Monotic and Dichotic Acceptable Noise Levels in Typically Developing Children and Adolescents

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Abstract

Introduction: Ability to tolerate noise and speech perception in noise (SPIN) are important auditory skills for adults and children, with and without hearing loss. Acceptable noise level (ANL) and SPIN are tests used for the evaluation of these processes. The present study aimed to develop normative data on ANL test (monotic and dichotic) in typically developing children and adolescents using Marathi versions of the test. **Methods:** Thirty typically developing Marathi-speaking children and adolescents in the age range of 8–16 years were tested using Marathi versions of ANL and SPIN tests. **Results:** Median scores and interquartile ranges were developed. The scores were in agreement with those obtained in adults. More than 90% of children had low ANL scores of ≤3 dB showing excellent ability to tolerate noise and none showed high ANL. The dichotic ANL was significantly lower than the monotic scores, implying the advantage offered by spatial separation of speech and noise on the ability to tolerate noise. However, the scores obtained in monotic versus dichotic conditions were not correlated. There was a negative correlation between monotic ANL scores and SPIN scores (weak correlation in the left ear and moderate correlation in the right ear). Further, the ANL scores in dichotic condition did not correlate with SPIN scores. **Conclusions:** Children show ANL scores similar to adults. The processes underlying ANL and SPIN tests are not completely independent in children. The study does not support the role of binaural processing at higher auditory centers in the ability to tolerate background noise in children and adolescents.

Keywords: Acceptable noise level, dichotic, monotic, speech perception in noisy

Introduction

One of the main consequences of cochlear hearing loss is difficulty in communication, more so in the presence of noisy or reverberant listening conditions.[1,2] Difficulty in understanding speech in the presence of background noise is also a frequently cited problem by hearing aid users. The extent to which background noise masks the speech signal depends on the number of variables such as spectrum of noise, average intensity of noise versus speech, and the intensity fluctuations of the noise over time. The most important variable that affects speech perception is the relationship between the speech level as a function of frequency and noise level as a function of frequency, which is referred to as signal-to-noise ratio (SNR). The value of SNR needed for communication varies with the degree of hearing loss in individuals with hearing impairment. Individuals with cochlear hearing loss of 30 dB HL require +4 dB greater SNRs than normal hearers.[3] Hearing aids provide little benefit in speech perception in noisy (SPIN) environments.[4] Around half (49%) of the hearing-impaired individuals who have rejected their hearing aid stated difficulty hearing in noise as a reason for not wearing the hearing aid.[5] Poor SPIN is also a commonly reported complaint by children with auditory processing disorders. Thus, the need for testing auditory discrimination in the presence of noise cannot be ignored.

Kalikow *et al*. developed a test called SPIN test.[6] In this test, the test sentence is presented in a background of speech babble and the listener's task is to repeat the last word of the sentence. This test was designed to assess word recognition skills under two controlled levels of contextual information. High-predictability sentences provide several syntactic and semantic cues as to the identity of the final word, and

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low-predictability sentences provide few if any such cues. SPIN is affected by the mother tongue of the listener and hence it must be evaluated using material recorded in the native language of the listener.[7] Hence, this test has been successfully adapted in Indian languages such as Kannada, Telugu, Hindi, and Odiya so as to enable testing of speech perception in Indian population.[7-10] However, there is a dearth of SPIN studies in children. A study of SPIN in children using sentences recorded in Indian English showed that speech-in-noise perception in children improved with age and matured by the age of 9 years. The process of auditory closure tapped by this test is thought to be mediated in the anterior temporal lobe and is associated with reduced activity in the left hemisphere with an increase in the activation of the right hemisphere.[11]

Various authors have proved that though SPIN test can be used as a measure of benefit from the amplification, it cannot be used as a test for predictability of hearing aid use.[12,13]

To determine the tolerance of background noise while listening to speech with good predictability of hearing aid use, Nabelek *et al*. introduced a procedure called acceptable noise level (ANL; then called tolerated SNR).[14] Although both speech-in-noise testing and ANL deal with the effect of noise on speech, they assess different perceptual processes and are known to be separate phenomena. The premise of ANL is that some listeners are unwilling to wear the hearing aid due to an inability to accept background noise due to which they cannot benefit from hearing aids. ANL quantifies the highest level of background noise that the person will accept without compromising his/her speech listening. It is a clinical test that makes accurate prediction about whether an individual will be successful with the hearing aids or not.

It is an adaptive procedure where the speech is presented through headphones or speaker and takes only few minutes to administer. To obtain ANL conventionally, the clinician presents a recorded story of running speech. The listener is asked to adjust the loudness of speech so that it is too loud; then too soft; and then to their most comfortable listening level (MCL). Then, the background noise is added and the listener is asked to adjust the level of the noise to the highest level that they are willing to put up while listening to speech (called background noise level [BNL]). The difference between the listener's MCL and his or her maximum tolerated BNL is his/her ANL (dB).

ANLs can be classified into three different categories – low, mid, and high. Individuals with low ANLs, i.e., <7dB are successful hearing aid users and individuals having high ANLs, i.e., >13 dB are unsuccessful hearing aid users.[15] A lower ANL value indicates higher tolerance for background noise and a higher ANL value indicates lower tolerance for background noise. ANL was shown to be unaffected by gender,[14] hearing sensitivity,[14] hearing aid use,[13] type and preference of noise,[12,14] and presentation level.[16,17]

Freyaldenhoven and Smiley measured ANL in normal hearing children (8–12 years old) to report that ANL characteristics in children were similar to those in adults.[18] They found no significant difference in the ANL values of children and adults. Further, ANL is thought to be mediated above the level of superior olivary complex (SOC) where binaural processing occurs[19] and thus can be considered as a central auditory process. This implies that ANL is not only a tool for predicting successful hearing aid use but may also be a useful addition to the test battery to diagnose central auditory processing disorder (CAPD) in children. Many children with CAPD show difficulty in speech perception in the presence of noise, and various forms of speech-in-noise tests are an important part of CAPD evaluation. A recent study determined the utility of ANL in CAPD diagnosis.[20] These authors reported significantly larger ANL scores in children diagnosed with CAPD as compared to other children. ANL score was correlated with the scores on other CAPD tests such as frequency pattern test and random gap detection task. These results need to be corroborated in other studies, using the Indian versions of this test and in Indian children.

It has been proved previously that various central auditory processes mature with age and the rate of maturation is different for different processes.[21] Thus, it is important to develop normative data in children and adolescents for different auditory processes in order to use them for valid clinical diagnosis. Further, such normative values for speech-based tests must be obtained across different languages in order to make these tests accessible to clinicians in a multilingual country like India. A previous study of ANL in adults with varying language backgrounds concluded that language of the speech signal as well as the babble may affect listener's performance and the ANL values were not independent of the language used.[22] Although there are few studies of ANL in children, none are present in the adaptation of ANL in Marathi which is the official language of the state of Maharashtra and Goa and has fourth greatest number of native speakers in India after Hindi, Bengali, and Telugu.[23] Hence, the need for present study was felt.

The study aimed to develop normative scores for the Marathi version of ANL test in typically developing children and adolescents in the age group of 8–16 years. The correlation of ANL scores with those of Marathi speech-in-noise (SPIN) test was determined. Further, the correlation of monotic scores with dichotic scores on the ANL test and the correlation of SPIN scores with dichotic ANL scores were also studied.

Materials and Methods

Participants

The study included thirty typically developing children in the age group of 8–16 years who were native Marathi speakers. All children passed pure tone hearing screening at 25 dBHL tested at octave frequencies (250 Hz–8 kHz) bilaterally and had normal middle ear function as shown by the presence of bilateral "A" tympanograms with the presence of ipsilateral stapedial reflexes for 500, 1000, 2000, and 4000 Hz at or below 100 dB HL. The participants were recruited through acquaintances of the investigators. Children with reported academic difficulties were excluded.

Instruments and materials

Testing was done in a sound-treated room. Pure tone hearing screening was administered on Maico MA-41 with supra-aural TDH39P headphones. Presence of middle-ear pathology was ruled out using Immittance Audiometer GSI 38 Auto Tymp. ANL and SPIN tests were administered using laptop (Dell Inspiron 3558) compact disk player which routed the recorded speech test material to the dual channel GSI Audiostar audiometer connected to TDH 49P supra-aural headphones. The speech material for ANL and SPIN tests developed at Bharati Vidyapeeth Deemed University were used in the present study.[24,25] ANL test material consisted of female voice recording of a passage which served as the primary speech stimulus and recorded Marathi speech babble (seven speakers) as competing background noise. SPIN test material consisted of female voice recording of 50 Marathi monosyllabic words divided equally into two word lists presented ipsilaterally with speech spectrum noise.

Procedure

ANL test was administered using the procedure given by Nabelek *et al*.[14] First, the MCL was calculated. Children were told to indicate at what level they heard the passage at a comfortably loud level using gesture of thumbs up for increasing the loudness, thumbs down for decreasing the loudness, and a straight hand for tolerable loudness. The initial presentation level of the recorded passage was 30 dB HL, the intensity of the passage was increased in 5 dB step size until the participant signaled that the passage was too loud, and then the intensity of the passage was decreased in 5 dB step-size until the participant signaled that speech was soft. After obtaining the range wherein the passage was heard most comfortably, the intensity of the passage was adjusted in 2 dB step-size and the final score of MCL was obtained using bracketing method. Next, the BNL was calculated. The recorded passage was presented at participants' MCL level, and the noise babble was added to speech signal. The level of the noise was increased in 2 dB steps until the participant indicated that the noise was intolerable. The highest level of noise tolerated by the child was referred to as BNL. The difference between the two values was documented as the ANL score. The ANL scores were obtained under monotic condition for each ear followed by dichotic condition. In dichotic presentation, half of the participants were tested by presenting primary speech stimulus in the right ear and competing background babble in the left ear. For the other half participants, this condition was reversed. Participants were instructed in Marathi language.

Further, SPIN was performed under headphones using half-word list (25 words) at MCL level (determined in ANL test) in each ear separately at 0 dB SNR. Word lists 1 and 2 were used for right and left ears, respectively. Participants were instructed in Marathi that they would hear words along with background noise. They had to repeat the words that they heard. The raw scores of SPIN were used for analyses.

Test duration for ANL and SPIN tests were 15–20 and 10–15 min, respectively.

All the values were documented in MS Office Excel 2007 and further statistical analyses were done using Medcalc software (version 16.8.4, Ostend, Belgium). Significance level of 0.05 was set for significance testing.

Results

ANL and SPIN scores of thirty children and adolescents in the age group of 8–16 years (mean age of 11.4 years) were analyzed. Right monotic ANL scores, left monotic ANL scores, and dichotic ANL scores were documented and are represented graphically in Figure 1. Initially, the ANL scores in the right ear versus the left ear were compared to study if ear effect was present in monotic ANL scores. It was observed that the distribution for right monotic ANL scores did not reach normality on Shapiro–Wilk test ($W = 0.89$, $P = 0.0043$) while the left ANL distribution reached normality ($W = 0.95$, $P = 0.1357$); hence, Wilcoxon's signed-rank test was used to compare the right versus left monotic scores on ANL. There was no significant difference in these scores ($Z = 0.029$, $P = 0.9772$); hence, right and left ANL scores were merged for developing normative scores. When the scores of the two ears were merged, the combined distribution did not reach normality ($W = 0.94$, $P = 0.0039$). Hence, the descriptive statistics/normative scores were expressed as median (4 dB) and 95% confidence interval (CI) of median (2.0–4.06 dB). The median score for dichotic ANL score was 2 dB (95% CI of median: 2.0–4.0 dB). There was a significant difference in the ANL scores of participants obtained in monotic versus dichotic conditions on Wilcoxon's signed-rank test ($Z = 4.78$, $P < 0.001$). Further, there was no correlation seen between

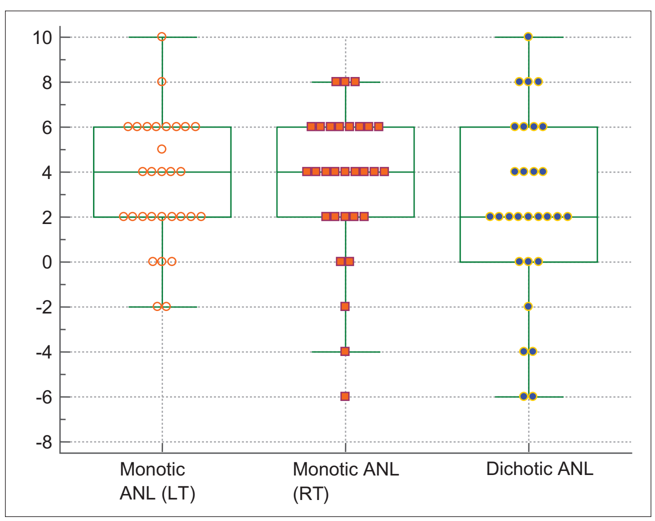

Figure 1: Marathi acceptable noise level scores

the monotic and dichotic ANL scores (ρ =0.175, P = 0.27). Figure 2 depicts the scatter-plot for the same.

The next objective was to determine the descriptive statistics for SPIN scores for the participants. Figure 3 depicts the SPIN scores for the study group in each ear. The distributions for right ear scores as well as left ear scores did not reach normality on Shapiro–Wilk test (W = 0.92, P = 0.04 in the right ear; W = 0.86, P = 0.0013 in the left ear). Hence, Wilcoxon's signed-rank test was used to determine the significance of difference in SPIN scores of the two ears; no significant difference was observed (Z = 0.12, P > 0.05). Hence, the SPIN scores of the two ears were merged to obtain normative scores. The median score on SPIN was 20 (80%) with 95% CI of 19.0–20.0. Table 1 depicts the normative scores for ANL and SPIN tests in typically developing children in the age group of 8–16 years.

Further, the investigators determined whether ANL and SPIN scores were correlated, and Figures 4 and 5 depict scatter-plots for the same. A weak, negative, and statistically nonsignificant correlation was observed for the ANL scores and SPIN scores of the right ear (ρ = −0.31, P = 0.06) while a moderate, negative, and significant correlation was obtained for the ANL and SPIN scores in the left ear (ρ = −0.47, P = 0.029).

Finally, the correlation between the SPIN scores (monotic) and ANL scores obtained in dichotic condition was determined. Figures 6 and 7 depict the scatter-plots for the same which show no correlation of dichotic ANL scores with SPIN scores of either ear.

Table 1: Normative scores

Test	Monotic		Dichotic	
	Median	95% CI	Median	95% CI
ANL (dB)	4	2-4.06	2	2-4
SPIN	20	19-20		

CI: Confidence interval; ANL: Acceptable noise level; SPIN: Speech perception in noise

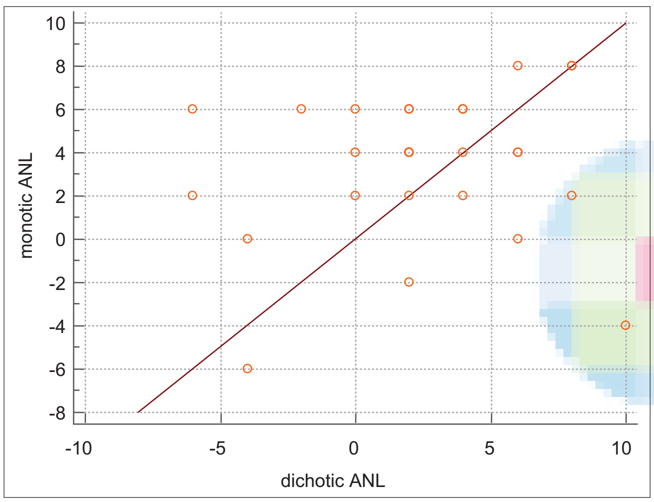

Figure 2: Scatterplot of acceptable noise level scores in monotic and dichotic conditions

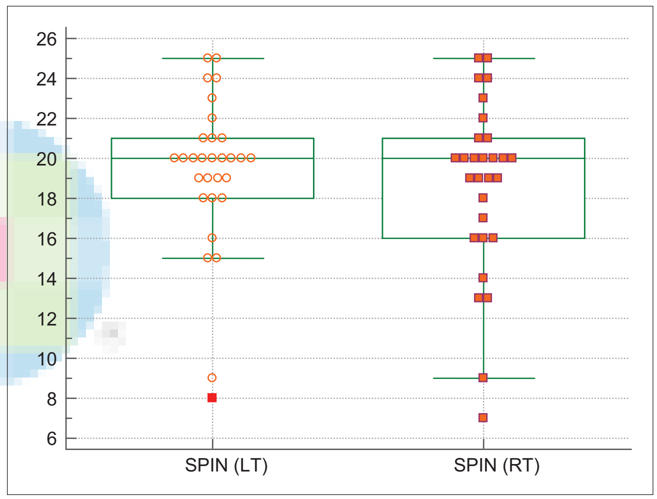

Figure 3: Marathi speech perception in noise scores

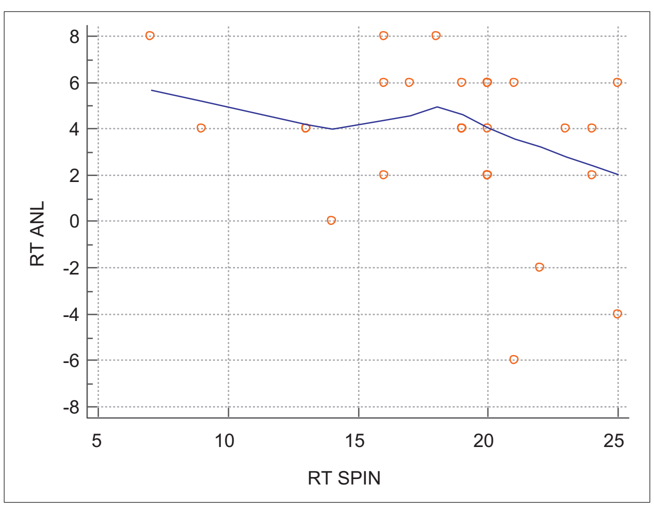

Figure 4: Correlation of acceptable noise level and speech perception in noise scores in the right ear

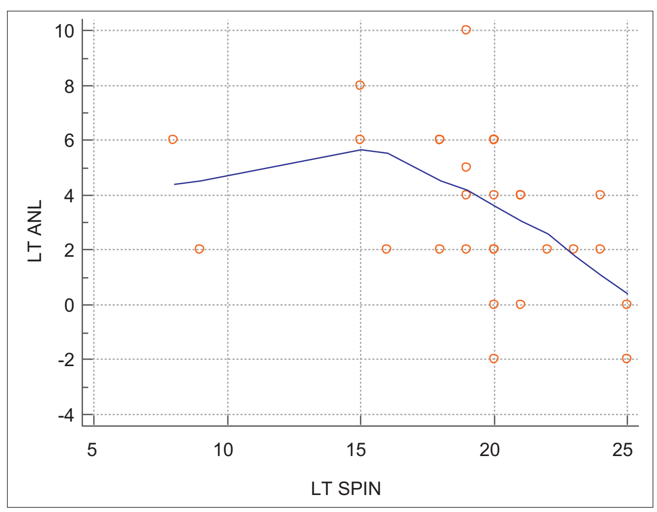

Figure 5: Correlation of acceptable noise level and speech perception in noise scores in the left ear

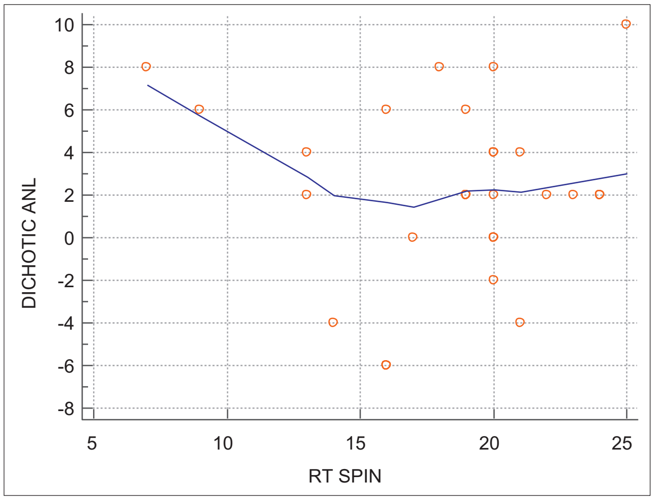

Figure 6: Correlation of dichotic acceptable noise level and right ear speech perception in noise scores

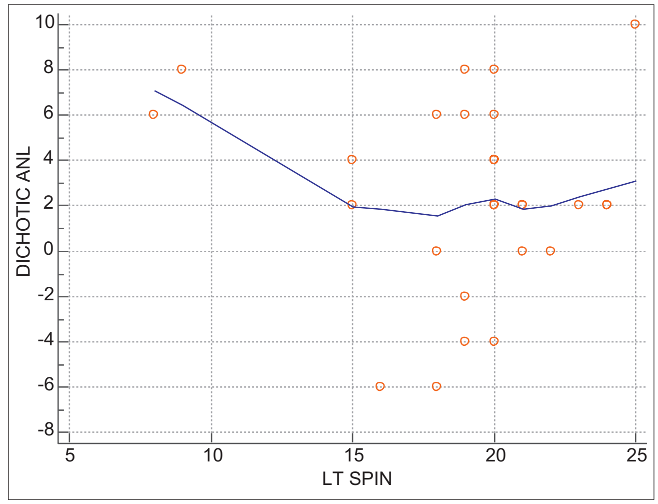

Figure 7: Correlation of dichotic acceptable noise level and left ear speech perception in noise scores

Discussion

The study aimed at developing normative scores for Marathi ANL test in children. The ANL scores obtained for the two ears did not show significant difference. Low ANL scores were obtained by 90% children in the right ear and 93% in the left ear, indicating good tolerance of noise. In the dichotic condition, 86.66% of children obtained low ANL scores. None of the children showed high ANL scores under any condition. The median value of monotic ANL in the study group was 4 dB. This was in agreement with previous studies in adults which also found the mean value of ANL for normal hearing group to be in the range of 3–5 dB.[17,26] However, other studies have reported the mean value of ANL for normal hearing individuals to be in the range of 7–15 dB, i.e., much higher than found in the present study.[12,19] This difference could be attributed to differences in stimuli used across studies, or could be partly attributed to the fact that Indian participants tolerated greater noise levels, probably owing to their habitual exposure to greater noise levels. However, no significant difference was seen in ANL values in children (present study) and those obtained in a previous study in adults using the same material and instrumentation.[26] This is in agreement to a previous report[18] and indicates that the ability to tolerate noise reaches maturation at 8 years of age.

The ANL scores in dichotic condition were lower as compared to monotic condition in the present study, with a median value of 2 dB. In dichotic condition, the speech signal and competing noise signal were presented to opposite ears at the same time. This caused the two signals to be separated spatially, thereby leading to easier identification of speech signal. Hence, individuals might accept or tolerate more amount of background noise (low ANLs) while following the story. Similar results were obtained in adults by Sahgal using the same test material and instrumentation.[26] On the other hand, Harkrider and Smith found that many adults accepted similar amounts of noise in monotic versus dichotic conditions.[19] Further, Harkrider and Smith found a strong correlation in ANL values obtained in monotic versus dichotic conditions.[19] They explained that for dichotic ANL, the brain requires to process auditory information binaurally, as the two stimuli are presented to both ears independently. This happens at the level of SOC where the first binaural processing occurs. Therefore, they concluded that for dichotic ANL, auditory processing occurs at higher auditory centers, and a strong correlation between monotic and dichotic scores suggests that similar processing beyond the level of SOC occurs for both modes of ANL. However, the present study did not find the monotic and dichotic scores to be correlated in children. Thus, children probably use different perceptual processes while listening to noise in the same ear as speech versus when both are presented to opposite ears. Presence of speech and speech babble in the same ear probably increased the task difficulty in children leading to higher ANL values as compared to dichotic tasks.

The findings of the present study show that children and adolescents make use of binaural separation ability to tolerate greater noise levels in dichotic listening conditions. It would be interesting to see whether children with deficits in binaural separation show such advantage in dichotic conditions.

Further, the study aimed to determine whether the scores on SPIN and monotic ANL were correlated. A weak negative correlation was observed in the right ear while a significant but moderate negative correlation was seen in the left ear. This indicated that children who tolerated more background noise also showed better speech recognition in the presence of noise. Presence of correlation in the scores obtained in the two tests suggests that probably the underlying tasks in the two tests were not completely independent of each other. This is in contrast with the results of Crowley and Nabelek who tested sentence recognition in noise and also contradicts the findings of Harkrider and Smith who studied phoneme recognition in noise using monosyllabic words as used in the present study.[12,19] However, these studies were carried out in adults. It appears that in children, the ability to tolerate noise is influenced by speech recognition in noise. Children and adolescents probably used similar perceptual processes for the two tasks. They may not clearly understand the difference in instructions for the two tasks, i.e., may be confused in speech recognition in noise (auditory closure) and willingness to tolerate noise. There are no previous studies in children to compare the findings of this study and hence future studies in this area are warranted.

Finally, it was observed that the ANL scores in dichotic condition were not correlated with SPIN scores in either ear in the present study. This is contradictory to the findings of only a previous research that studied such correlation in adults.[19] However, the previous authors cautioned that their study involved computation of several correlation coefficients and hence type I error was possible, though not likely, considering the large effect size obtained in their study. They reported that individuals, who tolerated greater amounts of noise in dichotic conditions, were able to perform better speech perception in the presence of ipsilateral noise. The present study did not support these results in children.

The small sample size of this study may restrict generalization of results to population at large, and the results of this study need to be corroborated with further studies using a larger sample size. Further, the results in the study are obtained using Marathi language and cannot be generalized to other languages.

Conclusions

The present study demonstrated that ANL could be successfully determined in children in a short time. The ANL scores in typically developing children were similar to those found in adults. About 90% or more typically developing children could tolerate background noise very well and none showed high ANL values. ANL values obtained in dichotic condition were lower than that in monotic condition although no correlation was observed between the ANL scores in the two conditions. Thus, spatial separation of speech and noise improved the ability to tolerate background noise. There was a negative correlation between monotic ANL scores and SPIN scores, indicating that in children, speech recognition in noise was dependent, at least to some extent, on the ability to tolerate background noise. However, ANL in dichotic condition was not associated with speech recognition in noise.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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