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Research Article

Acceptable Noise Levels, Speech Perception in Noise and Contralateral Suppression of Otoacoustic Emissions in Kannada Speaking Adults with Normal Hearing Sensitivity

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Abstract

Introduction: The Acceptable Noise Level (ANL) measures an individual's noise tolerance during speech listening, unrelated to factors like age, gender, language, and hearing sensitivity. ANL assessments are consistent for normal and impaired hearing individuals. The Speech-in-Noise Test (SPIN) assesses speech perception in noise and hearing aids. The role of contralateral Oto Acoustic Emissions (OAEs) and the medial olivocochlear (MOC) system in noise perception is acknowledged. However, there is a need to explore the correlation between ANL, OAE suppression, and SPIN to understand the physiological basis of these measures.

Aim: The current study aims to investigate the correlation between acceptable noise level, speech in noise, and contralateral suppression of OAEs in Kannada-speaking young adults with normal hearing.

Method: The research involved a group of 60 young adults, aged between 18 and 25 years, who were native Kannada speakers with normal hearing abilities. The Acceptable Noise Level (ANL) was determined by subtracting the Background Noise Level (BNL) from the Most Comfortable Level (MCL) and expressed in decibels (dB). Speech perception of noise was assessed using Quick Speech in Noise (QSIN). The Signal-to-Noise Ratio at which speech was understood 50% of the time (SNR-50) was estimated. To quantify contralateral suppression, the difference in Transient Evoked Otoacoustic Emissions (TEOAE) amplitude in quiet (averaged from two recordings) was compared to the TEOAE amplitude in the presence of noise on the contralateral side.

Results: Appropriate correlation analysis was conducted to establish the correlation between the studied variables. Data analysis revealed no statistically significant correlations between ANL and SPIN, ANL and contralateral suppression of OAEs in both ears, and speech perception in noise and contralateral suppression of OAEs in both ears.

Conclusion: The study found a weak and statistically insignificant correlation between ANL and SPIN, suggesting that ANL alone may not fully assess noise tolerance during speech perception. The investigation into ANL and contralateral suppression of OAEs also did not yield significant results, indicating the complexity of these measures. The study did reveal weak correlations between SPIN and OAE suppression at specific frequencies in the left ear, hinting at the role of the auditory system in noise perception. Further research is needed to understand these findings better.

Keywords: Acceptable Noise Level; Speech in Noise; Contralateral Suppression of OAE's

Abbreviations

ANL: Acceptable Noise Level; SPIN: Speech in Noise; CSOAE's: Contralateral Suppression of OAE's

Introduction

The acceptable noise level (ANL) refers to an individual's capacity to listen speech amidst background noise, where they can choose a highest background noise level (BNL) without feeling fatigued. The process for determining and comprehending ANLs during speech perception was introduced by Nabelek, Tucker, and Letowski in 1991 [1]. This method was termed the "acceptable noise level", formerly known as "tolerated SNR".

Previous research has showed that ANLs are not related with age [1,2], gender [3], type of background noise, or preference for sounds in the background [1], the first language of the listener (von Hapsburg and Bahng, 2006), hearing thresholds [1,2], acoustic reflex thresholds (ARTs), contralateral suppression of otoacoustic emissions (CSOAEs) [4], or perception of speech in noise i.e. SPIN scores [1].

ANLs have proven to be consistent and exhibit a normal distribution in individuals with both normal as well as impaired hearing [1]. Furthermore, ANLs have been assessed over 3-week and 3-month periods for individuals with normal and impaired hearing, respectively. The findings demonstrated that ANLs remained consistent over at least 3 weeks or 3 months for the given group of participants [1,2].

The speech perception in noise (SPIN) test is an alternative evaluation that employs either words or sentences when noise is present in the background. The widely used test in English is the Quick Speech-In-Noise Test (QuickSIN; Etymotic Research). Speech-in-noise tests are reported to be valuable in detecting SNR loss, which assists clinicians and patients in making well-informed decisions regarding selection, fitting, and rehabilitation to maximize the benefits derived from hearing aids. Additionally, speech-in-noise tests efficiently verify the proper functioning of directional microphone hearing aids [5].

Valame., *et al*. [6] conducted a study to establish normative data for the ANL test in typically developing Marathi-speaking children and adolescents aged 8 to 15 years, including both monotic and dichotic presentations. They also explored the potential link between ANL and SPIN. For the dichotic presentation, half of the participants experienced the primary speech stimulus in the right ear and competing background babble in the left ear, while the other half had the condition reversed. Additionally, they used a half-word list of 25 words in the SPIN test at the most comfortable level. determined during the ANL assessment, with 0 dB SNR, separately for each ear. Word lists used were different for the both right and left ears.

The obtained ANL scores for both ears did not demonstrate any significant difference. The findings demonstrated that 90% of children exhibited low ANL scores in the right ear, and 93% in the left ear, indicating a good tolerance for noise. In the dichotic condition, 86.66% of children achieved low ANL scores. None of the children had high ANL scores under any condition, and there was no such significant difference observed in ANL values among the children.

While the ANLs in the dichotic condition were a little lower than those in the monotic condition, no such significant correlation was seen among the ANLs obtained in these two conditions. However, they discovered a negative correlation among monotic ANL and SPIN results, suggesting that in children, recognition of speech in noisy environments partly depends on their ability to tolerate background noise. Interestingly, the study did not show any association between ANL in the dichotic condition and speech perception in noise.

Jones., *et al*. [7] conducted a study to assess ANLs in children with and without hearing impairment and to investigate the relationship between acceptable noise levels and speech understanding in noise among children. They utilized a between-subject design, with sixteen children having normal hearing forming the control group, and sixteen children with hearing loss comprising the experimental group. The research did not reveal any significant differences in acceptable noise levels between children with normal hearing and those with hearing loss. Moreover, there was no significant correlation found between acceptable noise levels and speech reception threshold for sentences in children with and without hearing loss.

In a different study, Nabelek., *et al*. [1] conducted a study comparing speech perception in noise to acceptable noise levels in both aided and unaided conditions. Their findings suggested that SPIN scores could serve as an indicator of the benefit from amplification and might even improve with the usage of amplification. However, SPIN scores could not predict the likelihood of a successful candidate for hearing aids. The study also noted that ANLs remained stable with the use of amplification and seemed to predict the probability of individuals becoming good users of hearing aids even before they were fitted.

Contralateral suppression of oto-acoustic emissions (CSOAEs) has been identified as a factor influencing the perception of speech in noise, as reported by Kumar & Vanaja [8]. The medial olivocochlear (MOC) system is believed to play a crucial role in enhancing signal detection in noise [9]. Cochlear structures and the auditory efferent system's activity and functioning are measured through Oto-acoustic emissions and CSOAEs, respectively (Kemp., *et al.*).

Boer., *et al*. [10] delved into a study aimed at exploring the relationship between medial olivocochlear (MOC) activity and speech-in-noise processing in a cohort of individuals with normal hearing. They elucidated how the MOC bundle, when activated reflexively by sound, diminishes the cochlear amplifier's gain, thereby amplifying the responsiveness to signals presented amidst masking noise. The researchers gauged MOC activity using contralateral suppression of otoacoustic emissions (CSOAEs), while their assessment of speech-in-noise processing entailed measuring the significance of noise interference on performance during a consonant-vowel (CV) discrimination task. Their discoveries unveiled a noteworthy correlation between the suppression of OAEs and the proficiency of speech-in-noise processing.

Harkrider., *et al*. (2015) performed a study involving 31 young individuals aged between 19 to 40 years. The objective was to investigate the differences in dichotic and monotic ANL and their correlation with efferent auditory system activity, quantified using SPIN measurements. All 31 participants had hearing thresholds below 25 dBHL. ANLs were calculated for both dichotic and monotic conditions, and SPIN scores were obtained using the Phoneme Recognition Task, which involved 50 monosyllabic words (NU 6) embedded in a multi-talker babble stimulus. The study's findings revealed that monotic ANL and PRN (phoneme recognition in noise) were not correlated, indicating that each measure provides distinct information about a listener's speech-in-noise performance. Furthermore, the study didn't find any significant correlation between ANL and MOCB (medial olivocochlear bundle) activity, as assessed by contralateral suppression of OAEs.

Materials and Methods

The major aim of the current study was to investigate the correlation ANL with SPIN and CSOAE in Kannada speaking young adults with typical hearing sensitivity. To obtain this, the following procedure was followed.

The research study was computed in the following phases:

- **Phase 1:** Participants Selection
- **Phase 2:** Administration of ANL, Administration of Quick Speech in Noise (QSIN), Assessment of Contralateral Suppression of OAE's
- **Phase 3:** Data Analysis.

Phase 1: Participants selection

- 60 adults who are native Kannada speakers with good proficiency in the English language were taken.
- All the subjects in the age range of 18-25 years were included to be part of the study.
- Both male and female participants were considered.
- Normal hearing sensitivity as identified using Pure Tone Audiometry
- Normal middle ear functioning as assessed using Inventis clarinet immittance meter, all the participants had an "A" type of tympanogram with normal ipsilateral and contralateral reflexes.

Participant selection criteria

Participants were selected based on the following criteria.

Inclusion criteria

- Native Kannada speakers with good English Language proficiency.
- Normal hearing sensitivity
- Normal middle ear function

Exclusion criteria

- No indication of psychological, visual, systemic, behavioral, or other related pathologies.
- Subjects under the influence of any alcohol, sedative, or any drugs at the time of testing.
- Subjects who had difficulty in following the instructions during testing, ontological deficits, or neurological deficits.

Instrumentation

To determine air conduction thresholds and bone conduction thresholds for all participants, a properly calibrated two-channel Inventis Piano Diagnostic audiometer was employed, with connections to a TDH-39 headphone and a Radioear 71 bone vibrator. The same audiometer was used to assess the uncomfortable loudness level for each participant.

For tympanometry and reflexometry, a calibrated Inventis Clarinet immittance meter was utilized, following the standard procedure outlined by the British Society of Audiology (1992) to exclude the presence of middle ear pathology. A 226 Hz probe tone at 85 dB SPL was presented to the subjects while altering the ear canal pressure from -400 dapa to +200 dapa, and the admittance was plotted as a function of ear canal pressure. Participants with an A-type tympanogram (peak pressure: +100 to -100, static compliance: 0.32 to 1.6cc) were selected for the study, indicating normal middle ear functioning.

All procedures elated to audiology were carried out in a sound-treated room, adhering to ambient noise level standards set by ANSI S3.1-1999. The measurement of ANL involved delivering stimulus and noise through a custom application named "Audacity software version 3.1.3".

Phase 2

Administration of ANL, Quick Speech in Noise (SIN), and assessment of contralateral suppression of OAEs.

Acceptable noise level

The current study adopted the procedure given by Nabalek, Tucker, and Lebowski (1991) for determining ANL while listening to speech. The stepwise procedure is explained in detail below.

Step 1: Stimuli

A standardized Kannada passage was considered to be used as the speech stimulus for the measurement of ANL. With the help of a native female Kannada speaker, the passage was recorded on a computer and a speech shaped noise was added as the noise in the background. Stimuli and noise for the calculation of ANL were delivered via a custom application in Audacity® Cross-Platform Sound Editor software. A standardized Kannada passage which was spoken by a normal native female speaker in a normal effort was considered and recorded on the computer. The background noise used was speech shaped noise. A calibrated Sennheiser HD headphone was used to deliver speech as well as noise bilaterally to each participant through MATLAB.

Step 2: Procedure

A distraction-free room was carefully chosen as the setting for the experiment. Participants were comfortably seated in chairs, with the investigator positioned across from them at a table. All instructions were conveyed in the Kannada language. The process began by determining the MCL for each subject, which was then followed by ascertaining the BNL. The ANL, measured in decibels (dB), was subsequently computed by deducting the BNL from the MCL (ANL = MCL - BNL). In simpler terms, a low ANL indicates a high capacity to tolerate background noise, while a high ANL (>13 dB) signifies a diminished tolerance for such noise.

Most comfortable level (MCL)

Procedure

Instructions were given to listen to the narrative being played through headphones. The initial level of loudness of the spoken content was set at 0 dB HL, and it was then gradually raised in increments of 10 dB until the participant signaled that it had become "too loud." Subsequently, the volume was decreased by 10 dB steps until the listener indicated that it was "too soft." At this juncture, the story's volume was fine-tuned, increased and decreasing in 5 dB intervals, until the listener signaled their MCL.

Instruction

The participants received instructions in Kannada, and they were informed as follows: "I will present a Kannada story through the headphones, and your task is to listen to the narrative. After a brief period, I will gradually raise the volume of the story until it becomes uncomfortably loud for you. Subsequently, I will decrease the volume until it becomes too quiet. Finally, you will need to indicate the loudness level that feels most comfortable for you".

Background noise level (BNL)

Procedure

After determining the MCL, subjects were introduced with background noise to derive the BNL. Initially, the noise was set at a 0 dB HL and was incrementally increased in 5 dB steps until the listener signaled that it had become "too loud" for him to continue listening to the ongoing narrative. Following that, we decreased the noise level in 5 dB increments until the listener indicated that it had become "too soft" while still listening to the continuous narrative. At this stage, the noise level was finely adjusted up and down in 1 dB increments until it reached the highest level that the participant could tolerate without feeling tense or fatigued. This level was recorded as the participant's BNL.

The ANL was computed by deducting the BNL from the MCL (ANL = MCL - BNL). Both the BNL as well as MCL were measured three times, and the average of these three ANL values was used.

According to their ANL values, the participants were classified into three groups:

- "Low" ANLs (ANL that were less than 7 dB)
- "Mid" ANLs (ANL that were between 7 to 13 dB)
- "High" ANLs (ANLs that were greater than 13 dB)

Instruction

The participants received instructions in Kannada, which included the following guidance: "You will listen to the same Kannada story at a comfortable intensity level you've determined. Afterward, we will introduce background noise. Your task will be to specify the noise level in the background that remains acceptable while listening to the speech without feeling tense or fatigued while following the story's words. I will gradually increase the background noise level until it becomes too loud for you to hear the story clearly, and then I will decrease it to a softer level. Finally, please indicate the maximum level of background noise that you would be willing to tolerate for an extended period while following the story".

Speech Perception in Noise

A quick SIN sentence list in Kannada was utilized in the current study to assess the speech perception abilities in noise. The sentences were adopted from the study "Development of Sentences for Quick Speech in Noise (QSIN) test in Kannada" (Avinash, Methi, and Kumar, 2009).

Instructions

Each of the subjects was instructed as follows:

Instruction in English: "You will be hearing some sentences along with noise and you should ignore the noise and repeat the sentences that were heard in its entirety".

Procedure

The study involved measuring the Signal-to-Noise Ratio (SNR) required for understanding 50% of the words in a sentence, known as SNR-50. This measurement was carried out using a rapid speech perception test in Kannada, as described by Methi., *et al*. in 2009. The testing took place with the subjects wearing earphones and being exposed to four simultaneous talkers speaking in the background.

The test encompassed seven equivalent lists, with each list comprising seven sentences, each containing five keywords. The SNR was adjusted, starting from +8 dB SNR and decreasing in 3 dB increments from the first to the seventh sentence within each list.

The target sentences were presented individually to each participant through a single Lifeline speaker positioned 1.5 meters away from the participant, precisely at 0 degrees in both the horizontal and vertical planes within an acoustically treated room. Participants were instructed to either write down or verbally repeat the target sentences. A score of one point was awarded for each correctly identified keyword, and the total number of correctly recognized keywords at each SNR level was tallied.

The Quick SIN lists were presented in a random order, which led to the sentences being presented in a mixed order as well. The testing was conducted in a single 45-minute session, with breaks provided whenever necessary.

Scoring

Five target words were scored for each sentence, and the total number of correctly repeated words was tallied for each list. Two sentence lists were presented. The total number of correctly repeated words for each list was tabulated and averaged.

The SNR-50 was estimated using the Spearman-Karber equation (Finney, 1978) taken as:

SNR-50 = I + ½ (d) – (d) (# correct) / (w) where:

I = the initial presentation level (dB S/B);

d = the attenuation step size (decrement);

w = the number of keywords per decrement;

correct = total number of correct keywords.

Contralateral suppression of TEOAEs

TEOAEs' presence for nonlinear clicks was ensured before recording contralateral suppression of TEOAEs. The details of the stimuli, procedure, and analyses employed in this study are elaborated upon in the subsequent sections.

Stimuli

Study utilized Otodynamics ILO v6 to capture TEOAEs. Initially, the study employed sweeps of 260 using nonlinear clicks, each presented at an intensity of 80 dB SPL (± 0.5 dB), to verify the existence of TEOAEs. These sweeps of nonlinear clicks consisted of four clicks, with the click four being of the opposite polarity and 10 dB more in intensity as compared to the initial three clicks.

Contralateral suppression of TEOAEs was conducted following the protocols and guidelines outlined by Durante and Carvallo (2008) and Hood., *et al*. (1996), similar to the approach employed by Shastri., *et al*. [11]. For this measurement, we used linear clicks at 65 dB SPL (± 0.4 dB), with each sweep containing four clicks of the same intensity as well as polarity. These clicks were of 80 µs duration and were presented at a 50 per second rate, resulting in a response window of 20 ms. During the recording process, we set the rejection level for the response recorded at 12 millipascals (mPa). If the consistency of the stimulus dropped below 95%, the entire recording for that participant was invalidated, and the recording was redone. In the evaluation of contralateral suppression of TEOAEs, uninterrupted white noise at 60 dB SPL, produced through a calibrated audiometer, worked as the suppressor.

Procedure

Participants were seated comfortably in chairs, and a probe was inserted into their ears, ensuring a flat frequency spectra adjustment. The instrument routinely verified the probe's fit both before commencing each recording and throughout the recording process. Initially, TEOAEs were recorded in response to nonlinear clicks. TEOAEs were deemed present when the response amplitude exceeded the noise level by at least 6 dB in each frequency band, with a reproducibility rate surpassing 80%. Importantly, all participants in this study exhibited the presence of TEOAEs in both ears.

After the assessment, contralateral suppression of TEOAEs was computed by employing linear clicks. This involved placing the probe in the participant's right ear and using an insert ER-3A receiver (Etymotic Research Inc., Elk Grove Village, IL) in the left ear. We recorded TEOAEs using 260 sweeps of linear clicks in a quiet environment (without contralateral noise). Subsequently, another recording was conducted, introducing uninterrupted white noise at 60 dBSPL to the other ear via an insert receiver attached to a calibrated audiometer (noise condition). The choice of a 60 dB SPL noise level ensured that the noise in other ear remained insufficient to trigger the middle ear muscle reflex. Furthermore, as the noise was delivered through insert earphones, the likelihood of intra-aural cross-over was minimal.

For each participant, four times TEOAEs were recorded, with a sequence of two quiet conditions followed by two noise conditions (quiet-noise-quiet-noise). This identical sequence was maintained for all participants.

Analyses

The study examined the amplitude of TEOAEs within the 8-18 milliseconds specified time window. This time frame was selected based on prior research findings that identified it as optimal for measuring the amount of contralateral suppression (Berlin., *et al*. 1993; Veuillet, Collet, & Duclaux, 1991). Kresge Echo Master emissions analysis program was taken in use to perform the entire analysis.

The study recordev d the rms-amplitude of TEOAEs across the frequency spectrum, referred to as the global TEOAE amplitude, for all recorded data. To quantify the magnitude of contralateral suppression, the study calculated the difference in TEOAE amplitude between two conditions: TEOAE amplitude obtained in a quiet environment (averaged from two recordings) and TEOAE amplitude obtained in the presence of contralateral noise (averaged from two recordings). Both the global TEOAE amplitude in a quiet setting and the contralateral suppression amplitude of TEOAEs were utilized for statistical analyses.

Phase 3

Data analysis

The results obtained in each test for each participant on all the tests were computed and tabulated. This data was further subjected to statistical analysis using the IBM SPSS software version.

Results

The present study primarily aimed to investigate the correlation of ANL with Speech in Noise and Contralateral suppression of OAEs among native Kannada speaking young adults with normal hearing sensitivity. 60 subjects underwent the evaluation. The data thus obtained was subjected to a series of statistical analysis.

Descriptive statistics and normality checks were carried out in the obtained data. The Shapiro–Wilk test revealed that the data were not normally distributed, and hence, nonparametric tests were used for further analysis.

The following statistical analysis was carried out on the data:

- Shapiro Wilk test to check for normal distribution of data.
- Descriptive statistical analysis on MCL data.
- Descriptive statistical analysis on BNL data.
- Descriptive statistical analysis on ANL data.
- Descriptive statistical analysis on SNR50 data

- Descriptive statistical analysis on contralateral suppression of OAEs in both ears.
- Spearman correlation analysis to analyze the correlation between ANL and SNR50.
- Spearman correlation analysis to analyze the correlation between ANL and contralateral suppression of OAEs in both ears.
- Spearman correlation analysis to analyze the correlation between SNR50 and contralateral suppression of OAEs in both ears.

Most comfortable level (MCL)

In this research, a population of 60 native Kannada speaking young adults were studied. Each subject's most comfortable level (MCL) was obtained. These results were tabulated and analyzed. Table 1 depicts the mean and standard deviation of MCL obtained.

Table 1: Mean value and standard deviation of MCL.

MCL (dB)	
Mean	45.87
Standard Deviation	2.98

Background Noise Level (BNL)

The Mean(average) and standard deviation of BNL obtained from all 60 participants were also estimated. Each subject's background noise level measurements were obtained and the results were tabulated. Table 2 depicts the mean and standard deviation of BNL.

Table 2: Mean value and standard deviation of BNL.

BNL (dB)	
Mean	36.32
Standard Deviation	3.32

Acceptable Noise level (ANL)

For each person, the ANL was calculated. This was achieved by deducting the BNL from the MCL to obtain the ANL. The results were then tabulated. Table 3 depicts the mean values and standard deviation of ANL obtained.

Table 3: Mean value and standard deviation of ANL.

ANL (dB)	
Mean	9.548
Standard Deviation	2.883

Quick Speech in noise (QSIN)

SNR50 was calculated for each participant. For every correct repetition of the words in the sentences, a score was awarded. These scores are evaluated to obtain SNR50. The results were then tabulated. Table 4 depicts the average values and standard deviation of SNR50 obtained.

Contralateral Suppression of OAEs in the left ear and right ear

Contralateral suppression of OAEs was calculated for both ears by subtracting 'obtained OAEs amplitude in the presence of contralateral noise' from 'obtained OAEs amplitude without noise' and for each participant.

Table 4: Mean value and Standard deviation of SNR50.

SNR50 (dB)	
Mean	-5.90
Median	-5.50
Standard Deviation	1.63

Correlation between ANL and SNR50

The acceptable noise level was derived for each individual by subtracting the background noise level (BNL) from the maximum comfortable loudness (MCL). SNR50 was also determined for every participant using quick speech perception in a noise test in Kannada (Methi., *et al*. 2009). These collected scores were then analyzed to derive the SNR50 ratings.

Since the data didn't follow a normal distribution pattern, Spearman's rank correlation coefficient was carried out to establish the correlation between ANL and SNR50 in young adults with normal hearing sensitivity. The correlation coefficient between ANL and SNR50 ($r = 0.236$), indicated a weak positive relationship which was not statistically significant ($p = 0.069$).

Correlation between ANL and contralateral suppression of OAEs in both ears

The acceptable noise level was computed for each individual by subtracting the background noise level (BNL) from the maximum comfortable loudness (MCL), resulting in the acceptable noise level (ANL). Contralateral suppression of OAEs were calculated for both ears by subtracting obtained OAEs values in the presence of contralateral noise' from 'obtained OAEs values without noise' and for each participant.

Since the data did not follow a normal distribution and hence nonparametric statistical analyses Spearman's rank correlation coefficient were carried out to establish the correlation between ANL and contralateral suppression of OAEs in both the ears at each frequency i.e., 1kHz, 1.5kHz, 2kHz, 3kHz, 4kHz.

The correlation analysis between ANL and suppression of OAEs in the left ear at 1kHz revealed a weak positive relationship (r = -0.096). However, this correlation was not statistically significant (p = 0.463). Similarly, correlation coefficient between 1.5kHz and ANL was (r = -0.081), (p = 0.538), between 2kHz and ANL was (r = -0.083), (ρ = 0.531), between 3kHz and ANL was (r = -0.068), (p = 0.603), between 4kHz and ANL was (r = -0.083), (p = 0.529).

The correlation coefficient between ANL and the amount of contralateral suppression of OAEs in the right ear at 1kHz was found to be (r = -0.061), indicating a weak positive relationship. Nonetheless, the correlation didn't come out as statistically significant (p = 0.642). Similarly, the correlation coefficient between 1.5kHz and ANL was (r = -0.070), (p = 0.597), between 2kHz and ANL was (r = -0.018), (p = 0.894), between 3kHz and ANL was -0.034, (p = 0.798), between 4kHz and ANL was (r = -0.121), (p = 0.356). Thus, the analysis revealed that there is no statistically significant correlation between ANL and contralateral suppression of OAEs in both ears across frequencies.

Correlation between SNR50 and contralateral suppression of OAEs in both ears

SNR50 was determined for every participant. A score was granted for each accurate repetition of the given words. These collected scores were then analyzed to derive the SNR50 ratings. Contralateral suppression of OAEs were calculated for both the ears by subtracting obtained OAEs values in the presence of contralateral noise' from 'obtained OAEs values without noise' and for each participant.

Since the data did not follow a normal distribution and hence nonparametric statistical analyses Spearman's rank correlation coefficient were carried out to establish the correlation between SNR50 and contralateral suppression of OAEs in both the ears across the frequencies.

The correlation coefficient between SNR50 and contralateral suppression of OAEs in left ear at 1kHz was found to be (r = 0.043), indicating a weak positive relationship. This correlation was not statistically significant (p = 0.742). Similarly, the correlation coefficient between 1.5kHz and SNR50 was (r = -0.179), (p = 0.171), and between 4kHz and SNR50 was (r = 0.240), (p = 0.065) was not significant. However, between 2kHz and SNR50 (r = -0.442), (p = .000), and between 3kHz and SNR50 (r = -0.388), (p = 0.002), there was a weak negative correlation observed which was statistically significant as (p < 0.05). The correlation coefficient between SNR50 and contralateral suppression of OAEs in the right ear at 1kHz was found to be (r = 0.222), indicating a weak positive relationship. However, this correlation was not statistically significant (p = 0.088).

Similarly, correlation coefficient between 1.5kHz and SNR50 was (r = -0.248), (p = 0.056), between 2kHz and SNR50 was (r = -0.223), (p = 0.086), between 3kHz and SNR50 was (r = -0.021), (p = 0.875), between 4kHz and SNR50 was (r = -0.224), (p = 0.086) which were all not statistically significant.

Thus, the analysis revealed that there is no statistically significant correlation between SNR50 and contralateral suppression of OAEs in the right ear at each frequency i.e., 1kHz, 1.5kHz, 2kHz, 3kHz, 4kHz whereas significant correlation was observed in the left ear at 2kHz, 3kHz, 4kHz.

To summarise, descriptive statistics and normality checks were carried out in the obtained data. The Shapiro–Wilk test revealed that the data were not normally distributed, and hence, nonparametric tests were used for further analysis. Spearman correlation analysis between ANL and SNR50 revealed no statistically significant correlation. Similarly, the correlation between ANL and contralateral suppression of OAEs at different frequencies showed no significant association. Additionally, the correlation of SNR50 with contralateral suppression of OAEs was explored, revealing a statistically significant correlation at specific frequencies in the left ear (2kHz, 3kHz, 4kHz) alone.

Discussion

Present study primarily aimed to investigate the correlation of ANL with SPIN and Contralateral suppression of OAEs among native Kannada speaking young adults with typical hearing sensitivity. The Acceptable Noise Level (ANL) was established by deducting BNL from the MCL, revealing the ANL for comfortable speech perception. Additionally, contralateral suppression of Transient Evoked Otoacoustic Emissions (TEOAEs) was measured by calculating differences between TEOAEs with and without contralateral noise, providing insights into noise suppression. The Quick Speech-in-Noise (QSIN) evaluation involved determining SNR50, where participants repeated words, yielding scores used to analyze and rate the perception of speech amidst noise. A total of 60 subjects underwent the evaluation. The data thus obtained was subjected to a series of statistical analysis, the results of which are discussed below.

Most comfortable level (MCL) in young adults

Most comfortable level was acquired from young adults with normal hearing sensitivity The mean scores and standard deviation of MCL obtained were 45.87dBHL and 2.98 respectively. The present study's findings of mean MCL scores align with and support the results of prior research, including the studies conducted by Franklin., *et al*. (2006) and Plyler., *et al*. (2011).

Plyler., *et al*. (2011) studied the effects that speech signal and gender have on acceptance of noise in normal hearing adults. The participants were 43 adults (26 males and 17 females) with a mean age of 22). The average mean and the standard deviation for MCL in adults in various experimental conditions were 46.3dBHL and 4.9 respectively. The scores were almost similar to those of the present study.

Franklin., *et al*. [12] reported in their study that as the level of presentation increases, acceptance of background noise increases. The participants were 20 adults (10 males and 10 females) with a mean age of 21.8 years. All the participants had normal hearing. The mean and standard deviation for MCL in young adults were 42.7dBHL and 6.6 respectively which is similar to that of the present study.

Background noise level scores in young adults

Background noise level was acquired from young adults with normal hearing sensitivity. The mean BNL score obtained was 36.32 dBHL, with a standard deviation of 3.32. The current investigation discovered that the mean BNL scores were in line with the outcomes of prior research studies (Rogers, 2003; Janardhan and Savithri, 2012).

Rogers (2003) investigated if background noise is affected by gender. The participants were 50 adults (25 females and 25 males) within the range of age i.e., 19-25 years. Speech babble (SPIN test; Kalikow., *et al*. 1977) was the noise used in the background. The mean BNL score and standard deviation reported were 39.2dBHL and 8.1, which is similar to the present study. Janardhan and Savithri (2012) studied the effect of reverberation on ANLs in 30 adult participants divided into two groups i.e., individuals with normal hearing and hearing impairment. Kannada Speech babble (Anitha, 2003) was used as background noise to obtain BNL. ANLs obtained from the participants with normal hearing were better than participants with hearing impairment. The mean BNL score and standard deviation observed in normal hearing adults were 36.20 dB and 5.80 respectively, which is also similar to the present study.

Acceptable noise level scores obtained in young adults

The Acceptable Noise Level (ANL), a measure documented from the deduction of BNL from the MCL, was successfully obtained from all 60 participants associated with the study. The mean ANL score calculated was 9.548. This average ANL score closely corresponds to ANL scores reported in prior research studies conducted by Freyaldenhoven., *et al*. (2007), Rogers (2003), and Moore, Gordon-Hickey, and Jones (2011).

Moore, Gordon-Hickey, and Jones (2011) centered their study on younger adults, uncovering a mean ANL of 8.5 dB with a standard deviation of 6.5. In a study focused on normal hearing adults, Freyaldenhoven., *et al*. (2007) reported a mean ANL of 7.52 dB based on a sample of 24 participants. Rogers., *et al*. (2006) explored ANL scores in relation to gender, encompassing 50 adults with an overall mean ANL score of 10.9 dB.

Further, a research study by Hemavathi and Vipin (2018) centered on ANL testing involving 100 normal hearing individuals. Among these participants, the mean ANL score was calculated at 6.86 dB, accompanied by a standard deviation of 5.82 dB.

Speech perception in noise obtained in young adults

Quick speech in noise test in Kannada language (QSIN-K) was performed where SNR50 was calculated for all 60 participants. For every correct repetition of the words in the sentences, a score was awarded. These scores are evaluated to obtain SNR50. The average (mean) SNR50 obtained was -5.90 with a standard deviation of 1.63.

Leclercq., *et al*. in 2018, performed a study with the aim to create French-language speech-in-noise tests that included a well-balanced range of speech material difficulty. The first phase of the study involved 10 adults who had normal hearing. They utilized an ascending method with a fixed noise level of 73 dB SPL to determine the Signal-to-Noise Ratio (SNR) required for 50% correct keyword identification in each sentence, known as SNR-50. To standardize sentence difficulty, they adjusted the relative levels between the sentences and noise on a sentence-by-sentence basis until they achieved an SNR-50 of 0 dB.

In the second phase, involving 12 adults with normal hearing, the study aimed to validate the equalization of sentence difficulty. The mean SNR-50 obtained in this validation phase was approximately -6.64 dB.

Contralateral suppression of TEOAEs obtained in young adults

Amount of CSOAEs were calculated for both the ears by subtracting 'obtained OAEs amplitude in the presence of contralateral noise' from 'obtained OAEs amplitude without noise' and for each participant. The mean suppression amplitude for both ears documented in the study was 1.98 dB.

Kalaiah., *et al*. in 2017 studied contralateral suppression of transient evoked otoacoustic emissions (TEOAEs) within adults with normal hearing sensitivity to investigate the influence of white noise on contralateral suppression phenomena in 19 young adults aged between 18 and 23 years. The investigation employed a method involving the measurement of TEOAEs using click stimuli in linear mode, with and without the presentation of noise to the contralateral ear. The noise was delivered using ER-6A insert phones at 60 dB SPL. Notably, the emphasis was on white noise as a key noise stimulus. The results revealed a mean suppression of 1.6 dB when white noise was applied.

Abdollahi., *et al*. (2011) explored disparities in gender among young adults in terms of TEOAE (Transient Evoked Otoacoustic Emissions) amplitude and the inhibition of TEOAEs, utilizing an average intensity of 84 dB peak SPL. They applied a 70 dB SPL white noise stimulus as contralateral acoustic stimulation (CAS), with a 20ms time window following the stimulus. This was in response to nonlinear clicks delivered at a rate of 50 per second, using 80µs electrical pulses. The study encompassed 60 young adults (30 females and 30 males), aged 21 to 27, all of whom met normal hearing criteria. Their findings revealed an average TEOAE suppression of 2.07 dB for male participants and 1.54 dB for female participants. It is important to note that TEOAE suppression in normal hearing adults exhibits significant individual variability. However, numerous studies have indicated that 1 dBSPL is considered the threshold for normal medial OC bundle function (Prasher., *et al*. 1994; Collet, 1993).

Correlation between acceptable noise level and speech perception in noise

The ANL was established for each participant by subtracting the BNL from the MCL. For each participant, SNR50 was also calculated through a quick speech perception test in Kannada (Methi., *et al*. 2009). These gathered scores were then studied to get the SNR50. Since the data did not align with the normal distribution pattern, Spearman's rank correlation coefficient was obtained to establish the relation between ANL and SNR50 in young adults with normal hearing sensitivity. Statistics revealed that there is no such statistically significant correlation between ANL and SNR50.

Harkrider and Smith (2005) explored the concept of "acceptable noise level" (ANL) in 31 adults with normal hearing and its connection to speech perception in noisy situations. They utilized a phoneme recognition task involving 50 monosyllabic words (NU 6) presented at 55 dB HL, with multi-talker babble noise at the same level as the competing stimulus. The study calculated the percentage of correctly identified phonemes in the word list for each participant. Their findings revealed no correlation between ANL and speech perception in noise. Therefore, participants who could tolerate more background noise tended to perform better in recognizing phonemes in noisy environments, indicating a common processing level beyond the superior olivary complex for both ANL and speech perception in noise.

Nabelek and Freyaldenhoven (2006) involving 191 participants with hearing impairment, investigated the ANL and SPIN scores. ANL was estimated using male speech as the target stimulus and 12-talker speech babble as background noise. Additionally, speech perception in noise was assessed using the revised SPIN test (Bilger., *et al*. 1984), and SPIN scores were recorded. There were no significant correlations reported between ANLs and SPIN scores in both unaided and aided conditions.

Thus, the results acquired from the present study agrees with the previous literature, suggesting that there is no such significant correlation between ANL and SPIN in normal hearing adults.

Correlation between ANL and contralateral suppression of OAEs in both ears

The acceptable noise level was computed for every participant by subtracting the BNL from the MCL, resulting in the ANL. Amount of contralateral suppression of OAEs were calculated for both the ears by subtracting 'obtained OAEs values in the presence of contralateral noise' from 'obtained OAEs values without noise' and for each participant. Present study showed no statistically significant correlation between ANL and the amount of contralateral suppression of OAEs in both ears at each frequency similar to earlier literature (Harkrider and Smith, 2005; Vishal and Hemanth, 2015. Although a weak positive correlation was observed for the left and right ear at 1kHz.

Harkrider and Smith (2005) conducted a study involving young adult women to examine the influence of the auditory efferent system on acceptable noise levels (ANL). They conducted a comparison analysis of ANLs within a group of 31 normal adults and explored the relationships between ANLs and various auditory factors, including CSTEOAEs. The study involved obtaining TEOAEs from the right ear using click stimuli delivered linearly at a rate of 50 per second, with the click level set at 60 dB peak Sound Pressure Level (SPL) (±3 dB). Simultaneously, contralateral broadband noise was presented at 65-67 dB SPL. Interestingly, the study revealed no significant correlations, particularly when examining the correlation between CSTEOAEs and ANL. This suggests that the activity level in the medial olivocochlear bundle, as assessed via CSOAEs, does not impact the tolerance to noise during speech perception. Additionally, no significant associations were found with otoacoustic emissions.

Vishal and Hemanth (2015) explored the connection between the behavioral measure known as ANL and its underlying physiological mechanism. They conducted their research with a group of forty participants with normal hearing, all aged between 15 and 30 years. ANL measurements were obtained at four fixed presentation levels, specifically 50, 55, 60, and 65 dB HL. To investigate the physiological aspect, otoacoustic emissions were recorded using 100 μs duration condensation clicks presented at a level of 60 dB equivalent SPL. These clicks were delivered at a rate of 10 per second while broadband noise at 65 dB SPL (5 dB above the click level) was simultaneously introduced in the contralateral ear through an insert earphone. However, their findings did not reveal any significant correlation between the overall ANL scores and CSOAE.

Thus, earlier studies are in agreement with the current study highlighting that no such significant relation is present between ANL and CSOAE across different frequencies in both ears. This aligns with studies by Harkrider and Smith (2005), and Vishal and Hemanth (2015) suggesting that ANL and auditory efferent processes are distinct, with no influence on noise tolerance during speech perception.

Correlation of speech perception in noise and contralateral suppression of OAEs in both ears

SNR50 was determined for every participant. A score was granted for each accurate repetition of the given words. These collected scores were then analysed to derive the SNR50 ratings. CSOAEs were calculated for both the ears by subtracting obtained OAEs values in the presence of contralateral noise' from 'obtained OAEs values without noise' and for each participant.

Since the data did not follow a normal distribution and hence nonparametric statistical analyses Spearman's rank correlation coefficient were carried out to establish the correlation between SNR50 and CSOAEs in both ears. In our study, no such statistically significant correlation between SNR50 and CSOAEs in both ears although a weak significant correlation was observed in the left ear at 2kHz, 3kHz, and 4kHz.

Yashaswini and Maruthy (2019) conducted a study to evaluate the connection between the level-dependent function of efferent inhibition and perception of speech in noise, considering different intensities of suppressor and various signal-to-noise ratios (SNRs) of speech. They measured CSTEOAEs for three suppressor levels (40, 50, & 60 dB SPL) on 26 adults. They also measured SNR-50 with or without the same three levels of contralateral broadband noise. The results demonstrated that the magnitude of TEOAE suppression increased with higher suppressor levels. However, neither the SIS nor SNR-50 was affected due to the presence of contralateral noise. Furthermore, there was no such significant correlation between the SIS and SNR-50 with the CSTEOAEs. This observation was consistent across all SNRs and contralateral noise levels taken in the study. The findings indicate that the intensity of noise directly influences the efferent inhibition mediated by the MOCB.

Stuart and Butler, (2012) conducted a study involving young adults with normal hearing. Their research focused on examining the suppression of TEOAEs in response to 60 dB peSPL click stimuli. This examination was carried out both in the presence and absence of a contralateral white noise suppressor set at 65 dB SPL. Additionally, the study assessed Reception Thresholds for Sentences (RTSs) in various listening conditions, including monaural and binaural settings in quiet environments and amid competing continuous and interrupted noises. These two noises shared the same power spectrum but differed in their temporal characteristics.

The study's findings revealed that there were no such significant correlations or linear relationships that could predict the degree of suppression of TEOAEs and any indicators related to the recognition of sentences in noisy environments.

These findings are quite similar to our current study results, where we similarly observed no significant correlation between speech perception in noise and contralateral suppression of OAEs in the majority of the frequencies. Similar to the studies conducted by Stuart and Butler (2012), Yashaswini and Maruthy (2019) demonstrated no direct relation between efferent activity and speech perception in noise which aligns with the pattern observed in the current study by indicating that the findings are not consistent with the notion that increased medial olivocochlear efferent feedback, as assessed via CSTEOAEs, is associated with improved speech perception in noise.

However, some of the previous studies have reported significant correlations between CSTEOAEs and speech perception in noise (Giraud., *et al*. 1997; Kumar and Vanaja, 2004). Giraud., *et al*. (1997) aimed to explore the link between perception of speech in noisy settings and the CSOAEs. Participants included were 20 older adults with normal hearing and 5 individuals who went for vestibular neurotomy (VNT). They used 80 ms non-filtered clicks delivered at 50 per second rate, testing five different loudness levels between 55 and 75 dB with and without contralateral white noise. Speech intelligibility in noise was assessed using a vocal audiometry procedure featuring 23 lists of 10 words each, spoken by male and female voices. Notably, normal hearing individuals exhibited an intriguing correlation i.e., those with stronger contralateral OAE suppression showed enhanced speech intelligibility in noisy environments. However, VNT patients did not experience the same speech improvement with contralateral noise, despite preserved OAE suppression, suggesting that other factors, potentially related to specific olivocochlear fibers, influence speech perception in noise. This study underscores the relationship between OAE suppression and the perception of speech in noise.

Kumar and Vanaja (2004) aimed to assess the impact of contralateral acoustic stimuli on speech identification scores. The participants included ten normal-hearing children with good academic performance. Speech identification scores were measured in various conditions, including quiet and different ipsilateral signal-to-noise ratios, in the presence and absence of contralateral acoustic stimuli. A speech identification test designed for Indian English-speaking children, comprising 50 monosyllabic words divided into two equally challenging lists, was employed. The study recorded the TEOAEs) in response to 70 dB SPL clicks stimuli in the presence and absence of contralateral acoustic stimuli, including broadband noise at a level of 30 dB sensation level (SL) presented contralaterally. The results indicated that contralateral acoustic stimuli improved speech perception, particularly at ipsilateral signal-to-noise ratios of -10 dB and -15 dB. This enhancement exhibited a significant positive correlation with contralateral OAE suppression. These findings support the hypothesis that MOCB may assist in the perception of speech in noisy environments, suggesting a potential role for cochlear efferent fibers in hearing processes. The study also highlighted the utility of psychoacoustic measures in evaluating efferent auditory pathways when direct OAE recording is not feasible.

Giraud., *et al*. (1997) carried out the study in the older population while the Kumar and Vanaja (2004) study was done in children. However, the current study was carried out in younger adults having normal hearing sensitivity. These variations in the study population characteristics might be the possible reason for a difference observed in the study findings. Moreover, the current study findings agree with some of the earlier reports as well (Stuart and Butler, 2012; Yashaswini and Maruthy, 2019) [13-24].

Thus, this study investigated the relationship between ANL, SPIN, and CSOAEs in young adults with normal hearing. ANL, BNL, and other measurements were obtained and analyzed. The study found that the mean ANL scores aligned with prior research. There was no significant correlation between ANL and SPIN or CSOAEs. Similar findings were reported in previous studies, though some studies showed a correlation between CSOAEs and SPIN. In essence, this study gives insights into auditory processing within this group.

And discussion must illustrate and interpret the reliable results of the study.

Conclusion

ANL is a crucial measure of an individual's ability to endure background noise during speech perception, has been somewhat overlooked in the existing literature, particularly concerning its association with speech perception in noise. Furthermore, the available literature provides inconsistent and conflicting results, necessitating a more in-depth examination of these auditory measures in conjunction with the functioning of the efferent auditory system. The study's primary focus was on young adults with normal hearing, providing valuable insights into the physiological basis of ANL.

To achieve its objectives, the study enlisted the participation of 60 adults who were native Kannada speakers, ensuring a suitable population for the research. The selection criteria rigorously stipulated native language proficiency, normal hearing sensitivity, and normal middle ear function, while excluding participants with any indications of psychological, visual, systemic, behavioral, or other related pathologies. Additionally, individuals under the influence of sedatives, alcohol, or drugs during testing, or those with difficulties following instructions, ontological deficits, or neurological deficits, were excluded.

A comprehensive audiological assessment was carried out, including air conduction and bone conduction threshold measurements. Tympanometry and reflexometry were also performed. These assessments ensured the absence of middle ear pathology and selected participants with A-type tympanograms, indicating normal middle ear functioning.

The investigation centered on exploring the connection between the ANL, SPIN, and CSOAEs in a cohort of young adults possessing normal hearing. Various measurements, including ANL and background noise level (BNL), were collected and subjected to analysis. The study's results indicated that the average ANLs were in alignment with prior research findings. Notably, there was no statistically significant correlation observed between ANL and Speech in Noise performance or Contralateral Suppression of OAEs. These outcomes align with conclusions drawn in previous research, although it is important to note that certain studies have indicated a correlation between contralateral suppression of OAEs and the ability to perceive speech in noisy environments. These differences may be attributed to the variation in the study population included. Thus, this study contributes valuable insights into the physiological basis of ANL in normal hearing young adults.

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