International Journal of Engineering & Technology, 7 (1.9) (2018) 99-106

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Auditory psychophysical analysis of healthy individuals based on audiometry and absolute threshold tests

Sanjay H. S. [1] *, Bhargavi S. [2], Madhuri S.[3]

[1] *Research Scholar, Jain University & Assistant Professor, Dept of Medical Electronics, MSRIT, Bangalore-560054*
[2] *Professor & Head, Dept of Telecommunication Engineering, SJC Institute of Technology, Chickballapur-562101*
[3] *Project Assistant, MedNXT Innovative Technologies & Dept of Medical Electronics, MSRIT, Bangalore-560054*
**Corresponding author E-mail: sanjaymurthyhs@gmail.com*

Abstract

Psychophysics is one of the most important aspects to assess the auditory behavior in human beings. The present study has been successful in exploring the temporal resolution with respect to auditory stimulus thereby helping in the analysis of the auditory psychophysics in human beings which has been gaining wide acceptance in behavioral research. This research work concentrated on subjects with no known auditory pathological history, both males and females of different age groups, subjects exposed to noise (fabrication industry, chemical industry) and professional basketball players. The subjects were made to undergo conventional Audiometry Test (AT) as well as the Absolute Threshold Test (ATT) developed. A similar pattern was observed in the results of AT across all types of subjects. There were no eminent variations observed other than a characteristic dip between 4000 – 6000 Hz. Hence it was concluded that the AT cannot assess the variations in hearing perception for normal individuals with respect to age, sex and occupational exposure. The Absolute Threshold (ATTh) obtained from the ATT were found to be varying in subjects with respect to age and sex wherein the males had a better ATTh than females. Also ATTh was found to deteriorate with age. ATTh was able to differentiate the hearing perception of the positively conditioned (basketball players) and negatively conditioned (chemical and fabrication industry) subjects thereby proving to be an efficient tool to assess the hearing perception in the conditioned and the control set of subjects. Hence ATT based approach could be very useful in sports training and rehabilitation approaches and hence can be a very useful tool in the assessment of auditory temporal resolution of human beings in various applications.

1. Introduction

The auditory function (the process of hearing) is controlled by the auditory cortex of the human brain.The cortex is responsible for recognizing and categorizing the various sounds which are heard. By studying the functions of the auditory cortex, it is possible to understand the process of hearing and the presence of any auditory malfunctions. Although the understanding of information happens in the brain, there are abundant cues to conclude upon the physiological process at the brain with the help of several perception based tests.[1]Psychophysics, a scientific study relating the stimulus and sensation, accounts for behavioral analysis for auditory stimulus in human beings.[2]Temporal resolution analysis helps in assessing the abnormal conditions concerning human auditory system and understanding speech-processing dysfunctions in humans which is a proven fact that has been gaining wide acceptance as a research tool. [3] Such an evaluation is necessary for the assessment of Auditory Processing Disorders (APD) and speech-processing dysfunction in human beings. The auditory temporal discrimination provides abundant information about the smallest time interval needed to resolve acoustic events.Existing Audiometry Test (AT) fails to assess the hearing perception and the variations in case of normal subjects. [4] Towards the same, a novel approach based on intensity, termed as the Absolute Threshold Test (ATT) has been developed to obtain the subjective hearing perception of normal individuals.

2. Background

Language and speech are integral parts of today's world.[5] It is hence apt to term this as an auditory world. Interactions with the central nervous system and peripheral nervous systems contribute to the understanding of formal and informal type of communication with people as and animals as well. Problems with any part of the nervous system will hamper this interaction. In such cases, individuals demonstrate conditions such as hearing loss, learning problems, autism, dysgraphia, dyscalculia, dyslexia, left right disorientation and finger agnosia which are generally seen due to complications in the cognitive functions.[6] Due to such an impact, auditory processing is considered to be one of the most important aspect of human life and hence domains such as audiology, neuroscience and cognitive physiology are gaining more prominence in healthcare.An audiometry evaluation is a painless, noninvasive hearing test that measures a person's ability to hear different sounds, pitches, or frequencies. Patients who have a tumor in or around the ear may undergo audiometry testing to determine whether hearing loss has occurred or to monitor their hearing before and after surgery. It is also used to evaluate whether hearing aids or surgery may improve one's hearing.Absolute thresholds are measured using maximum likelihood approach. Pure tone of 1 KHz and 500 ms are presented to the subject. The tone is designed using various approaches. The subject is asked to respond if they tone was heard or not and based on this response, the threshold value of the hearing perception is calculated. Many more approaches such as staircase, neural network based approaches exist to design absolute threshold assessment paradigm.

3. Methodology

The present work was divided into two parts. The first part included the assessment of hearing threshold with the help of an Audiometer (AT). The second part was carried out to obtain the Absolute Threshold (ATTh) based on Absolute Threshold Test (ATT).
Audiometry Test (AT)
The threshold of hearing of an individual was found using an Audiometer. [8]The device comprised of a simple hardware with a headphone used to provide audio inputs to the subjects and a bone vibrator. A feedback switch was provided for the subject to respond. The hardware consisted of a tone generator and an audio amplifier. Tones with variations in intensity and frequency were provided as input to the subjects and the subject was asked respond as to whether the tone was heard/not heard with the aid of a feedback switch. The values at which the sounds were heard were noted and an audiogram was plotted. The graph obtained provided information about the frequency range at which the subject was not able to hear. The present work concentrated on the assessment of hearing thresholds of various types of subjects using a standard Audiometer. The testing was done in a sound proof room. The subject was made to wear a headphone and both left and right ears were tested individually with respect to variations in intensity and frequency. Pure tones were presented to the subject. The AT did not include the testing with masking or bone vibrations and was confined to the assessment of hearing threshold of both left and right ears without masking noise. The results were tabulated and average audiograms were plotted for both left and right ears. The block diagram of a clinical audiometer is shown in figure 1 and figure 2 depicts the PAMTRONICS audiometer used in the AT paradigm.

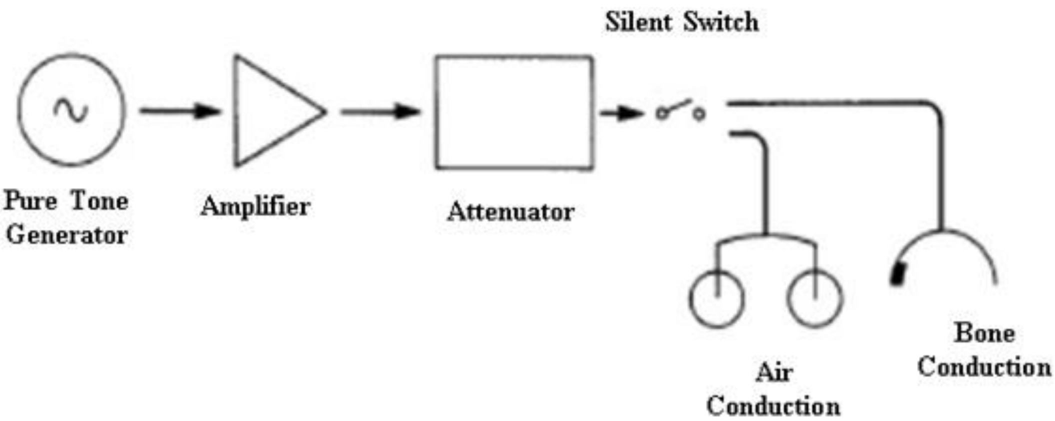


Fig. 1: Block Diagram Representation of an Audiometer.

Fig. 2: PAMTRONICS Audiometer Equipment Used for the AT Protocol.

3.1. Absolute threshold test (ATT)

The Absolute threshold of hearing is defined as "The minimum sound level of a pure tone that an average human ear with normal hearing can hear with no other sound present". [9] The absolute threshold signifies the sound that is "JUST HEARABLE" by an individual. Conventionally, human beings can perceive the sounds of frequencies in the range of 20 Hz – 20 KHz. Any sound above or below this range goes unnoticed and are not known to influence the hearing perception in anyways, irrespective of the pressure level of the sound being perceived. The absolute threshold is always relative to the frequency of the sound. The human ear is most sensitive at frequency levels of 1 KHz – 5 KHz at which the hearing threshold goes upto -9 dB SPL. The Absolute threshold can vary based on various factors such as the adaptability of the subject to the given sound and the cognitive ability of an individual. [7] Proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs). The group signature scheme is widely used in VANETs for secure communication, the existing systems based on group signature scheme provides verification delay in certificate revocation list checking. In order to overcome this delay this paper uses a Hash message authentication code (HMAC). It is used to avoid time consuming CRL checking and it also ensures the integrity of messages. The Hash message authentication code and digital signature algorithm are used to make it more secure. In this scheme the group private keys are distributed by the roadside units (RSUs) and it also manages the vehicles in a localized manner. Finally, cooperative message authentication is used among entities, in which each vehicle only needs to verify a small number of messages, thus greatly alleviating the authentication burden.

3.2. Maximum likelihood procedure (MLP)

The sound input can be varied with respect to conventional staircase based variations. However, better results can be obtained by varying the sound parameters based on the Maximum Likelihood Procedure (MLP). [10] MLP is a unique approach depending on two aspects namely Stimulus selection policy and Maximum Likelihood Estimation. In this case, the psychometric parameters are hypothesized so as to arrive at an efficient result. The parameters, termed as hypothesis functions in the present approach are as follows:
α = Array of mid-points of all the hypothesis
β = Slope of the psychometric function
γ = False alarm rate
λ = Attention lapse rate in the subject
α is the only entity which varies throughout the experiment. With every trial β, γ and λ are retained the same throughout the experiment.
The ATT relied on a generic MLP based Adaptive N-Altered Forced Choice (nAFC) detection approach for the estimation of absolute threshold.[11] The process began with the provision of an auditory input above a predefined threshold value. The intensity of this sound was varied based on the MLP approach as the experiment progressed. The intensity response, below which the subject was not able to perceive the sound, was noted. The likelihood of each of the hypothesis being defined as the psychometric function was estimated using equation 1.

$$L(Hj) = \sum_{i=1}^{n} C \log H(xi) + W \log [1 - H(xi)] \quad (1)$$

Where
L (Hj) = Likelihood of the j^{th} hypothesized function
i = the trial number
C = the exponent denoting the correct responses (which is equal to 1)
W = the exponent used to denote the wrong responses (which is equal to 0)

After the likelihood was calculated for all hypothesis, the ones with the highest occurrence were considered to be same as that of the psychometric function of the subject and was identified by its midpoint, α. The selection policy employed to choose the stimulus for the next trial involves the setting of a threshold at the end of the previous trial using the p-target (the psychometric function to be considered) and is given by equation 2. [12]

$$x = \alpha - \left(\frac{1}{\beta}\right) \times \log[\frac{1-\lambda-\gamma}{p-target-\gamma} - 1] \quad (2)$$

Where x is the stimulus value (threshold) estimated for next trial.
The ATT was used to assess the threshold of the perception of the sound with respect to the intensity. Here the pure tone sound generated using MATLAB was presented to the subjects and the intensity was varied as per the response of the subject with respect to whether he/she was able to perceive this sound. The Present experiment used the MLP approach to vary the intensity of the sound input provided to the subject. A pure tone of 1 KHz was provided for 500 msec. This tone was gated off and on with 2 raised cosine ramps of 10 ms each.Three blocks with 15 trials each were developed. In each of these trials, the subject was provided with the sound input and asked if the same was heard or not. The subject provided 0 as the input if the sound was not heard and 1, if heard in the laptop keyboard. The hypothesis was fixed to be 100. As defaults, the initial midpoint was set as 30 dB FS and the last mid-point was 110 dB FS. The slope (β) was set at 1 and gamma (γ) was 0, the p-value was 0.631 at the beginning. The first block of sound was given at 10 dB FS. Based on the subject response, as heard or not heard, the psychometric function was calculated based on equation 1. Using the result of equation 1, the threshold value of the stimulus for the next trial was calculated using equation 2. The complete duration of the test was 3 minutes. The complete ATT [13] process flow is shown in figure 3.

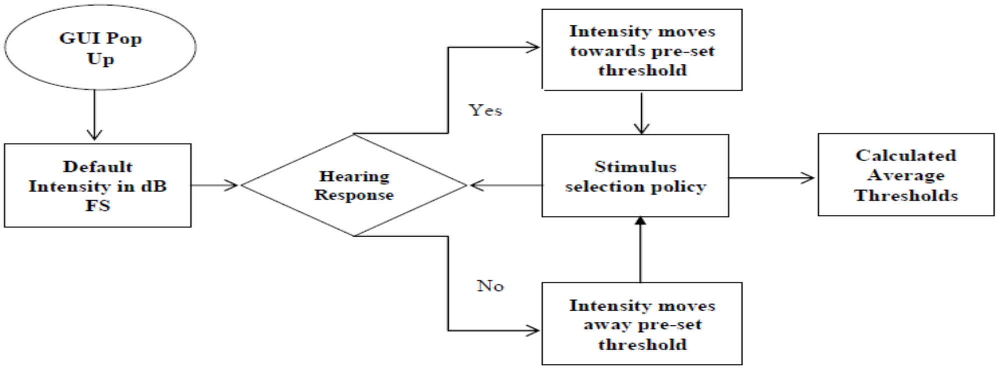


Fig. 3: ATT – Process Flow.

3.3. Subjects considered

The present work considered both conditioned and control set of subjects. The control set provided a reference baseline to assess the behavior of the conditioned dataset during the experiment. 44 subjects were considered (both males and females of age group 20-30, 30-40 and 40-50 years) for control set and 44 subjects working in chemical industry and fabrication industry for atleast 2 years (age group 20-50 years - negative conditioning) and 44 subjects who were known to be playing basketball game at professional level for atleast 2 years (20-30 years) were considered to be the subjects for the experiment after obtaining an informed consent. Adequate care was taken to ensure that the subjects chosen were not under the effect of any illicit drugs or alcohol for a minimum of 24 hours before the administration of the test [14].

4. Results and discussions

4.1. AT results

The Audiometry Test (AT) was included in this experiment due to its wide acceptance by clinicians all over the world in order to assess the hearing threshold [15]. In the present experiment, 44 subjects from each category, as mentioned in the methodology section, were made to undergo this test and the readings obtained for both left and right ears are tabulated in Table 1 and Table 2. It is to be noted that the readings obtained were from standard PAMTRONICS audiometer with air conduction mode without any masking involved in a sound proof room (silent environment) thereby simulating a clinical environment for the experiment.
The AT results obtained as in Table 1 and Table 2 are graphically represented in figure 4 which provides the audiograms for air con-

duction for both left and right ears for all the categories of subjects considered

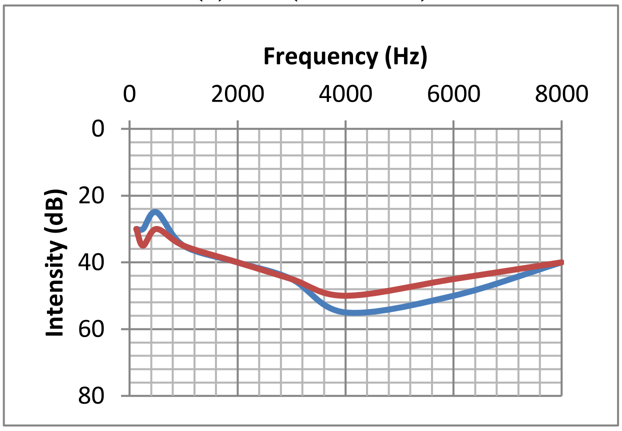
Table 1: Audiometry Readings (db. vs. Hz) Obtained for Left Ear

			Left Ear (Intensity – dB)								
Frequency (Hz)			125	250	500	1000	2000	3000	4000	6000	8000
Males	20 - 30 years	M1	30	30	25	35	40	45	55	50	40
Males	30 - 40 years	M2	30	35	40	40	40	50	60	40	40
Males	40 - 50 years	M3	40	40	45	50	50	55	60	45	50
Females	20 - 30 years	F1	25	35	30	35	45	50	60	35	30
Females	30 - 40 years	F2	25	30	30	40	45	55	50	45	30
Females	40 - 50 years	F3	40	45	40	50	50	55	65	30	30
Chemical Industry		CH	25	30	35	30	40	35	60	35	35
Fabrication Industry		FB	30	35	30	40	50	45	50	30	30
Basketball Players		BB	25	30	25	30	40	35	45	30	30

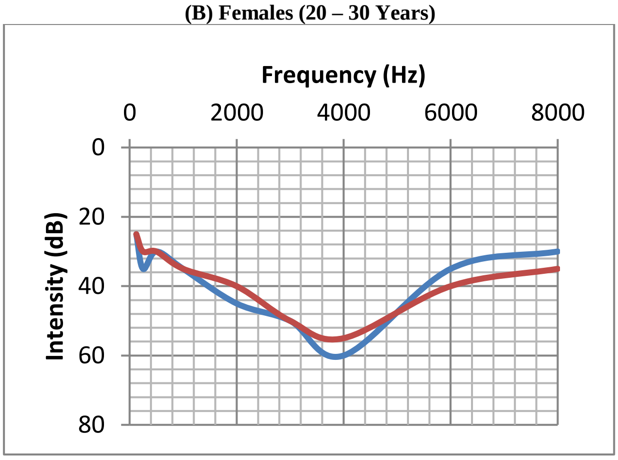
Table 2: Audiometry Readings (db. vs. Hz) Obtained for Right Ear

			Right Ear (Intensity – dB)								
Frequency (Hz)			125	250	500	1000	2000	3000	4000	6000	8000
Males	20 - 30 years	M1	30	35	30	35	40	45	50	45	40
Males	30 - 40 years	M2	30	30	35	40	40	45	50	45	45
Males	40 - 50 years	M3	40	40	45	45	50	55	60	50	45
Females	20 - 30 years	F1	25	30	30	35	40	50	55	40	35
Females	30 - 40 years	F2	25	35	35	40	45	50	50	30	30
Females	40 - 50 years	F3	40	45	45	55	55	60	65	40	35
Chemical Industry		CH	25	30	35	35	40	45	55	40	45
Fabrication Industry		FB	30	30	35	40	45	50	60	40	40
Basketball Players		BB	20	35	30	35	40	40	45	35	35

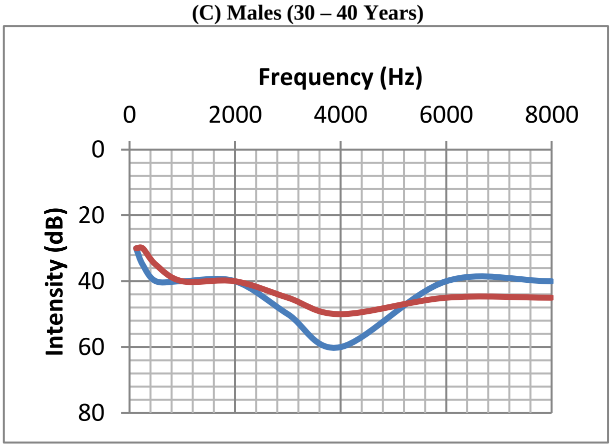
(A) Males (20 – 30 Years)



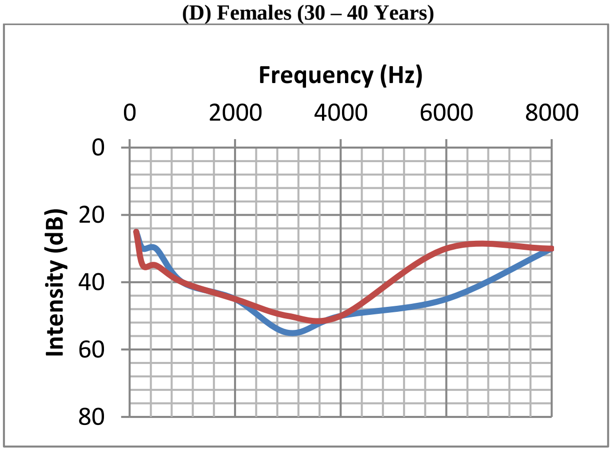
(B) Females (20 – 30 Years)



(C) Males (30 – 40 Years)

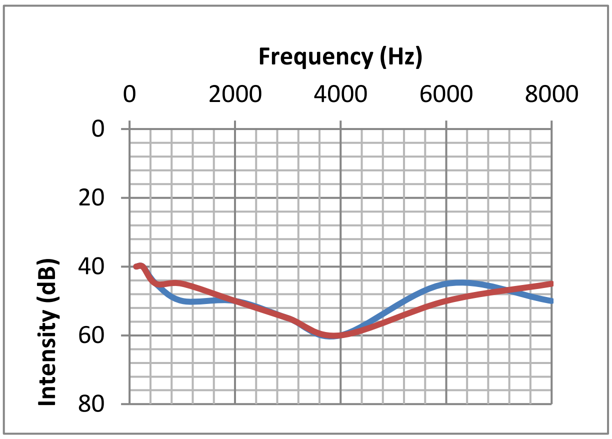


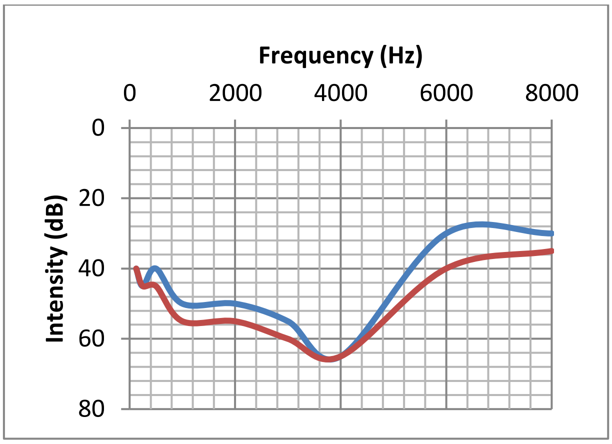
(D) Females (30 – 40 Years)



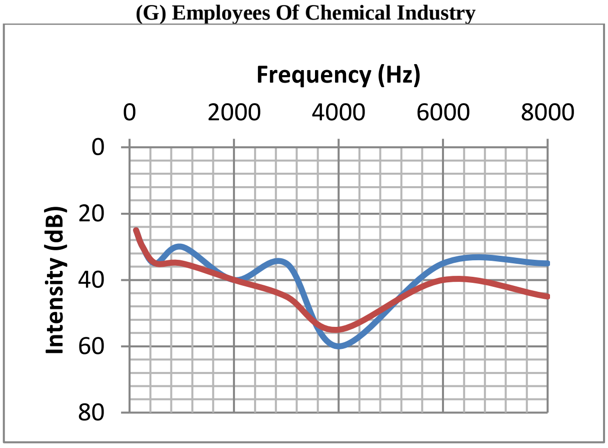
(E) Males (40 – 50 Years)

(F) Females (40 – 50 Years)

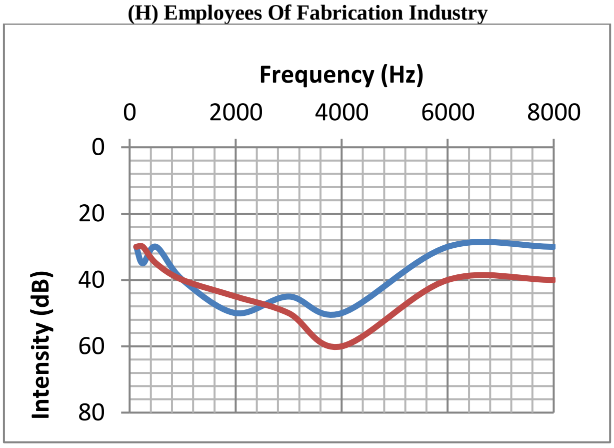




(G) Employees Of Chemical Industry



(H) Employees Of Fabrication Industry



(I) Basketball Players

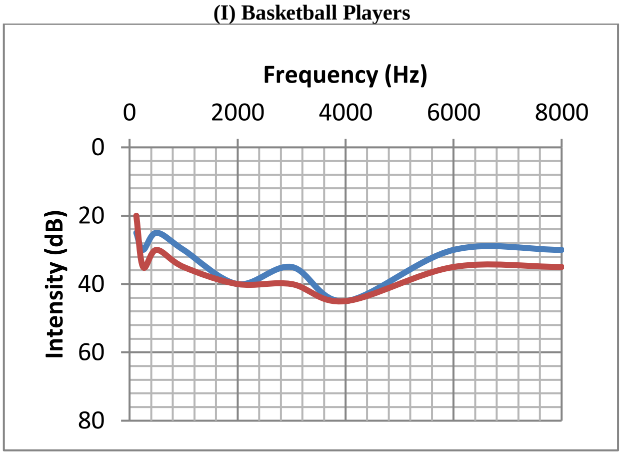


Fig. 4: (A - I): Audiograms Obtained for Various Categories of Subjects.

4.2. Absolute threshold test results

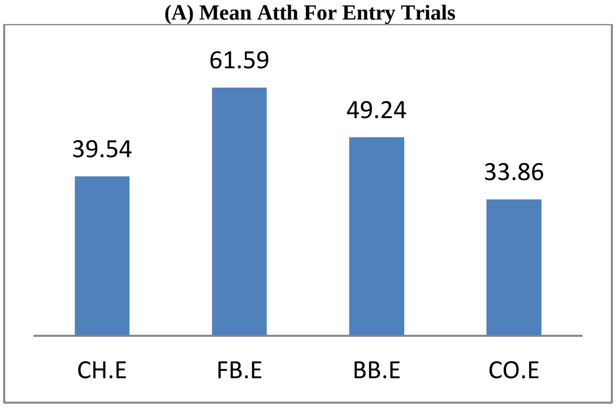
As mentioned in the previous sections, the ATT was conducted for both conditioned (negative and positive) and control set of subjects. The ATTh obtained at the entry and the exit of the work timings for the employees of chemical industry, fabrication industry as well as for basketball players were compared with the control set of data. The statistical parameters obtained for the ATTh are tabulated in Table 3.

Table 3 provides a statistical analysis of the ATTh obtained for conditioned and control set of subjects. [CH.E-Chemical Industry Employees(entry), CH.O – Chemical Industry Employees(Exit), FB.E-Fabrication Industry Employees (entry), FB.O – Fabrication Industry Employees (Exit), BB.E-Basketball players (entry), BB.O – Basketball players (Exit), CO.E – Control set(entry), CO.O-Control set(exit)]. The statistical results obtained in table 2 are graphically represented in figure 5 for a better understanding

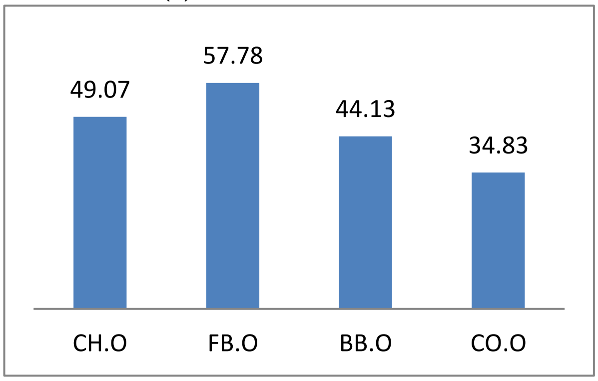
Table 3: Statistical Analysis of the ATTH Obtained – Conditioned vs. Control Set

N = 44	CH.E	CH.O	FB.E	FB.O	BB.E	BB.O	CO.E	CO.O
Mean	39.54	49.07	61.59	57.78	49.24	44.13	33.86	34.83
Median	41.55	50.94	61.14	61.74	50.84	42.23	33.91	32.14
Std Dev	10.44	13.35	12.5	12.28	13.52	12.82	8.98	11.88
Kurt	-1.12	-0.94	0.72	0.09	-0.56	-0.53	0.32	3.53
Skew	0.12	-0.38	-0.25	-0.67	-0.4	0.32	0.98	1.29
KST	0.90	0.75	0.95	0.91	0.93	1.03	1	0.98

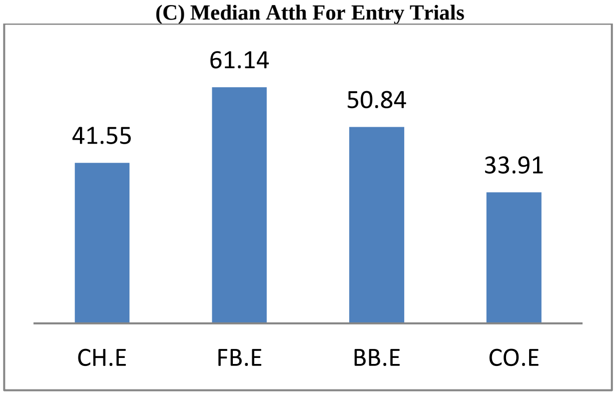
(A) Mean Atth For Entry Trials



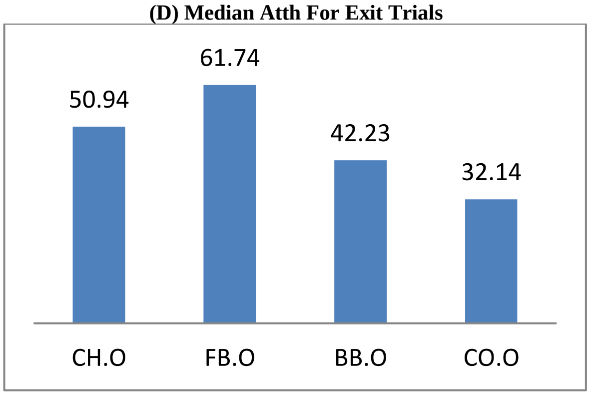
(B) Mean Atth For Exit Trials



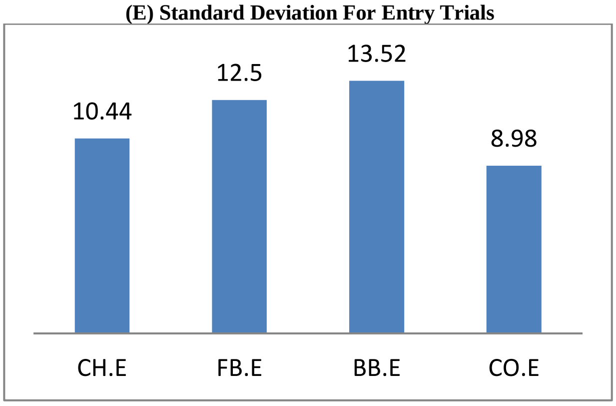
(C) Median Atth For Entry Trials



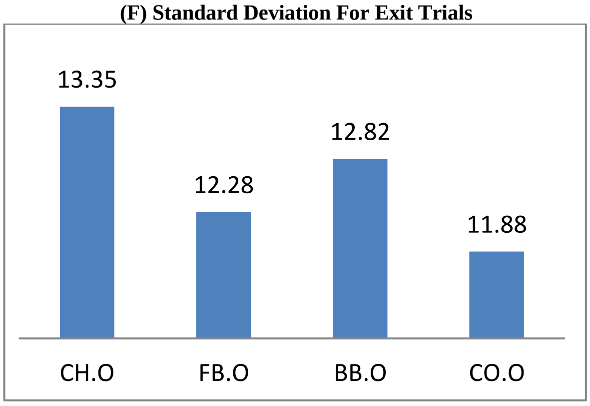
(D) Median Atth For Exit Trials



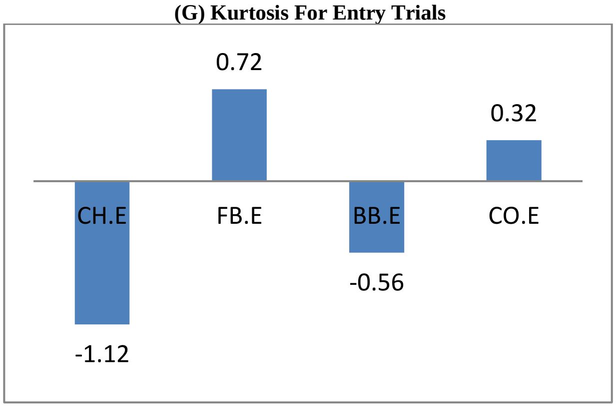
(E) Standard Deviation For Entry Trials



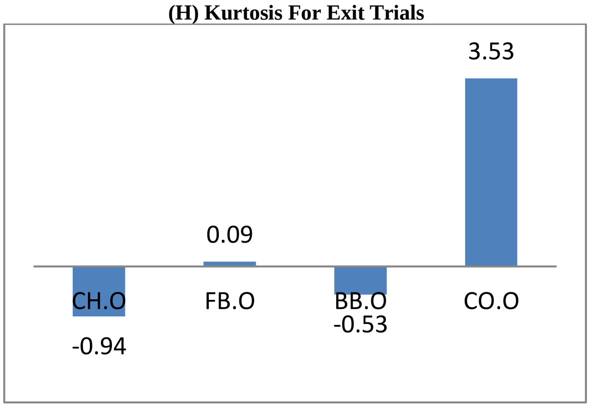
(F) Standard Deviation For Exit Trials



(G) Kurtosis For Entry Trials



(H) Kurtosis For Exit Trials



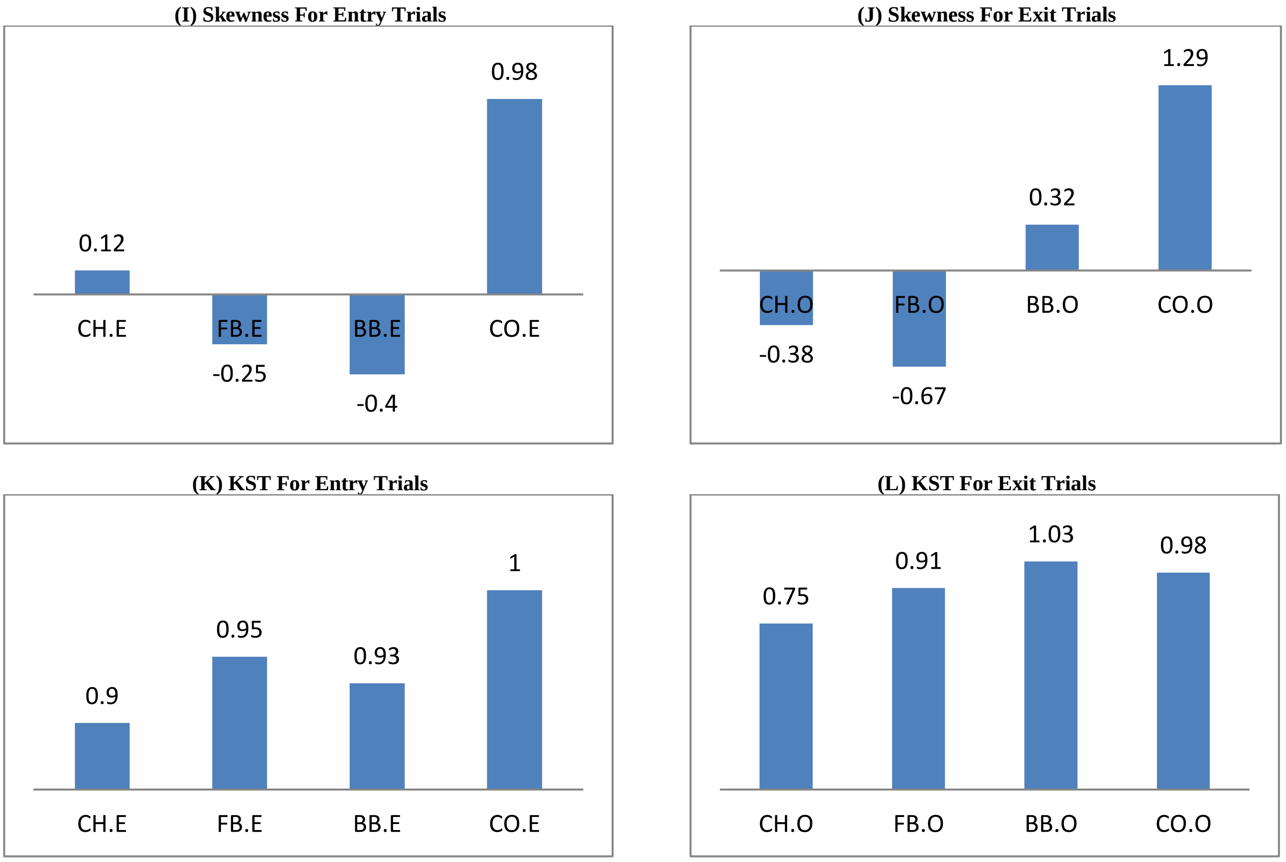


Fig. 4.5: (A – L): Statistical Analysis of the ATTH Obtained for Various Categories of Subjects.

5. Discussions

From the results obtained for the AT paradigm, it is observed that the audiograms for the left ear and right ear are almost similar for every category of subject. Also there is a characteristic dip in the graph at the 4000 Hz and a rise around 6000 Hz. Overall, from a clinician's point of view, these audiogram seem normal and do not hint at any audiological abnormality. The audiograms also fail to differentiate between any category of subjects with respect to age, sex or occupation. Hence one could clearly infer that the conventional audiometry approach cannot be used to differentiate between normal subjects with respect to age, sex and occupation, in case of subjects with normal hearing abilities.

For the ATT paradigm, based on the results provided in Table 3 and figure 5, the following aspects could be inferred.

Mean: The mean value obtained for both entry and exit readings for the subjects indicate a definite pattern. While it is always expected that control set has a better ATT than the undesired conditioning set, the same is seen here as well. The CO.E is better than CH.E and FB.E. (CO.E = 33.86 dB, CH.E = 39.54 dB, FB.E = 61.59 dB). This proves that the absolute threshold is deteriorated in case of employees of chemical industry and fabrication industry. Also the entry values are better than exit values for CH and CO (CH.E = 39.54 dB, CH.O = 49.07 dB, CO.E = 33.86 dB, CO.O = 34.83 dB). This hints at a possible deterioration of the absolute threshold response over the day. Also in case of BB, the exit values are better than the entry values as expected due to their regular basketball practice (BB.E = 49.24 dB, BB.O = 44.13 dB). But this pattern is surprisingly not observed in case of FB where FB.O is better than FB.E. (FB.E = 61.59 dB, FB.O = 57.78 dB). This variation in mean ATTvalue is depicted in Figure 5 (a and b).

Median: The behavior of the median was as similar to that of the mean. While the median value of undesired conditioning (CH and FB) deteriorates from entry to exit (CH.E = 41.55 dB, CH.O = 50.94 dB, FB.E = 61.14 dB, FB.O = 61.74 dB). Also due to a combined exposure to noise and solvents in case of chemical industries, the difference between CH.E and CH.O is greater than that of FB.E and FB.O due to the fact that in case of fabrication industries, there is an exposure to only noise and not to any kind of solvents. In case of desired conditioning (BB), there is a betterment in the exit value as compared to the entry value (BB.E = 50.84 dB, BB.O = 42.23 dB). This is because of the fact that basketball practice between the entry and exit period would improve the hearing perception. But the variation in control set is minimal in the median values. This is depicted in Figure 5 (c and d).

Standard Deviation: As seen in Table 3, the standard deviation is higher in exit readings in case of CH and CO (CH.E = 10.44 and CH.O = 13.35, CO.E = 8.98 and CO.O = 11.88). This is attributed due to the daily activities performed between the entry and exit tests. But this is reversed in case of BB wherein regular basketball practice has helped them to concentrate more and hence improve the hearing perception and therefore a lower standard deviation in the exit readings (BB.E = 13.52 and BB.O = 12.82). But in case of FB, both entry and exit readings have a very less difference (FB.E = 12.5 and FB.O = 12.28). This is depicted in Figure 5 (e and f).

Kurtosis: Kurtosis depicts the flatness/peakedness of the response obtained and in case of CH, the flatness has reduced at the exit (CH.E = -1.12 and CH.O = -0.94). Also in case of CO, the peakedness has increased in the exit values (CO.E = 0.32 and CO.O = 3.53). For FB and BB, Kurtosis simply fails to elicit any meaningful analysis based on the results obtained. This is depicted in Figure 5 (g and h).

Skewness: The skewness indicates the amount of asymmetry around the mean value of a given distribution. In the present case, the CO has positive skew value (CO.E = 0.98 and CO.O = 1.29) hinting at an asymmetric tail extending more towards the positive values. This is due to the absence of any factor such as industrial exposure of conditioning. While the skew value is positive in CH.E (CH.E = 0.12), CH.O is negative indicating at a higher variations in the ATT result obtained for CH.O (CH.O = -0.38). This means that the ATT values are influenced by chemical exposure. Also in case of FB, the variations are high at both entry and exit values (FB.E = -0.25 and FB.O = -0.67). In case of basketball players, although the entry readings have more variations, the same reduce at the exit readings (BB.E = -0.4 and BB.O = 0.32) indicating a better ATT perception due to the sporting activity. Overall, CO is said to be better than any other conditioned data due to no exposure towards any kind of disturbances such as noise or solvents. This variation in skewness is depicted in Figure 5 (i and j).

KST: While all the previously presented results and analysis emphasized on various statistical parameters such as mean, median, variance, standard deviation, kurtosis and skewness, every parameter was not satisfying the expected pattern in one or the other category of subject. Hence the ATT were subjected to another second order statistical test namely KologorovSmrinov Test (KST). The KST is used to determine if the two given datasets differ significantly. Due to the fact the KST makes no prior assumptions about the distribution pattern of the data, this test succeeds where other conventional statistical approaches fail. In the present case, KST successfully differentiates between every category of subject with respect to entry vs exit, desired conditioning vs undesired conditioning and also with conditioning vs control set. In case of every category of subject other than BB, the KST is higher at entry and reduces at the exit. But the extent of decrease in the KST value is highest in case of CH where there is a combined exposure to noise as well as to solvents (CH.E = 0.9, CH.O = 0.75). This difference reduces in case of FB (FB.E = 0.95, FB.O = 0.91) due to the fact that the exposure is only to noise and not to any kind of solvents. In case of control set, this decrement is the least due to the absence of any occupational exposure (CO.E = 1, CO.O = 0.98). But in case of BB, where the hearing perception has improved due to basketball activity, the KST increases at the exit (BB.E = 0.93, BB.O = 1.03). This is depicted in Figure 5 (k and l). Hence KST is considered to be the best statistical analysis approach to assess the variation in hearing perception. KST also helps to assess the variations in auditory temporal resolution with respect to conditioning and control set and also to differentiate between desired and undesired conditioning aspects in daily life.

6. Conclusions

Based on the results obtained, it is hence apt to conclude that the ATT is a better tool when compared to AT. Further is can be inferred that the AT was not able to highlight hearing perception oriented aspects and failed to differentiate normal subjects with respect to age, sex and occupation thereby emphasizing the need to develop novel approaches such as the ATT. The ATT was able to assess the variations in the perception of sound with respect to intensity and was found to be a better paradigm than AT.ATT can be used to successfully differentiate between conditioned (desired and undesired) and control set of subjects along with the entry and exit based variations as well. The statistical analysis of the ATT reveals abundant information about variations in hearing perception with respect to occupational exposure in chemical and fabrication industries as well as in professional games such as basketball which helps to successfully establish a pattern to differentiate between the conditioned and the control dataset.

The present protocol can be extended to assess the hearing perception of subjects such as those manning the traffic, sportsmen undergoing training and rehabilitation in basketball and cricket, in order to verify if their hearing perception varies as compared to those who do not play these sports on a regular basis. This test can be used for a wide range of behavioral applications in case of occupational disorders as well as in sports training based approaches. Also, the ATT is able to differentiate between the conditioned and unconditioned subjects as well as desired and undesired conditioning. Hence it can be considered as the best tool to assess the hearing perception in human beings with respect to their occupation and training as well.

Acknowledgements

The authors wish to thank Jain University for providing a constant support during the present work. Also credits to Centre for Medical Electronics Research, MSRIT for helping with data collection. The analysis of the data has been conducted with the aid of MedNXT Innovative Technologies, Bangalore. The authors wish to thank them as well. Also the authors hereby clarify that there is no financial interest associated with this work and the authors also wish to hereby declare that there is no conflict of interest of any kind regarding the publication of this research.

References

[1] Sanjay H S, Bhargavi S, Dinesh P. A. “Auditory Temporal Resolution Based Psychophysical Evaluation of Healthy Individuals Exposed to Desired and Undesired Conditioning”. Biomedical and Pharmacol Journal, Vol. 10(3), 1449

[2] Sanjay H S, Bhargavi S, and Syed Faisal Ali, "Psychophysical Response for Intensity Variation in Pure Tone Sound-Attention & Retention Assessment in Human Beings." Indian Journal of Science and Technology (IJST), Vol 10.2 1-8, (2017) (DOI: 10.17485/ijst/2017/v10i1/110289)

[3] Saenz, Melissa, and Dave RM Langers. "Tonotopic mapping of human auditory cortex." Hearing research 307 (2014): 42-52. https://doi.org/10.1016/j.heares.2013.07.016.

[4] Kumari, Rakhi, et al. "Auditory assessment of children with severe hearing loss using behavioural observation audiometry and brainstem evoked response audiometry." International Journal of Research in Medical Sciences 4.7 (2017): 2870-2873.

[5] Boboshko, M. Y., et al. "The speech audiometry test with the verbal tasks and motor responses." Vestnik otorinolaringologii80.4 (2015): 47-51. https://doi.org/10.17116/otorino201580447-51.

[6] Hodges, John R. Cognitive assessment for clinicians. Oxford University Press, 2017. https://doi.org/10.1093/med/9780198749189.001.0001.

[7] Christo Ananth, M.Danya Priyadharshini, “A Secure Hash Message Authentication Code to avoid Certificate Revocation list Checking in Vehicular Adhoc networks”, International Journal of Applied Engineering Research (IJAER), Volume 10, Special Issue 2, 2015,(1250-1254).

[8] Hederstierna, Christina, and Ulf Rosenhall. "Age-related hearing decline in individuals with and without occupational noise exposure." Noise & health 18.80 (2016): 21.

[9] Kam, Anna Chi Shan, et al. "Improving mobile phone speech recognition by personalized amplification: application in people with normal hearing and mild-to-moderate hearing loss." Ear and hearing 38.2 (2017): e85-e92. https://doi.org/10.1097/AUD.0000000000000371.

[10] Wang, Xinyang, Dehui Wang, and Haixiang Zhang. "Poisson autoregressive process modeling via the penalized conditional maximum likelihood procedure." Statistical Papers (2017): 1-16. https://doi.org/10.1007/s00362-017-0938-0.

[11] SANJAY, HS, S. BHARGAVI, and PA DINESH. "Auditory Temporal Resolution Based Psychophysical Evaluation of Healthy Individuals Exposed to Desired and Undesired Conditioning."

[12] V. Ilic, "Model of data analysis on interactive web environment for psychometric diagnostics of cognitive functions," 2008 IEEE International Conference on Computational Cybernetics, StaraLesna, 2008, pp. 133-137. https://doi.org/10.1109/ICCCYB.2008.4721393.

[13] Masahiro Yonemitsu, Junji Yoshida, Hiroshi Hasegawa and Masao Kasuga, "Influence of a flash light on the absolute threshold of hearing," TENCON 2007 - 2007 IEEE Region 10 Conference, Taipei, 2007, pp. 1-3.

[14] Sanjay H S, Bhargavi S, Dinesh P. A. “Auditory Temporal Resolution Based Psychophysical Evaluation of Healthy Individuals Exposed to Desired and Undesired Conditioning”. Biomedical and Pharmacol Journal, Vol. 10(3), 1449

[15] Laback, Bernhard. "The Psychophysical Bases of Spatial Hearing in Acoustic and Electric Stimulation." Cumulative habilitation treatise, University of Vienna (2013): 21-30.