RELATIONSHIP BETWEEN PHYSIOLOGICAL NOISE AND SPEECH IN NOISE PERCEPTION IN NORMAL HEARING ADULTS

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CERTIFICATE

This is to certify that this dissertation entitled "**RELATIONSHIP BETWEEN PHYSIOLOGICAL NOISE AND SPEECH IN NOISE PERCEPTION IN NORMAL HEARING ADULTS**" is a bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number: 18AUD011. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
July, 2020

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CERTIFICATE

This is to certify that this dissertation entitled "**RELATIONSHIP BETWEEN PHYSIOLOGICAL NOISE AND SPEECH IN NOISE PERCEPTION IN NORMAL HEARING ADULTS**" has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "**RELATIONSHIP BETWEEN PHYSIOLOGICAL NOISE AND SPEECH IN NOISE PERCEPTION IN NORMAL HEARING ADULTS**" is the result of my own study under the guidance of Dr. Sandeep M., Associate Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore **Registration No: 18AUD011**

July, 2020

Dedicated to my Guide

Dr. Sandeep M.

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Chapter 1

INTRODUCTION

Speech perception is a ubiquitous process. Human beings inevitably have to understand speech in the presence of noise, as most of the real-life environments have significant noise. Many individuals with normal hearing complain of difficulty in understanding speech in noisy areas (Vermiglio et al., 2012). Several studies report that a normal audiogram is not sufficient for normal speech recognition in noise (Alvord, 1983; Ferman et al., 1993; Middelweerd et al., 1990; Duquesnoy, 1983; Dubno et al., 1984; Blandy & Lutman, 2005).

The reasons for such deficits have been identified in auditory, physiological as well as cognitive domains. Physiological noise is known to influence auditory perception. Such noise includes vibrations in the skull and canal wall that arises from respiration, blood flow and muscle tremor. It is generally a low-frequency phenomenon with a spectrum falling from 5-15dB/octave across 32-250Hz (Anderson & whittle, 1971). Shaw (1974) found circulation, respiration and muscle activity to be the primary sources of noise in the external ear that interferes with signal detection. Physiological noise was thought to exert limited influence on auditory sensitivity before the work by Wever and Lowrence (1954). They conducted the series of experiments and found that there is some influence of physiological noise at ear canal level on auditory performance. Brogden and Miller (1947) first introduced this phenomenon of influence in auditory sensitivity due to physioogical noise, and later it was detailed by Shaw and Piercy (1962). Theories on the influence of physiological noise on auditory perception suggest that it has a masking effect; this can result in elevation of hearing threshold, reduced detectability of sound and also increased false-positive responses in hearing testing. Berger and Kerivan (1983) found that the amplification of physiological noise in occluded ear causes significant masking. Watson, Franks and Hood, (1972) found elevated hearing threshold at low-frequencies due to masking by physiological noise. Buss, Porter, Leibold, Gross and Hall (2016) measured hearing thresholds at 0.25, 1 and 4kHz in children using adaptive, three-interval forced-choice method. The levels of self-generated noise were measured in the ear canal using a probe microphone. The results showed that self-generated physiological noise interferes with low frequency hearing, and low-frequency hearing shows a developmental trend. Stiepan, Siegel, Lee, Souza, and Dhar (2020) studied the association between physiological noise and speech understanding in noise. Physiological noise was quantified from the noise floor of the otoacoustic emission recordings, and speech perception was assessed using the QuickSIN test. They found that the higher levels of physiological noise accounted for maximum variance in the speech in noise perception.

1.1 Justification for the Study

Earlier studies hint at definite effects of self-generated physiological noise on auditory perception. Higher levels of physiological noise are shown to result in a poorer low frequency hearing sensitivity and poorer speech in noise perception. This is because physiological noise masks the signal, thereby leading to poorer auditory perception. It is well known that speech perception involves complex auditory neural processing. The background EEG activity present during the listening task may challenge such neural processing. This background activity can be the spontaneous activity of neurons, the activity of other neurons with similar frequency of firing or the neural activity induced by the background noise, which is invariably present in most listening situations. The normal EEG is extremely diverse and broadly distributed across the physiological variability. The background EEG activity varies across individuals in its frequency, amplitude and temporal characteristics (Aurlien et al., 2004; Bodenmann et al., 2009; Klimesch, 1999; Lindsley, 1939). The background EEG activity is also task dependent (Basar, 2012; Klimesch, 1999). Having known that physiological acoustic noise influences speech in noise perception, one can speculate that the variations in the background EEG activity across individuals too can account for the differences in their speech in noise perception abilities. Moreover, the self-generated physiological noise that is known to induce masking effects will also translate itself as background EEG activity.

Therefore, if the physiological acoustic noise can account for speech in noise perception abilities, it is likely that the background EEG activity may also account for speech in noise perception.

1.2 Aim of the Study

To assess the relationship between the background EEG activity and speech in noise perception in normal-hearing adults.

1.3 Objectives of the Study

1) To assess the relationship between low-frequency background EEG activity (<30Hz) and physiological noise measured at the ear canal

2) To assess the relationship between high-frequency background EEG activity (100Hz-3000Hz) and physiological noise measured at the ear canal

3) To assess the relationship between low-frequency background EEG activity (<30Hz) and SNR-50.
4) To assess the relationship between high-frequency background EEG activity (<30Hz) and SNR-50.

Chapter 2

REVIEW OF LITERATURE

The ability to perceive speech in the presence of noise is a valuable skill, since background noise is present in every possible everyday day listening situation. Extensive research has been done to understand the different factors that influence speech perception in the presence of noise, and the extent of their influence on the task. Physiological noise is one such factor that influences different auditory measures (Anderson & Whittle,1971; Brogden & Miller, 1947; Berger & Kerivan, 1983; Shaw, 1974; Sivian & White, Soderquist & Lindsey, 1971, 1933; Stekelenburg et al., 2001; Stiepan et al., 2020; Watson, Franks & Hood, 1972; Wever & Lawrence, 1954).

Studies were done to see the effects of physiological noise on various measures of audition like detection thresholds for tones, masking effects and speech perception n noise ability (Brogden & Miller, 1947; Buss, Porter, Leibold, Gross & Hall, 2016; Diercks & Jeffress, 1962; Dolan, 1968; Francis et al., 2018; Shaw & Piercy, 1962; Sivian & White, 1933; Soderquist & Lindsey, 1971). However, limited studies have been done to measure the direct influence and/or relationship between physiological noise on the different auditory measures, and they are discussed below.

Within these limited studies, results have clearly shown the effect of physiological noise on auditory detection threshold, speech perception in noise performance and otoacoustic emission recordings (Berger & Kerivan, 1983; Francis et al., 2018; Stiepan et al., 2020).

2.1 Physiological Noise at Ear Canal

Shaw (1974) reported that, the circulation, respiration and muscle activity are the primary sources of noise in external ear which interfere with signal detection. The physiological noise is generally predominantly of low frequency, with a spectrum falling by 5-15dB/octave across 32-250Hz (Anderson & Whittle, 1971).

Brogden and Miller (1947) estimated the physiological noise at ear canal under earphones cushions. They estimated the frequency and intensity of the physiological noise at the ear canal and studied the effect of ear canal size on the levels of physiological noise. In their study, listeners were asked to match the quality and intensity of ambient noise to the quality and intensity of the noise heard while they held earphones over both ears: to know the spectrum of physiological noise, the listeners were asked to match its quality with the quality of four different ambient noises; to estimate the intensity of physiological noise, they were asked to match its intensity with the intensity of ambient noise. They also used intensity measurements of the noises in 9 different volume cavities enclosed under cushions to see intensity as a function of volume. They found that physiological noise is majorly comprised of low frequencies up to 200-250 Hz and that its intensity varies with ear canal size. It is more in persons with smaller cavities as compared to others with relatively larger ear canal cavity.

Ren, Zhang, Nuttall and Miller (1995) studied the changes in the levels of spontaneous oto-acoustic emissions (SOAEs) in guinea pigs and found that the heart beat and cochlear blood flow influences the SOAEs recordings. They observed a heartbeat modulation within SOAE recordings. Therefore, one method to monitor or record the levels of physiological noise at the ear canal is using the SOAE measures.

Francis, Zhao and Guinan (2018) estimated the noise levels at the ear-canal using SOAEs noise floors, and found that it varies across subjects. However, they observed a pattern in the noise floor levels across the subjects: the noise levels were largest at the lowest frequencies, smallest at mid frequencies (2–3 kHz) and increased towards higher frequencies.

2.2 Physiological Noise and Threshold of Detection

Deviations from ideal performances are common in auditory detection tasks, even in quiet listening conditions. The concept of "internal noise" has been invoked to explain these deviations (Green & Swets, 1966). Diercks and Jeffress (1962) attribute these deviations to internal noise, proposing that detection in the quiet is merely another case of masking, with internal noise as the masker. Several studies show that absolute detection thresholds are elevated by the presence of internal noise, and that the thresholds may be considered as masked thresholds- by internal noise (Brogden & Miller, 1947; Diercks & Jeffress, 1962; Dolan, 1968; Lawson, 1948; Lifschitz, 1939; Loeb & Dickson, 1961; Montgomery, 1935; Munson & Weiner, 1952; Moulin, 1968; Piercy & Shaw, 1963; Rudmose, 1962; Shaw & Piercy, 1962; Sivian & White, 1933; Soderquist & Lindsey, 1971; Stevens & Davis, 1938; Watson, Franks, & Hood, 1967).

The phenomenon of influence of physiological noise (i.e., internal noise) on auditory sensitivity was first introduced by Brogden and Miller (1947), and was later detailed by Shaw and Piercy (1962). The influence of physiological noise on auditory sensitivity was in fact thought to be limited before the work by Wever and Lawrence (1954). Theories of its influence on auditory perception suggest that physiological noise has masking effect; this can result in elevation of hearing threshold, reduced detectability, and increased false positive responses in hearing testing (Wever & Lawerence, 1954; Zwislocki et al., 1958)

Scientists have carried out several studies to understand the influence and mechanism of working of internal noise on different auditory detection tasks. Soderquist and Lindsey (1971) investigated the effect of cardiac noise on hearing sensitivity for tones, using a ‘yes-no’ paradigm on 4 adult subjects. They estimated the cardiac noise using Grass model PTTI photoelectric transducer placed on the ear lobe. The recorded and amplified information was fed into a computer. They found that the “lub-dub” sound of heart beat actually masks the low-frequency sounds and cause a reduction in auditory sensitivity.

Sivian and White (1933) measured the minimum audible field (M.A.F.) and minimum audible pressure (M.A.P.) in individuals with normal hearing. They found that the auditory thresholds obtained under headphones were elevated, compared to the thresholds obtained using speakers, using different methods (the ‘missing 6 dB’). They report that physiological noise (evident under the earphones) is one of the factors that caused this difference. Rudmose (1982) also arrive at similar conclusions regarding the missing 6dB.

The major influence of physiological noise on auditory detection is reported at low frequencies. Watson, Franks and Hood (1972) studied the detection of tones in the presence and absence of an external masking noise. They obtained puretone thresholds of twelve highly trained listeners with normal hearing, using two alternative temporal forced choice method (2ATFC) without a masking noise. They obtained the psychometric functions for 150 msec long tones across the range of 250Hz-4KHz frequencies. Even in the absence of a masking noise, the psychometric functions varied for different frequencies and signal detection threshold was elevated for low frequencies under headphones. They state that that internal noise at the level of ear canal influenced the auditory sensitivity.

Berger and Kerivan (1983) recorded the physiological noise at ears occluded using ear protective devices. They used a subminiature microphone mounted at the ear canal to measure the noise levels. Threshold differences due to the occlusion of the ear canal were measured using bone vibrators. They found that the amplification of physiological noise in occluded ear causes was predominantly in the low frequencies and that it causes significant masking effect in for low-frequency signals.

The phenomenon of elevation of auditory thresholds due to physiological noise was understood better and established further by examining the underlying physiology. Stakelenburg et al. (2001) conducted a study using electromyography (EMG) and found that auditory sensitivity was enhanced by inhibiting pericranial muscle activity and hear rate. They demonstrated a correlation between low-frequency tone detection threshold and EMG activity in the masticatory and lower facial muscles. Detection of near-threshold stimuli was inversely related to the prestimulus EMG levels in the masticatory and lower facial muscles. They compared the effects of activation of different facial muscles to auditory detection thresholds and found contraction of lower facial muscles plays role in decreasing auditory sensitivity compared to contraction of upper facial muscles.

In a more recent study, Buss, Porter, Leibold, Gross and Hall (2016) measured and compared the hearing thresholds at 0.25, 1 and 4kHz in children and adults with normal hearing using adaptive three-interval forced choice method. To evaluate the age effect or development trend they included four groups: 4- to 6-year-olds, 7- to 10-year-olds, 11- to 16-year-olds, and adults. The levels of self-generated noise were measured in the ear canal using probe microphone. In results they found that self-generated physiological noise interferes with low frequency hearing through energetic masking and plays a role in prolonged development of low frequency detection in quiet.

2.3 Physiological Noise and OAEs

Ear canal noise measured while recording otoacoustic emissions (OAEs) also comprise physiological noise at ear canal. For example, clinical experience and research studies show that large bursts in ear canal noise are seen during OAEs measurements when the subject moves (Decker, 2002; Francis et al., 2018, Jenssen & Muller, 2007). This observation shows that muscular activities contribute to the physiological noise observed at the ear canal, influencing OAE measurements.

Walsh et al. (2014 a, b; 2015) reported that ear-canal noise was reduced by activating medial olivo-cochlear efferents by selective attention. However, they also found a similar reduction in performance of the auditory task in the attended as well as non-attended ears. They hypothesized that cochlear-amplified random vibrations within the cochlea create backward traveling waves that produce ear-canal noise, and activation of medial olivocochlear efferent inhibition reduced cochlear amplification and therefore reduced the ear-canal noise.

Francis et al. (2018) carried out experiments with eight normal hearing individuals, to measure changes in ear-canal noise during a behavioral task. The subjects did a two-interval-forced-choice (2IFC) level discrimination task on monaural tone bursts in noise. They simultaneously assessed the changes in click evoked OAEs in order to assess the changes in medial olivocochlear efferent inhibition activation during behavioral task. They measured the ear canal noise levels in test ear as well as in the opposite ear and evaluated all measures in two trials; active trial and passive trial. During the active trials, measurements were done while the subjects were doing 2IFC task and during the passive trials, subjects sat quietly without doing any task. The findings showed that reduction in ear canal noise level was concurrent with attending task and medial cochlear efferent inhibition induced inhibition was small during the passive trials. Hence, the authors concluded that reduction in ear canal noise levels during an attentive task is not due to Medial olivocochlear efferent inhibition, but that it is majorly due to reduced subject motion (which consequently occurs in order to pay attention).

The studies detailed in this section indicate that OAE measurements are influenced by physiological noise at the ear canal.

2.5 Physiological Noise and Speech Perception in Noise

Vermiglio et al. (2012) investigated the relationship between pure-tone thresholds, articulation index, and the ability to recognize speech in quiet and in noise using the Hearing in Noise Test (HINT) for individuals with normal and elevated pure tone thresholds. A total of 215 participants belonging into a normal hearing group and slight, mild, severe, and profound high-frequency pure-tone threshold groups were included in the study. They found no significant differences in HINT performances between groups of participants with normal audiograms and those groups with slight, mild, moderate, or severe high-frequency hearing losses. But significant correlations were found between pure-tone averages and speech recognition in quiet performance. Weak correlations were found between pure-tone averages and HINT thresholds. However, this study could not account for the influence of physiological noise for relatively poor speech recognition scores with normal pure tone threshold and emphasized the fact that the ability to understand speech in steady-state noise cannot be predicted from the audiogram.

Stiepan, Siegel, Lee, Souza, and Dhar (2019) conducted a cross-sectional study to understand the association between physiological noise and speech understanding in noise. They found that higher levels of physiological noise accounted for maximum variance in speech in noise perception scores. Using 921 participants across the age range of 10 to 68 years having hearing sensitivity within normal limits, they investigated the relationship between their speech in noise performance, auditory function at extended high frequencies (>8 kHz), and OAE levels. They measured physiological noise through noise floors in OAEs. The authors found that physiological noise played the largest role in predicting speech understanding in noise in normal hearing individuals.

2.6 Physiological Noise and EEG

Electroencephalography (EEG) is one of the key tools for observing neural activity. Repovš (2010) in his review article on “Dealing with Noise in EEG Recording and Data Analysis" mentioned that physiological noise (generated by various noise generators such as cardiac signal, respiration, muscle contractions and ocular signal caused by eyeball movement) is one of the sources of noise in EEG. Repovš (2010) also saw the correlation between EEG and low frequency fluctuating noise generated during respiratory and cardiac processes in normal individuals at resting state. The study was conducted in two conditions: eyes-open resting and eyes-closed resting condition. He found strong correlation between EEG power changes in alpha frequency band and the low frequency fluctuations in respiration volume per time (RVT) in eyes-closed resting condition, whereas much less correlation was found between alpha global power and cardiac fluctuation in both conditions. In this study, fMRI was also used and the findings showed the same strong correlation between alpha global power field and respiration volume per time in several regions in a highly consistent spatial pattern, including the visual/parietal cortex, superior/middle temporal gyrus, inferior frontal gyrus, inferior parietal lobule, thalamus and caudate. However, the correlation was stronger with eyes-closed resting condition as compared to eyes-open resting condition. This suggests that physiological noise has an influence on EEG tracing and hence, EEG can be used to measure or estimate the levels of physiological noise.

With the all above findings, it can be concluded that physiological noise has impact on different auditory measures, from auditory thresholds to otoacoustic emissions. And, we can assume that background EEG activity is also a measure of estimation of physiological noise and has an impact on various auditory measures. However, there is a dearth in literature about the estimation of background EEG activity as a measure of noise and its influence on speech perception in noise and on other auditory measures.

Chapter 3

METHODS

The study aimed to establish the relationship between the background EEG activity and speech perception in the presence of noise (SPIN) in a group of normal hearing adults. Protocols and procedures used in this study abided to the all ethical guidelines stipulated for bio-behavioral research in human subjects at the All India Institute of Speech and Hearing, Mysuru (Venkatesan, 2009).

3.1 Participants

Eighty normal-hearing adults in the age range of 20 to 55 years (mean age-31.7years) participated in this study. All the participants were native speakers of either Kannada or Hindi language. Their hearing thresholds were within 15 dB HL, at all octave frequencies between 250 Hz and 8 kHz. They had type 'A' or 'As' type tympanogram with acoustic reflex thresholds within 100dBHL in both ears, indicative of normal middle ear functioning. They had present TEOAEs in both ears, suggesting normal cochlear functioning. They had no history of any otological or neurological dysfunctions.

The purpose and protocol of the study were explained to each participant and an informed written consent was obtained from them, prior to data collection.

3.2 Test Environment

All the tests were administered in acoustically treated and electrically shielded rooms. The ambient noise levels were within the permissible limits of ANSI/ASA S3.1-1999 (R2013). A two-room set-up was used for pure-tone audiometry. A one-room set-up was used for immittance evaluation and for recording otoacoustic emissions, auditory evoked potentials and background EEG.

3.3 Instrumentation

A calibrated two-channel Inventis Piano diagnostic audiometer with impedance matched Telephonic TDH-50 supra-aural headphones and Radioear B-71 bone vibrator were used for puretone audiometry. The same audiometer was used for assessing Speech perception in noise (SPIN) using phonetically balanced words. A calibrated GSI- Tympstar clinical immittance meter was used for tympanometry and reflexometry testing. Intelligent Hearing Systems AEP equipment with calibrated Etymotic research ER3A insert earphone and Smart-EP (version 3.95) software was used to record the low frequency and high-frequency EEG. ILO 292 DP Echoport plus (v6) was used to record acoustic noise levels in the ear canal in transient-evoked and spontaneous otoacoustic emissions platforms. The Smriti Shravan Software (version 1.0) developed by Kumar and Maruthy (2015) with a graphic user interface (GUI) written using the NETsoftware framework was used to measure SNR-50.

3.4 Test Procedure

The participants were first subjected to candidacy assessment, and only those who qualified in these tests were subjected to experimental procedure. The tests administered during candidacy assessment were, puretone audiometry, speech audiometry, immittance evaluation and otoacoustic emissions testing. ‘Pass’ criteria for these tests are mentioned under section 3.1. The air and bone conduction hearing thresholds were estimated using the modified Hughson -Westlake procedure (Carhart & Jerger, 1959). Tympanogram and acoustic reflexes were recorded using a 226Hz probe tone. Ipsilateral and contralateral acoustic reflex thresholds were elicited using pure-tones of 0.5, 1, 2, and 4 kHz.

The experimental test procedure followed in the study included estimation of background EEG activity, physiological noise in the ear canal and, speech perception in noise abilities.

3.4.1 Estimation of Background EEG Activity

To estimate the background EEG activity, EEG was recorded without delivering the stimulus to the ear. High-frequency background EEG and low-frequency background EEG were separately estimated using standard protocol used for recording auditory brainstem responses and late latency auditory responses (Hall, 2007) respectively. The background EEG estimated with the ABR protocol is operationally termed as ‘high frequency background EEG’, and that estimated with the ALLR protocol is termed as ‘low frequency background EEG’. Stimulus and recording parameters used in the two protocols are given in Table 3.1. Using each protocol, 50 separate single-sweep recordings were made (without delivering the stimulus). The data was then converted into ASCII output for further analysis. There were 50 sweeps under each condition from each participant.

Table 3.1: *Recording parameters used for recording high-frequency and low frequency background EEG Activity*

Recording Parameter	Settings for Low-Frequency Background EEG activity	Settings for High-Frequency Background EEG Activity
No. of sweeps	1	1
No. of recordings	50	50
Polarity	Rarefaction	Rarefaction
Filter	0.1 Hz to 30Hz	100Hz to 3000Hz
Amplification	50000	100000
Recording window	500msec	12msec
Artifact rejection	100 µV	100 µV
Electrode montage	Ground -M1 Positive-Cz Negative - M2	Ground – M1 Positive-Cz Negative - M2

Before beginning to test, the purpose and protocol of the procedure was explained to each participant. The participant was seated in a comfortable reclining chair and was instructed to relax and refrain from extraneous body movements. The electrode sites (as in table 3.1) were identified based on the 10-20 system (Jasper,1958). The sites were cleaned with Nuprep cleaning gel to remove the dust and dead skin. The silver chloride electrodes were then placed at these sites with the help of Ten-20 conductive paste and an adhesive tape. The inter-electrode impedance was maintained below 2 kΩ, and the absolute electrode impedance was maintained below 5 kΩ throughout the testing time. High-frequency EEG was recorded first followed by low-frequency EEG recording. All 50 sweeps recorded under each protocol were saved and converted into ASCII format separately. The ASCII converted waveforms were used to derive the RMS amplitude of each recorded EEG waveform using MATLAB software (version 2018). MATLAB codes were specifically written for processing high and low-frequency background EEG waveforms files. To calculate the RMS amplitude of high-frequency background EEG, the frequency bandwidth from 30 Hz to 3000 Hz was used. To calculate RMS amplitude for low-frequency background EEG, the frequency bandwidth from 0.1 Hz to 30 Hz was used. For each participant, there were RMS amplitudes derived individually from 50 separate recordings in the high-frequency background EEG and in the low-frequency background EEG conditions. The RMS values from all the 50 recordings were averaged to get the final RMS value in each condition.

3.4.2 Physiological noise in the ear canal

SOAEs were recorded as a measure of physiological noise in the ear canal. The participants sat in an erect posture in an armchair. They were instructed to minimize extraneous body movements and to avoid speaking, as it could affect the probe fitting. The probe was placed into the canal of the right ear using an appropriate probe tip. After ensuring a good probe fit as reflected by the stimulus waveform, SOAEs were recorded. From each participant, two such SEOAEs recordings were obtained and the estimated noise levels at the octave and mid-octave frequencies were noted down from the recordings. For further statistical analysis, the average noise floor level at 1, 1.5, 2, 3 and 4 kHz was noted.

3.4.3 *Speech perception in noise - SNR-50*

A total of 17 syllables belonging to the phonetic inventory of Kannada and Hindi language were used to estimate SNR-50. They were: /ka/, /ga/, /cha/, /dza/, /ta/, /da/, /tha/, /dha/, /na/, /pa/, /ba/, /ma/, /ya/, /ra/, /la/, /sha/ and /sa/. The recorded version of these syllables was taken from an unpublished dissertation (Swathi & Kumar, 2014) and were then embedded within a speech-shaped noise. Speech shaped noise was generated using MATLAB (version 8.5). The noise was normalized to -3dB using Adobe Audition 3.0 software and then a customized stimulus was made in Smriti-Shravan software (version 1.0) by mixing monosyllables and speech-shaped noise together. Both monosyllables and speech-shaped noise were presented through Smriti-Shravan software. The stimuli and noise were added into the software under the opinion to include custom stimuli.

SNR-50 was estimated using an adaptive procedure using Smriti-Shravan software. The syllables were presented through headphones at 60 dB SPL. The competing speech noise in the ipsilateral ear varied in intensity, varying the SNR of the stimuli. The testing commenced at 0 dB SNR, and the subsequent SNR depended on the correctness of the response. During the test, the Graphical user interface (GUI) in the software displayed a '+' sign before the presentation of the stimulus to alert the participant to direct attention towards the upcoming stimulus. Following the syllable presentation, the GUI displayed all the 17 CV syllables (one of them being the target syllable) on the screen (example in figure 3.1). The participant's task was to click on the syllable heard. Only one syllable was presented at each SNR. Based on the participant's response, the SNR presented either increased by 1 dB or decreased by 2dB. That is, in the event of the correct response, the SNR was decreased, and in the event of an incorrect response, the SNR was increased. The run terminated after ten reversals and the average of the last five reversals was used to determine the SNR-50.

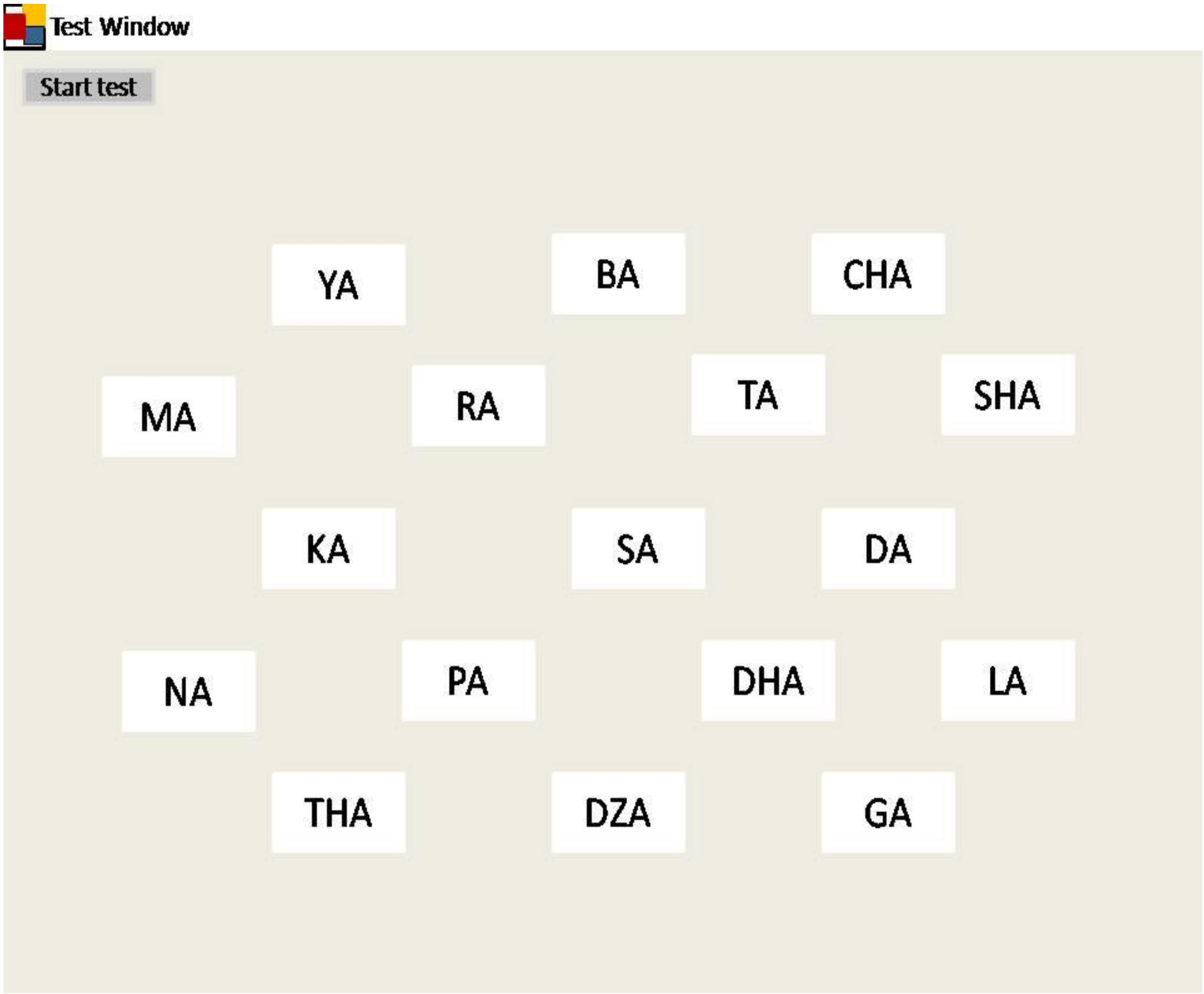

Figure 3.1: *Screen of GUI used for obtaining response for SNR-50 in Smriti-Shravan software.*

Chapter 4

RESULTS

This study aimed to assess the relationship between physiological noise and speech perception in noise in a group of normal hearing adults. A total of 80 participants in the age range of 20 to 55 years took part in the study. Among the parameters measured, low-frequency and high-frequency background EEG, and acoustic noise levels in ear canal were the independent variables. SNR-50 was the dependent variable.

The data were assessed for normality using the Shapiro-Wilks test of normality. The results (Table 4.1) showed that all the variables were normally distributed (p>0.05). Therefore, the relationship among test variables was statistically analyzed using parametric test.

Table 4.1: *Results of Shapiro-Wilks test of normality*

Variable	Statistic	*P*
Low-frequency background EEG activity	0.97	0.14
High-frequency background EEG activity	0.97	0.10
Noise floor in SOAEs	0.98	0.28
SNR-50	0.97	0.13

Table 4.2 presents the mean and standard deviation for each variable. Mean RMS amplitude of low-frequency background EEG activity was higher than the mean of high-frequency background EEG activity, indicating physiological noise contains more of low frequencies.

Table 4.2: *Mean and Standard Deviation of variables studied*

Parameter	Mean	Standard Deviation
RMS amplitude of low –frequency background EEG activity	3.1µV	0.53
RMS amplitude of high-frequency background EEG activity	0.62 µV	0.19
SOAE’s Noise floor level	-35.03 dBpeSPL	2.69
SNR-50	-0.6942dBpeSPL	3.17

4.1 Relationship between Low-Frequency Background EEG Activity and Physiological Noise Measured at Ear Canal

Figure 4.1 is a scatterplot showing the relationship between low-frequency background EEG activity and SOAEs noise floor. The figure shows no observable trend in the way two variables varied with each other. Pearson’s correlation coefficient was used to assess the relationship between the two. Results revealed no significant correlation (r = -0.15, $p > 0.05$) between the two variables.

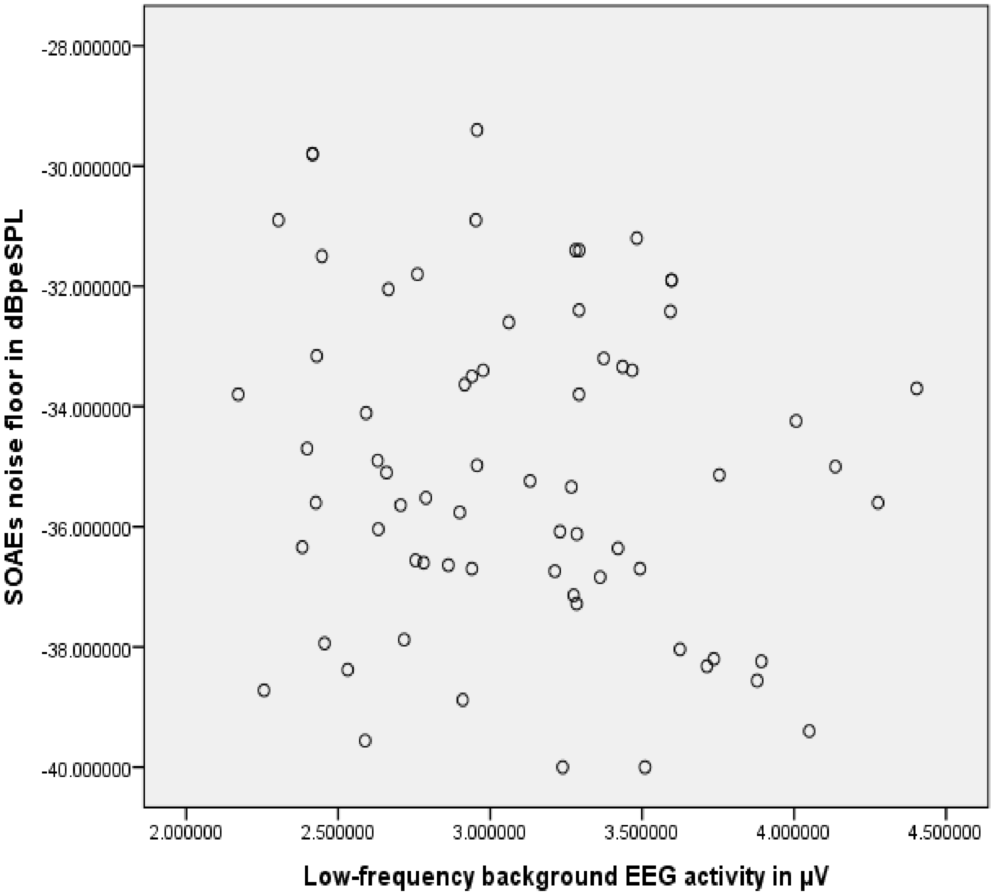

Figure 4.1: *Scatterplot for relationship between low-frequency background EEG activity and SOAEs noise floor level*.

4.2 Relationship between High-Frequency Background EEG Activity and Physiological Noise Measured at the Ear Canal

Figure 4.2 is a scatterplot showing the relationship between high-frequency background EEG activity and SOAEs noise floor. The figure shows no discernible trend in the way the two variables varied with each other. Pearson's correlation coefficient was used to assess the relationship between the two variables. Results revealed no significant correlation (r = -0.04, $p > 0.05$) between them.

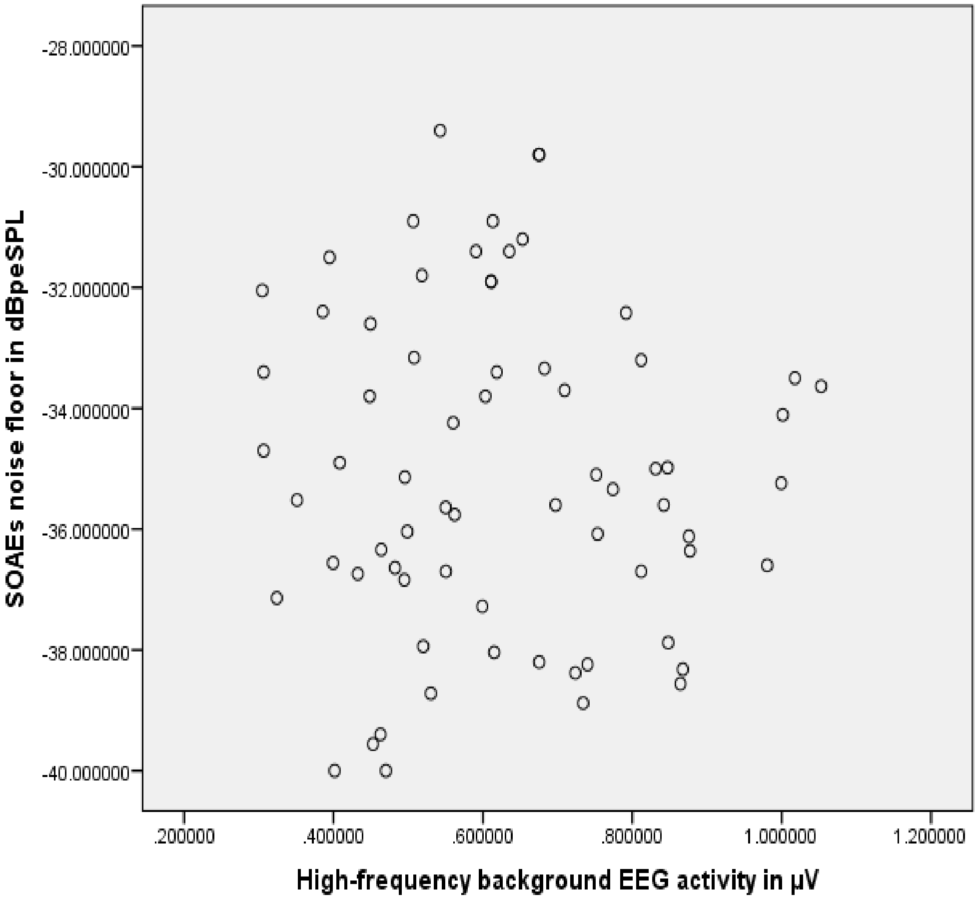

Figure 4.2: *Scatterplot for relationship between high-frequency background EEG activity and SOAES noise floor level*.

4.3 Relationship between Low-Frequency Background EEG Activity and SNR-50

Figure 4.3 is a scatterplot showing the relationship between low-frequency background EEG activity and SNR-50. The figure shows no observable trend in the way the two variables varied with each other. Pearson's correlation coefficient was used to assess the relationship between the two. Results revealed no significant correlation (r = -0.001, $p > 0.05$) between the two variables.

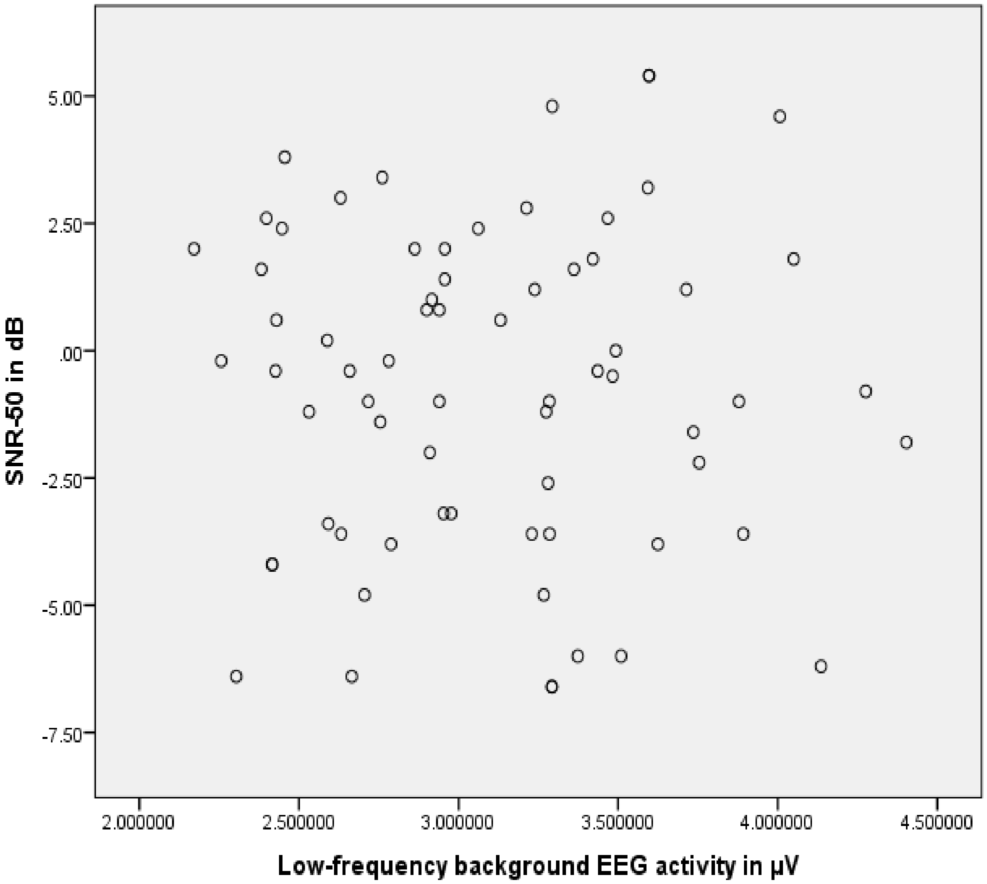

Figure 4.3: *Scatterplot showing relationship between low-frequency background EEG and SNR-50.*

4.4 Relationship between High-Frequency Background EEG Activity and SNR-50

Figure 4.4 is a scatterplot showing the relationship between the high-frequency background EEG activity and SNR-50. The figure shows no discernible trend in the way the two variables varied with each other. Pearson's correlation coefficient was used to assess the relationship between the two variables. Results showed no significant correlation (r = -0.04, $p > 0.05$) between them.

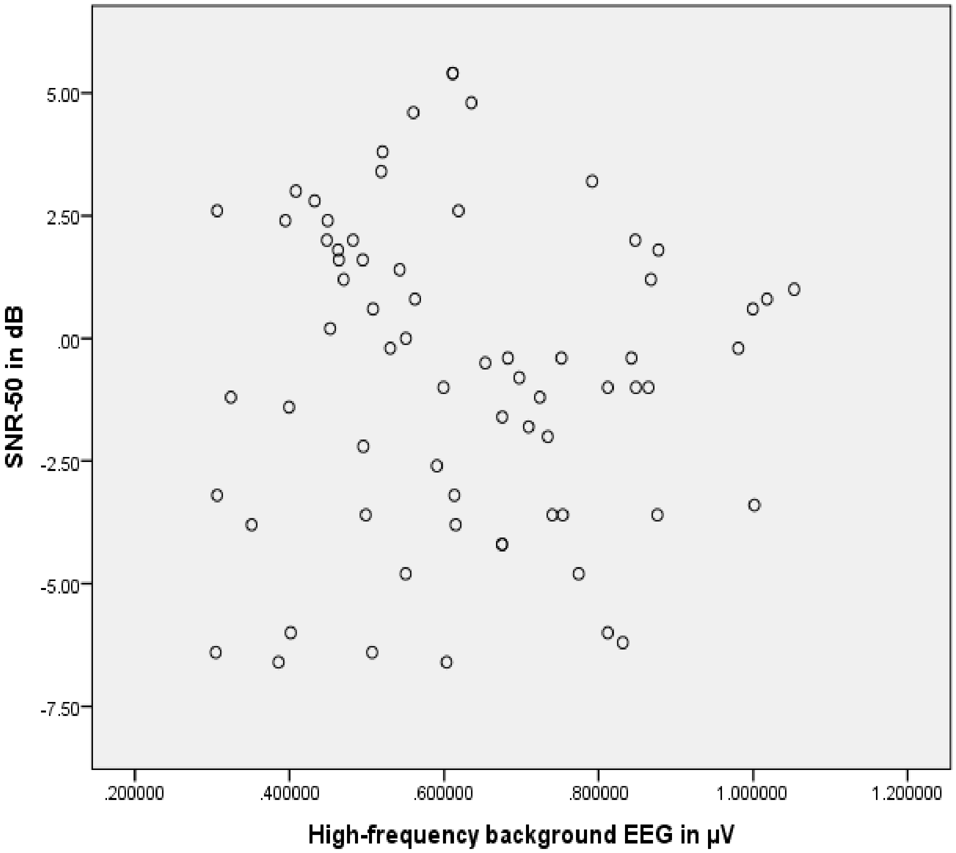

Figure 4.4: *Scatterplot showing relationship between high-frequency background EEG and SNR-50.*

Chapter 5

DISCUSSION

This study aimed to explore the relationship between the background EEG activity and the speech in noise perception in normal-hearing adults. The study also takes into consideration the physiological noise present in the ear canal for these comparisons. To do this, first relationships of low-frequency (<30Hz) and high frequency (100-3000Hz) EEG activity with physiological noise measured at the ear canal were examined. Following this, the relationship between the EEG activities and SNR-50 was studied.

This study was motivated by studies that found significant effect of physiological noise at the ear canal level on various auditory measures (Anderson & Whittle, 1971; Berger & Kerivan, 1983; Buss et al., 2016; Stiepan et al., 2020). However, the results of the present study show no significant correlation among the used measures of physiological noise and speech perception in noise. The study found no evidence for a significant impact of background EEG activity on the measure of speech perception in noise. The specific findings are discussed in subsequent sections.

5.1 Relationship between Low-frequency Background EEG Activity and Physiological Noise Measured at the Ear Canal

Correlation between the average RMS amplitude of low-frequency background EEG activity and SOAE noise floor revealed no significant relationship between them. To the best of our knowledge, there is no study that has seen the correlation between background EEG activity and physiological noise recorded at the ear canal. So, no comparison in this regard is possible with existing literature. However, the findings of the estimation of background EEG activity as a source of physiological noise is in correspondence with earlier studies (Repovš, 2010). As reported in literature, it was seen in the study that background EEG activities are comprised more of low frequencies. As shown in previous studies (Anderson & Whittle, 1971; Brogden et al., 1947; Shaw, 1974), physiological noise measured at the ear canal also primarily comprised of low frequency activity. However, direct comparisons regarding the background EEG noise cannot be made with these studies since such measurements were not made in these studies. Also, in the present study, spectral information of the noise present at the ear canal was not calculated.

The reason for not observing significant correlations between low frequency background EEG activity and physiological noise recorded at ear canal level could be the differences in their noise characteristics; they are generated by different sources. The noise generated due to neurological activities could be inherently different from noise generated due to non-neurological activities. Further, the measure of physiological noise at the level of the ear canal was calculated as an average of noise at the octave and mid-octave frequencies. The averaging process may have evened out any chance of correlation between the values.

5.2 The Relationship between High-frequency Background EEG Activity and Physiological Noise Measured at the Ear Canal

No significant correlation was found between high-frequency background EEG activity and physiological noise at the ear canal. As mentioned before, no study has explored the relationship between background EEG activity and physiological noise at the ear canal. Therefore, any comparison of the present findings with existing literature is difficult. However, under this condition, observing no correlation could also be because if the physiological noise consisted of predominantly low frequency information, the comparisons were made with high frequency EEG. Also, as mentioned under section 5.1, observing no significant correlation between the two parameters could be due to differences in characteristics of noises, generated by neurological activities and noise generated by non-neurological activities. However, future researches should be carried out on this concept to bring clarity to these findings and speculations.

5.3 The Relationship between Low and High-frequency Background EEG Activity with SNR-50

There was no correlation seen between low frequency and high frequency background EEG activity respectively, with SNR-50. So, it supported the null-hypothesis. The study was conducted with the idea of understanding the impact of EEG noise on speech perception in noise, and the results revealed no significant effect. To the best of our knowledge no study has been reported till now that has explored the relationship of background EEG activities (taken as a measure of physiological noise) with different auditory measures. Therefore, a direct comparison of the present findings with any existing literature cannot be justified.

However, studies have estimated physiological noise at ear canal level and its influence on various auditory measures has been seen. Berger and Kerivan (1983) found significant attenuation in low-frequency hearing sensitivity due to masking imposed by physiological noise in ear occluded condition and Buss et al. (2016) found that self-generated physiological noise (estimated through probe microphone) at ear canal influenced the hearing sensitivity for low-frequencies. These studies showed that physiological noise did impact the auditory thresholds of the participants, A study more close to the present study is the one by Stiepan,et al. (2020). They found that the physiological noise measured through DPOAEs noise floors were correlated with the participants' speech perception in noise ability. The findings of the present study, however, did not find a significant relationship between physiological noise and speech perception in noise. This could be because of the differences in noise characteristics used in the study, compared to the other studies, that have used physiological noise at the level of ear canal as the measure for comparison.

The finding could also be due to the insufficient amount of noise generated by background EEG activity to produce a significant effect on speech perception task score. The EEG noise in the brain must always be present during any listening task (for that matter, even during any non-listening task). So, it could be possible that the human auditory system is adapted to the presence of this noise, unlike the physiological noise in the ear canal which is enhanced with occlusion of the ear canal cavity. The findings could also be due to the involvement of an advanced auditory mechanism in the perception of speech in noise, such as the facilitatory role of medial olivocochlear bundle in speech perception in noise (Nieder & Nieder, 1970; Micheyl & Collet, 1993; Guinan, 1996).

Overall, the findings supported the null hypothesis and also supported the earlier findings that physiological noise comprises more of low frequencies. However, there was no significant influence of background EEG activity on speech perception in noise task. There is a need for future research to study in-depth about the effect of background EEG activity on various auditory measures.

Chapter 6

SUMMARY AND CONCLUSIONS

The present study investigated the relationship between background EEG activity and speech perception in noise. It also took into account the amount of acoustic physiological noise present at the ear canal. Low-frequency EEG noise was recorded from the participants using a standard auditory late latency response (ALLR) protocol and high-frequency EEG noise was recorded using a standard auditory brainstem response (ABR) protocol. The acoustic physiological noise at the ear canal was estimated from the noise-floor measured during spontaneous otoacoustic emissions (SOAEs) recordings and SNR-50 was the measure of speech perception in noise.

A total of 80 participants in the age range of 20 to 55 years took part in the study. Among the parameters measured, low-frequency and high-frequency background EEG, and acoustic noise levels in ear canal were the independent variables. SNR-50 was the dependent variable. The collected data revealed that the amplitude of low-frequency background EEG activity was higher than the amplitude of high-frequency background EEG activity. This indicated that the background EEG activity predominantly comprised of low frequencies.

Based on normality test, Pearson’s test of correlation was used to see the relationship between the background EEG and physiological noise and background EEG and speech perception in noise. The results revealed no significant correlation of the low and high frequency background EEG activity with the noise floor measured during SOAEs testing or the performance during SNR-50 testing. Therefore, from the findings of the present study it is seen that there is no relation between background EEG activity and speech perception in noise ability in adults with normal hearing sensitivity.

To conclude, the study found no relationship between background EEG noise and speech perception in noise in individuals with normal hearing sensitivity. To the best of our knowledge, the relationship between the background EEG noise and speech perception skills in individuals is an unexplored area in auditory research. Therefore, more research is needed to further understand the findings from this study. Further studies may be conducted to replicate this study to check for the consistency of the findings, or may also consider different measures of speech perception, like the detection threshold and speech recognition threshold. Future studies may also consider using continuous EEG recording with a wide frequency band (instead of using single sweeps as used in this study) for recording EEG noise and may also explore more efficient ways of improving the means to record acoustic physiological noise at the ear canal.

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