

In addition, SNR loss was calculated for the QuickSIN data. As noted previously, SNR loss is defined as the increase in SNR needed by a listener to obtain a score of 50% correct words compared to normal performance. SNR loss is used to quantify the participant's difficulties and is reported in dB. For the speech perception test used in this study, SNR loss was determined by subtracting the total number of key words correctly repeated from 25.5.[25] The interpretation of the SNR loss score is presented in Table 1.[25]

Table 1: Signal-to-noise ratio (SNR) loss interpretation

SNR loss	Degree of SNR loss
0–3 dB	Normal/near normal
3–7 dB	Mild SNR loss
7–15 dB	Moderate SNR loss
>15 dB	Severe SNR loss

Data analysis

The impact of exposure to noise on speech perception in the two groups (ML and BL) was examined using a quasi-experimental study to compare the difference in speech perception scores with increasing levels of background noise. The average SNR-50 and SNR losses measured from the test (QuickSIN) were subjected to an independent sample *t* test to determine whether there were significant differences between the two groups (ML and BL) and to compare the performance of the ML group with that of the early and late BL groups.

Results

English proficiency of bilingual Arabic listeners

Information obtained from the screening questionnaire indicated that all BL participants' L1 was Arabic and they had learned English as their L2. The participants spoke both Arabic and English fluently and one participant reported having spoken both English and Arabic simultaneously since birth. The age of acquisition for L2 ranged from birth to 12 years, with an overall group average of 7.0 years. Nine of the participants had learned English prior to the age of 7ven, and 6 participants had learned English between the ages of 8 and 12. All participants felt comfortable speaking either language. In addition, 12 of the 15 participants had taken a standardized examination in English to gain admission to the university, with an overall group average score of 7.1 (range 6.0–9.0). BL listeners reported speaking English and Arabic about 50% each in a typical day. When asked to rate their level of competence in speaking, understanding, reading, and writing adult material in each language, the overall average response for English was 4 (range 3–5) on a scale from 1 to 5, with 1 being "poor" and 5 being "excellent." All participants demonstrated at least a "good" level of self-reported English language competence. The specific language profiles determined for each participant in the BL group, including their age of acquisition, self-rated English proficiency, and language dominance, are summarized in Table 2.

Speech perception scores (SNR-50 and SNR loss)

To compare the differences between the speech perception in background noise of the ML group and the BL (ESL) group, the SNR-loss scores from the QuickSIN were calculated for each group. The value of SNR loss is derived from the SNR-50 score. A normal-hearing person requires 2 dB SNR (speech louder than the background noise by 2 dB) to identify 50% key words in the sentences on the test. It can be seen from the data in Table 3, which presents the groups' mean performance, that the BL group required a more favourable SNR than the ML group to achieve 50% recognition. The ML SNR-50 mean score was 2.90 and the BL SNR-50 mean score was 6.17; therefore, the MLs achieved a much better SNR-50 score.

Table 2: Language profile data for the bilingual group

Scores for	English competence	Daily	Daily	Primary	Languages	Starting age (in	Subject

standardized test of English proficiency	(understanding, reading, writing, and speaking) average score	exposure % L2 = E	exposure % L1 = A	language spoken at home	spoken fluently	years) for English acquisition	
9.0	5.00	75	25	A and E	A and E	Birth	B001
8.0	5.00	100	10	A	A and E	6	B002
N/A	5.00	75	25	A and E	A and E	8	B003
N/A	3.50	50	50	A	A and E	6	B004
7.0	4.00	50	50	A	A and E	10	B005
6.0	3.25	25	75	A	A and E	6	B006
7.0	4.25	25	100	A	A and E	6	B007
7.0	4.00	50	50	A	A and E	12	B008
7.0	4.25	25	75	A	A and E	12	B009
7.0	3.25	75	25	A	A and E	10	B010
7.0	5.00	50	50	A	A and E	6	B011
7.0	4.00	25	75	A	A and E	4	B012
6.5	3.75	50	50	A	A and E	12	B013
6.0	4.00	25	75	A	A and E	6	B014
N/A	3.00	50	50	A	A and E	6	B015

E, English; A, Arabic; N/A, not applicable.

To test the main hypothesis of the study (that ESL BLs' speech perception in background noise would be poorer than that of ML English speakers), an independent sample *t* test was carried out to compare SNR loss for the ML and BL groups. The results of this analysis revealed a statistically significant difference ($t(17.7) = -6.676$, $P < 0.001$) between the scores for the ML group ($M = 0.896$, SD = 0.654) and the BL group ($M = 4.164$, SD = 1.77). The group means for each condition are presented in Table 3, which show the differences in performance in background noise across listener groups. The mean QuickSIN scores were better for the ML group than the BL group.

Table 3: Mean speech perception scores for each group and condition

Difference between ML and BL groups for SNR-50 and SNR loss scores

Conditions	Listener groups	Mean	SD	*N*
QuickSINSNR-50 (dB)	ML	2.9033	0.65326	15
	BL	6.1707	1.77675	15
	Total group	4.5370	2.11918	30
QuickSINSNR loss (dB)	ML	0.8960	0.65425	15
	BL	4.1640	1.77943	15
	Total group	2.5300	2.12067	30
	Early BL	3.411	1.72209	9
	Late BL	5.2483	1.33242	6

Participants were tested in English only under conditions of background noise using the quick speech-in-noise (QuickSIN). BL, bilingual; ML, monolingual; SNR, signal-to-noise ratio.

Moreover, the box plots in Figure 1 illustrate that the range of SNR loss scores was 0.16 to 2.00 dB for the ML group participants and 1.33 to 6.83 dB for the BL group. A lower SNR indicates better speech perception in noise and a higher SNR denotes poorer speech perception in noise (Etymotic Research, 2001). The SNR loss scores for the groups were different: 1.85 dB for ML and 5.50 dB for BL. This indicates that the BL group showed a mild SNR loss [Table 1] and performed poorer than the ML group in background noise.

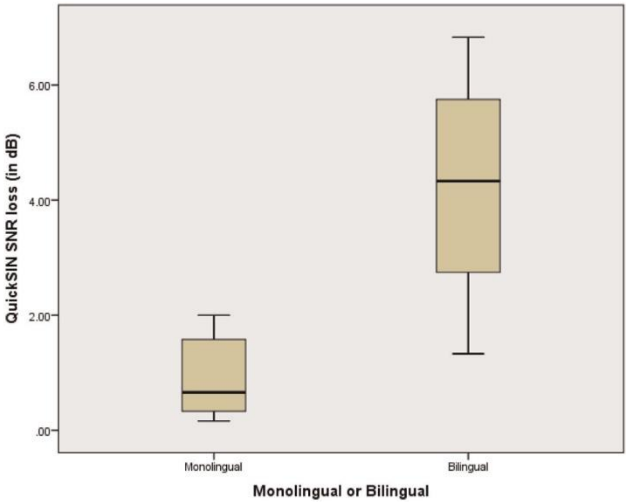

Figure 1: Signal-to-noise ratio (SNR) loss scores plotted for the monolingual (ML) and bilingual (BL) groups. The lower and upper lines encasing the box represent the 25th and 75th percentiles. The solid horizontal lines indicate the median. The whiskers represent the maximum and minimum quick speech-in-noise (QuickSIN) scores.

Difference between the early and late bilingual groupscores

The BL group was subdivided into early (EB) and late (LB) groups based on past similar studies using the range of 5 to 7 years as the upper level of inclusion for early BL groups and the ranges of 8 to 14 years as the lower level of inclusion for late BL groups.[3,8,20] The authors reported that learning ESL at an early age (before 6 years) helped improve individuals' top-down processing in noise and thus they performed significantly better than late ESL listeners who acquired the language after the age of 14, but poorer than MLs. The authors also indicated that there seemed to be phonetic interference from the nontarget language that further limited performance on the highly demanding speech-in- noise task. To test the hypothesis that the BL group who began their L2 (English) acquisition at an early age (EBL) would perform better in the speech perception test under conditions of background noise than the group with a later age of acquisition (LBL), an independent sample t test was performed. The EBL group ($N = 9$) achieved an SNR loss score of $M = 3.4$ (SD = 1.7). In comparison, the LBL group ($N = 6$) achieved an SNR loss score of $M = 5.2$ (SD = 1.3). The assumption of homogeneity of variance was tested using Levene F test and the condition was satisfied ($F(13) = 1.5, P = 0.2$). The results of the t test indicated a slight significantdifference between the early and late group scores ($t(13) = -2.1$, $P = 0.04$). These results show that a more favourable SNR was needed to obtain a 50% recognition score with increased age of acquisition, supporting the prediction that the LBL listeners would perform poorly compared to the EBL listeners. The mean speech perception scores across the two groups are shown in Figure 2.

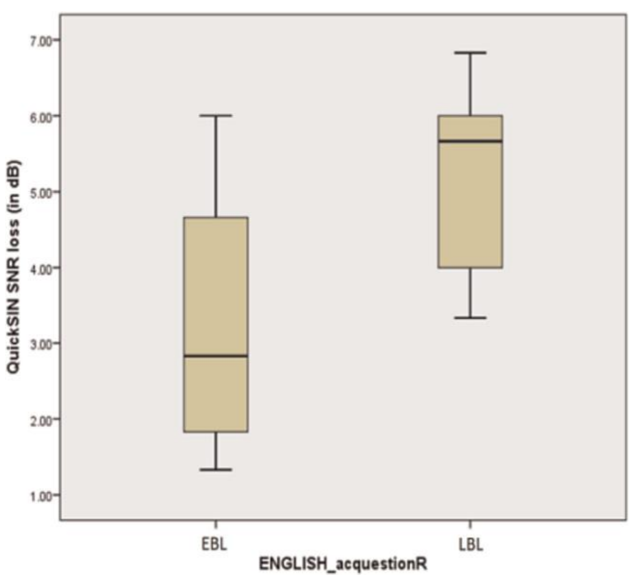

Figure 2: Mean speech perception scores for each group (early bilingual [EBL] and late bilingual [LBL]) and condition (1 = signal-to- noise ratio [SNR] loss) on the quick SNR (QuickSIN) test. Significant difference at $P < 0.05$ was reported between EBL and LBL groups.

Differences between the scores of the two bilingual groups and the monolingual group

On average, the ML listeners achieved better QuickSIN scores than the BL groups [Figure 3]. The ML advantage for speech in noise perception was confirmed by an independent sample *t* test, which revealed a significant (t (9.4) = − 4.256, P = 0.002) difference between the QuickSIN scores of the ML (M = 0.896, SD = 0.65) and EBL (M = 3.44, SD = 1.72) groups. The difference between the ML (M = 0.896, SD = 0.65) and LBL (M = 5.248, SD = 1.33) groups was also significant (t(5.99) = − 7.641, $P < 0.001$). The mean speech perception scores across the three groups are shown in Figure 3.

Discussion

Listener group effects

With regard to speech perception performance, the BL group scores for the SNR-50 and SNR loss were significantly poorer than the ML group scores. Despite the fact that the BL participants had normal hearing and were proficient in English, their speech perception test results showed a measurable SNR loss and higher than normal SNR-50. However, the SNR-50 scores determined for the ML group were in line with typical adult scores. To illustrate, the mean QuickSIN SNR-50 for the ML group (2.9 dB) was within one SD of the normal range reported by McArdle and Wilson[26] of 3.9 to 4.3 dB, whereas the mean QuickSIN SNR-50 for the BL group (6.2 dB) was significantly higher. In addition, the SNR loss scores in this study revealed that the BL listeners performed poorer in their L2 than the ML listeners (the groups obtained mean QuickSIN scores of 4.16 and 0.90 dB, respectively), which clearly indicates that BL listeners need more intense signals in noise to attain comprehension of speech. In this way, the study results support previous research findings.[3,8,9] According to Etymotic Research,[25] the BL listeners in this study can be classified as having mild SNR loss compared to a 2-dB SNR loss for individuals with normal hearing [Table 1]. The reason for this is not clear, but recent research has suggested that bilingualism itself may be the culprit and that speech perception problems are not limited to second or later acquired languages.[7] Additionally, studies have shown that BLs perform slower in reaction time tasks and less accurately in noisy conditions, due to the need, even in ML tasks, to search both lexicons.[4]

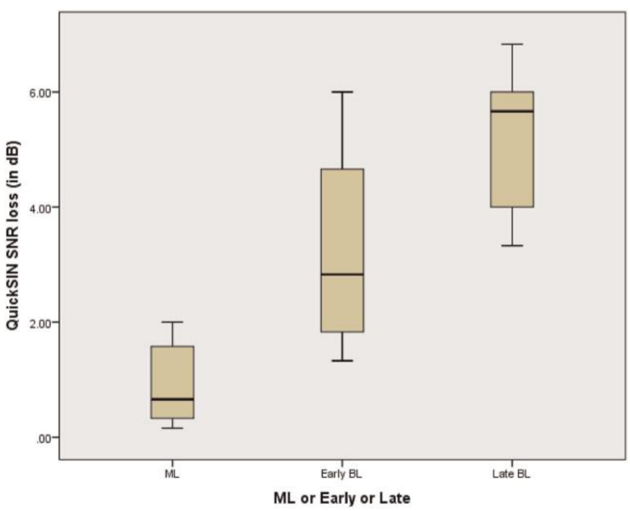

Figure 3: Mean speech perception scores for each group (monolingual [ML], early bilngual [EBL], and late bilingual [LBL]) and condition (1 = signal-to-noise ratio [SNR] loss) on the quick SNR (QuickSIN) test. Significant difference at $P < 0.05$ was reported between ML andEBL and ML and LBL groups.

Dividing the BL group into subgroups based on age of acquisition of the L2 shows that age of acquisition accounted to some extent for poorer speech perception performance in noise in the L2. The main findings of this study revealed that the simultaneous BL listeners performed similarly to the ML English listeners in terms of the mean SNR loss score (1.3 dB), which is within the range of the ML SNR loss scores (0.16–2.00 dB). This result is in line with Sundara and Polka's study,[27] which found that adult simultaneous BLs did not differ from ML English speakers in perceiving speech, but that the BLs who learned their L2 later, when entering school, did differ from MLs. On the other hand, Crandell and Smaldino[28] found that simultaneous BL children performed significantly poorer than ML children did in noise. A possible explanation for this might be a discrepancy between that study and the current research in considering the temporal maturing of processing capacities in children.[29] As simultaneous BL children develop speech perception skills in two languages simultaneously, their ability to achieve mature speech processing may take longer than in ML children. In the current study, the EBL group with a mean English acquisition age of 5.11 years and those who learned English simultaneously with Arabic, scored better in the QuickSIN than listeners who learned English later in life. These results support the research of Meador *et al.*,[30] which found that early acquisition BLs performed better than late acquisition BLs in a sentence-in- noise task in their L2. On the contrary, previous studies have suggested that early acquisition BL listeners perform more like MLs in speech perception tests (e.g., References [4,31]), the results of the current study suggests otherwise, because despite a relatively high level of self-rated skill in L1 and L2 (4 or 5 in both languages and in all language skill areas) and wide-ranging experience with L2, the EBL group continued to demonstrate much lower speech perception scores (with an average of 3.41 dB) than the ML group (with an average of 0.89 dB). Thus, the results of this research suggest that even when listeners have extensive experience of the L2, perceptual performance does not increase. Indeed, the results support evidence presented by Mayo *et al*.,[3] who argued that listeners with early acquisition and high levels of proficiency are affected and do not perform as well as ML listeners. It should be noted that previous studies classified early and late BLs differently from each other and from this study.

Furthermore, those in the LBL group (which had a mean English acquisition age of 10.66 years), scored significantly poorer than the ML group, with an average score of 5.24 dB compared to the ML group's average of 0.89 dB. These results support the work of Shetty[32] and Shi,[33] who found that speech perception was significantly poorer in groups with late age of English acquisition than in all other groups. The difference in age of acquisition might explain why previous studies have found performance among early and late acquisition BL listeners to be significantly poorer than in ML listeners, but no such difference between simultaneous BL and ML listeners' performance was observed in this study. Nevertheless, the results of this study did show that the BL and ML listeners did not perform similarly in auditory speech perception tasks involving background noise.

Factors affecting performance

Most studies, including the current research, have identified differences between the perceptual performance in background noise of BLs and MLs. The reasons for these differences remain somewhat unclear; however, a number of explanations have been suggested. For example, Weber-Fox and Neville[34] studied language processing in a group of early and late acquisition BLs using event-related potentials and found that the late learning BLs demonstrated slower linguistic processing than the early learning BLs, and that the language-related neural systems of the later learners were different in locus and function from those of the early learners. This is apparent in the results of the current study, as the LBL learners showed poor speech perception scores with many more errors than the EBL listeners. This supports the view that age is a primary mechanism in determining the end state of BL functioning, in accordance with the critical period hypothesis,[35] which argues that after a certain point in a person's maturation process, the ability to learn languages to a native-like standard is lost due to loss of brain plasticity. In the current study, one participant was BL from birth and performed at the same level as the ML listeners, but the EBL listeners' performance was between that of the MLs and LBLs at higher noise levels. It is possible that the results were affected by the small number of participants, meaning that it is impossible to resolve whether a sensitive period for acquisition exists or whether all BLs perform worse than MLs in noise.

Although some studies have shown age to be an important factor affecting language performance, others have suggested that cognitive and linguistic factors interact with age and play a vital role in determining the end state of L2 processing outcomes. The significant differences identified in this study might be due to the interaction of the two language systems, resulting in the BL group being less efficient in processing certain aspects of language. Indeed, Flege *et al*.[36] argued that the L1 and L2 phonetic systems within a BL individual interact and are not easily separated, which forces BLs to alter their underlying speech perception mechanisms and prompts them to reorganize their linguistic profile (i.e., manipulate and suppress multiple streams of lexical information in noise). He further claimed that the acquisition of L2 sounds follows three possible cues depending on whether a particular sound is perceived bythe learner to be totally new, identical, or similar to an L1 sound.

Another possible explanation for the different results in this study is the vocabulary used in the materials, which could have influenced the level of difficulty of the sentences. According to the neighbourhood activation model,[37] a spoken word activates several lexical items in a person's memory and word identification requires that the listener discriminate between these items. In addition, Langdon's study[38] points to an explanatory theory for this regarding bottom-up processing, whereby phonetic aspects of words are used to decode a message and thus even ML listeners experience some difficulty in perceiving speech in background noise, as the noisy environment makes the phonetic aspects more difficult to recognize. However, BL Arabic listeners do not have the same English phonetic inventory as ML English listeners. Therefore, the results of this study clearly suggest it is more difficult for BLlisteners to understand speech in more challenging listening conditions.

Flege *et al*.[36] argued that listeners' education level and years of schooling in English could affect performance, as one learns a language more formally and systematically in school than elsewhere. Participants in this study learned English in different ways and at different ages; some were educated in BL schools and some learned through working in English environments, reading English books, and watching English films. This might explain the variations in speech perception results under conditions of background noise. As has been shown, longer education in English may lead to a larger vocabulary size and higher literacy, which could influence listeners' performance based on linguistic variables such as acquisition and fluency.[39]

As noted previously in this study, even when a BL participant's hearing is within normal limits, speech perception in noise is not. Furthermore, the results emphasize the need for clinicians to have knowledge of their clients' linguistic profiles and to interpret the test results correctly when making comparisons with other listeners (here BL/ML). As adult speech perception is affected by noise, it should be expected that BL children's perceptions will be worse with background noise because speech perceptions depend heavily on the acoustic quality of the classroom; such deterioration in perception could result in children losing track of the content of the teacher's instructions due to the poor acoustic environment, potentially putting them at risk of poor academic achievement.

Further research is required to design a battery test that assesses the various aspects of auditory processing skills and develop a thorough linguistic profile to determine the specific linguistic factors contributing to auditory performance in noise among BLs with normal and impaired hearing. Moreover, a larger sample size of participants for both simultaneous and early acquisition BLs required to explore potential differences in their performance compared to MLs listeners. The main findings of this study deserve further exploration by performing extra analyses (e.g., analysis of variance) to compare whether the BLs do worse across all SNRs, in line with Rogers *et al*.,[31] or whether their scores drop more rapidly once the listening conditions get more challenging, as found byTabri *et al*.[7]

Conclusion

The findings of this study showed significant differences in performance between ESL and ML listeners in background noise. The research provided further evidence of the negative effects of background noise on adults' speech perception, regardless of their language background (early or late BL). Additionally, the results highlighted the importance of measuring SNR loss to obtaining accurate diagnosis andpotential rehabilitative information that is not obtained from audiogram studies.

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