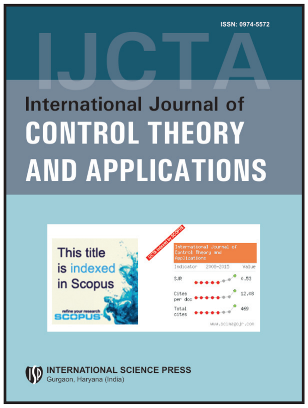

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Perception of Silence Intervals Between Sounds in Normal Human Beings Based on Gap Detection Paradigm – A CUE Towards Auditory Temporal Resolution

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Abstract: Temporal resolution is, perhaps one of the primary task of the human brain. Auditory temporal resolution (ATR) simply signifies the ability of the human brain to perceive the sound and differentiate between various categories of sounds. The aim of this study was to design a simple auditory test paradigm to analyze the ATR which signifies the ability of the human brain to perceive the sound and differentiate between various categories of sounds with respect to age and sex. ATR is, undeniably an important factor in auditory pathology which aids towards the hearing perception related pathology in human beings. Studies have determined that subjects challenged by Dyslexia and Dysgraphia have lesser ATR when compared to normal subjects and the same holds good for workers constantly exposed to solvents in chemical industries as well. Certain studies have also proved that ATR helps to detect the swiftness with respect to the auditory responses of a healthy individual. This paper establishes the use of Gap Detection Threshold (GDT) as a test for ATR, where a silent interval (GAP) is embedded between the sounds and the ability of the subject to detect the smallest possible interval between such sounds is analyzed as a subjective response which would be the threshold value. The current paper attempts to establish the difference in GDT across three sets of ages and between the genders, male and female, successfully and provides substantial theoretical proof for using GDT as a simple and proficient tool for conditioning and rehabilitation. Based on this paradigm, it is observed that females have a lower GDT than males for majority of age groups. Also, the GDT was found to be better in younger population and the same was found to deteriorate with age.

Keywords: Auditory Temporal Resolution (ATR), Gap Detection Threshold (GDT), conditioning, rehabilitation.

1. INTRODUCTION

Conventional tests such as audiometry which are clinically used, can detect the threshold of hearing, but fail to recognize the ability of an individual to perceive the sound in human beings. Perception of sound becomes a very important aspect of auditory screening. This is because, the inability to perceive the sound appropriately is a very common symptom in various pathological conditions such as Dyslexia, Dysgraphia, and Dyscalculia especially in children **[1][2]** and such an abnormality needs to be identified at a very early stage, rather than branding such children as "NOT GOOD IN ACADEMICS", which is a not a very unique situation in developing countries like India. If detected early, such children can be provided with special care and adequate treatment to improve their cognitive skills and temporal resolution abilities by various approaches. Also poorer gap detection threshold often accompanies hearing losses in subjects.

In case of normal subjects such as those involved with table tennis and volley ball, auditory perception becomes a very important factor to grade the ability of the player to perform better in such sports. For instance, it is a fact that a good table tennis player is one who can react swifter while playing. For this to happen, he/she needs to react faster to the sound generated by the racket of the opponent when he hits the ball, rather than reacting to the ball coming towards him after being hit by the opponent. Such an auditory cue can help the player to perform better in his/her game. A similar analogy holds good for the players fielding in close-in positions like slips and gully in case of cricket. This is definitely the reason why certain players are good while fielding in positions like long-on and long-off, but fail miserably while fielding at slips and gully positions to field the cricket ball. The primary reason behind this drastic change in the ability to field is because certain players react better to the sound generated when the ball hits the cricket bat. Such players perform exceptionally well close-in positions where they need to react before the ball passes them. The rest who cannot react to this sound need to depend on the visual cue after they sight the cricket ball and then field it, in which case, they can never field better in close-in positions as they need more time to see the ball and then react by trying to field it.

Also in cases of regular occupational exposure to sound, which is seen more often in manufacturing industries if the workers are deputed to operate huge machines which generate more noise, such as those in mechanical industries and also those manning the vehicular traffic in busy signals every day, noise is a common factor in their daily lives. Such employees are constantly exposed to undesired noise and there are definite chances of their auditory system being affected too, to this constant exposure, which one could term as Undesired Conditioning. In such cases, the hearing perception, thereby the ATR of such population gets adversely affected.

Studies suggest that workers who are constantly exposed to solvents in chemical industries are more prone to auditory disorders **[3][4][5]**. In such cases, if the hearing perceptions of these workers are periodically analyzed, then there can be a certain stage where the hearing perception decreases beyond a definite threshold, after which they need to be prevented from further exposure to such solvents until the period their perception abilities get back to normal. Till that time, they can be deputed to work in other departments wherein solvent exposure is not seen. Probably, a desk job during this phase would be advisable so as to aid the re-growth of the hearing perception in such workers.

It has also been proved that the hearing abilities deteriorate with age **[6]**. This can also be observed with many older populations reacting slower than the younger population in general, which is not confined to auditory input alone. While some substantiate this behavior due the fact the swiftness of reaction in human beings decreases with age, the same can be considered for auditory input as well, but with the reaction in this case, resulting only after one perceives the auditory input, for which the resolution of auditory input in the human auditory cortex is the primary link. In other words, ATR is the major cause because of which the individual can react to the sound. But before even the brain resolves such sounds, it is necessary to perceive the sound at the first instance.

Hence, perception of hearing needs to be assessed as the primary information to grade the subjects based on the ATR for any further conclusions about the ability of an individual to react for a given auditory input.

2. BACKGROUND

There are various tests available which are, to a certain extent relevant to detect the hearing abilities of an individual. To name few are Brainstem Evoked Auditory Response (BERA), Oto-Acoustic Emission (OAE) and the Speech Recognition Threshold (SRT) tests.

BERA is a test to measure the brain wave activity that occurs as a response to clicks or certain tones. Here the subject is required to lay on a reclining chair or bed and remain still and the electrodes are placed on the scalp and on each earlobe. The earphones are used to provide a brief click or tone. The electrodes pick up the responses of the auditory cortex to these sounds and record the same. In this case, many aspects like the placement of earphones, positioning of electrodes and the nature of click sounds cause discomforts to subjects. There are also certain complications involved with the setup of this test.

Another commonly used test is based on the OAEs. An OAE is a sound generated from within the inner ear (cochlea) which is known to enhance the ability to hear soft sound and inhibit loud sounds. Studies have proved that OAEs cease to exist in case of a damaged cochlea. OAEs are clinically important because they are the basis of a simple, non-invasive test to assess the hearing defects in newborn babies and in children who are too young to cooperate in conventional hearing tests. In case of a damaged cochlea, one would lose both the ability to hear soft sound as well as the ability to tolerate loud sound. Once the fine-tuning ability is lost, sound will be distorted and unclear. OAEs are acoustic signals generated by the normal inner ear, either in the absence of acoustic stimulation or in response to acoustic stimulation. Acoustically OAE testing allows the audiologist to understand how the outer hair cells of the inner ear are working. But OAEs are not known to highlight the auditory perception abilities in an individual to a great extent. Also OAE testing cannot produce accurate results if the head of the subject has moved. Also OAEs cannot assess the severity of hearing losses. There are chances of wrong diagnosis because of the interference of background noise, due to the fact that these signals are of very low scale and are difficult to be picked up without adequate setup.

The speech audiometry has become a fundamental tool in hearing-loss assessment. In conjunction with pure-tone audiometry, it can aid in determining the degree and type of hearing loss by assessing the Speech Recognition Threshold (SRT). Speech audiometry also provides information regarding discomfort or tolerance to speech stimuli and information on word recognition abilities. In addition, the information gained by Speech audiometry can help to determine proper gain and maximum output of hearing aids and other amplifying devices for patients with significant hearing losses and help assess how well they hear in the presence of noise. The objective of this is to obtain the shortest time at which speech can be identified. In addition to determining softest levels at which patients can hear and repeat words, the SRT is also used to validate pure-tone thresholds because of high correlation between the SRT and the average of pure-tone thresholds at 500, 1000, and 2000 Hz. But this test too concentrates on the hearing alone and not the perception as a major factor.

On a similar note, the electroencephalogram of the subject provides an objective analysis while the subject is provided with the auditory protocols. According to studies, these EEGs can be analyzed to find out the extent to which the sound is perceived by recording the EEG while the sound/GAP is being perceived by the subject and analyzed for variations while GAP was perceived and otherwise. [7][8]

While every other test emphasizes on hearing loss and the pathology associated, very less importance is provided to the hearing perception based approach and thereby the analysis of auditory temporal resolution of a given individual. Also in developing countries cheap labor is an important factor and in such a scenario, auditory tests are more often conducted to assess the hearing loss when one complains/feels a decrease in hearing due to his/her occupation and not as a regular tool for prevention of the same, so as to provide adequate care even before the auditory abilities of the individual begin to decrement due to occupational and environmental factors.

3. EXPERIMENTAL PROTOCOL - GAP DETECTION PARADIGM

Gap detection protocol is a simple paradigm to assess the ability of an individual to perceive silence intervals/ pauses between a sound complex and is perhaps the easiest approach to analyze the auditory perception in human beings with respect to random gaps which can be graded to conclude on the hearing perception based analysis [9][10]. In this test, the auditory input is provided as a pause embedded between the sound and the subject is asked to respond if he/she is able to identify the pause, in which case, the sound complex is perceived as two sounds with a pause in between. If so, the length of the pause is reduced till an extent where he/she cannot perceive this input as two sounds with a pause, instead is perceived as a single sound with the pause/gap going unperceived. The time interval of such a gap, after which the perception of gap ceases, is concluded to be the Gap Detection Threshold (GDT) which is an important tool to grade the ATR. Is the ATR is in the normal range, and then the subject is said to be possessing normal hearing abilities, else abnormal. Previous research suggests that the normal GDT is 0 – 20 msec. Anything above this may indicate the presence of a temporal processing disorder and difficulty in speech discrimination. A simple approach to design a Gap Detection Test is as follows.

Figure 1 depicts the protocol design of the current experiment. Here a sound-gap-sound protocol is used. Based on a pre-defined peak value, the ramp and cosine waves are generated using MATLAB toolbox. The Product of the up-ramp and the cosine wave is obtained. A white Gaussian noise is generated and then the mirror image of the product of up-ramp and the cosine wave is taken. The up-ramp, Gaussian noise and the down-ramp are concatenated (intermediate waveform). After this the first half of the Gaussian noise is generated and the gap length is assigned. By using an array of zeros a gap sequence/silent interval is created. Inserting this gap sequence at the central point of the intermediate waveform (Final waveform), gives the final waveform, as shown in Figure 2 which is provided as an input for the subject to hear, via earphones. The gap length is varied based on the subject's response to the tone, which is done by multiplying or dividing it by a factor prefixed factor, say k. The gap length is decreased by a factor 'k' if the subject is able to detect the gap, else it is increased. The turn-points are considered to calculate the geometric mean, which gives the value of the gap detection threshold in terms of milliseconds (after converting the scale in terms of time in MATLAB). This is repeated until desired number of turn-points are obtained (The present experiment includes 8 turn points to calculate the geometric mean of the GDT). To respond as to whether the individual perceived the gap or not, he/she is asked to press 1 or 0 respectively, according to which the gap widens or narrows down.

The experimental setup is very simple and consists of a computer and MATLAB tool. The stimulus, being white noise is provided to the subject by means of an earphone to which, the response is picked and the data is stored simultaneously. The use of a battery operated laptop enables recordings at locations remote from power sources. MATLAB is an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Also it is simpler to visualize the signals in time and frequency domain and is used for waveform and pulse generation including sine, cosine, and Gaussian pulse that are played on a PC - based audio output device. MATLAB simplifies the analysis of mathematical models and saves a lot of time with computations.

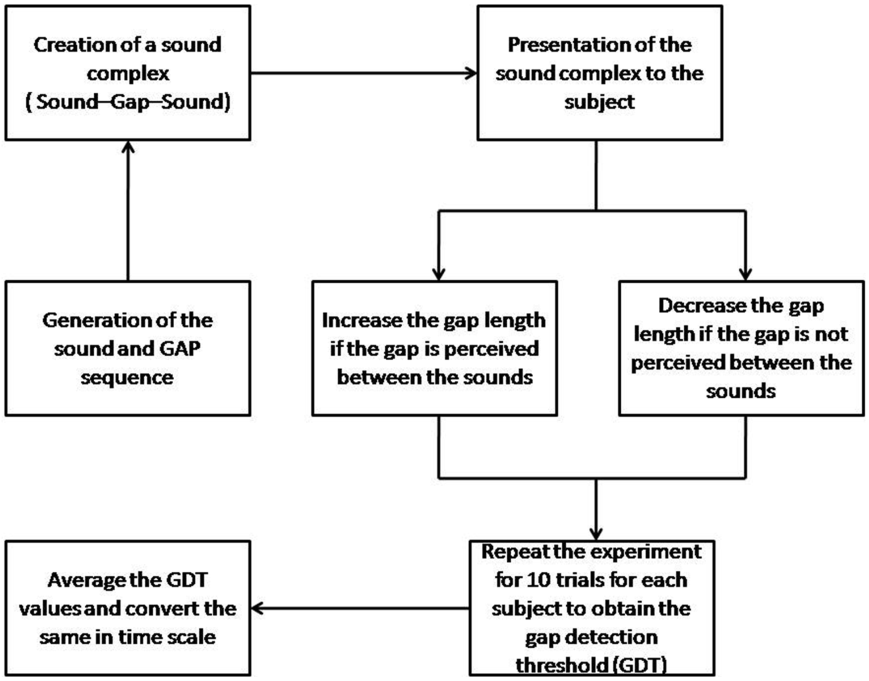

Figure 1: Protocol designed for Gap Detection Test paradigm.

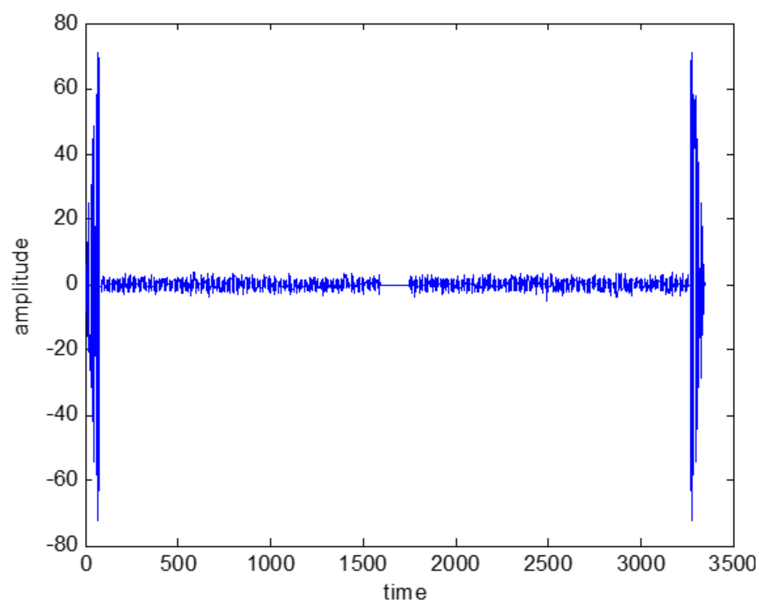

Figure 2: Sample sound complex (sound-gap-sound) generated using MATLAB tool

x-axis: Time of the test (msec) with a sampling rate of 8000 samples per second
y-axis: amplitude of sound in dB.

This experiment is conducted on three age groups, 20 – 30 years, 30 – 40 years and 40 – 50 years. A total of 44 subjects are considered for this experiment, both males and females, for each age group, all known to be healthy and void of any known neurological or auditory or any known pathological history. To the maximum extent possible, adequate care is taken to conduct these tests between 8 am – 11 am i.e., first half of the day, to avoid the influence of the fatigue component seen due to their daily activities, if any. The thus obtained GDT is analyzed with age and sex being the discriminating factor and is presented in the results section. Also mentioned in Figure 3 is a sample case of GDT protocol run on a subject illustrated with the help of a timing diagram for the proposed paradigm.

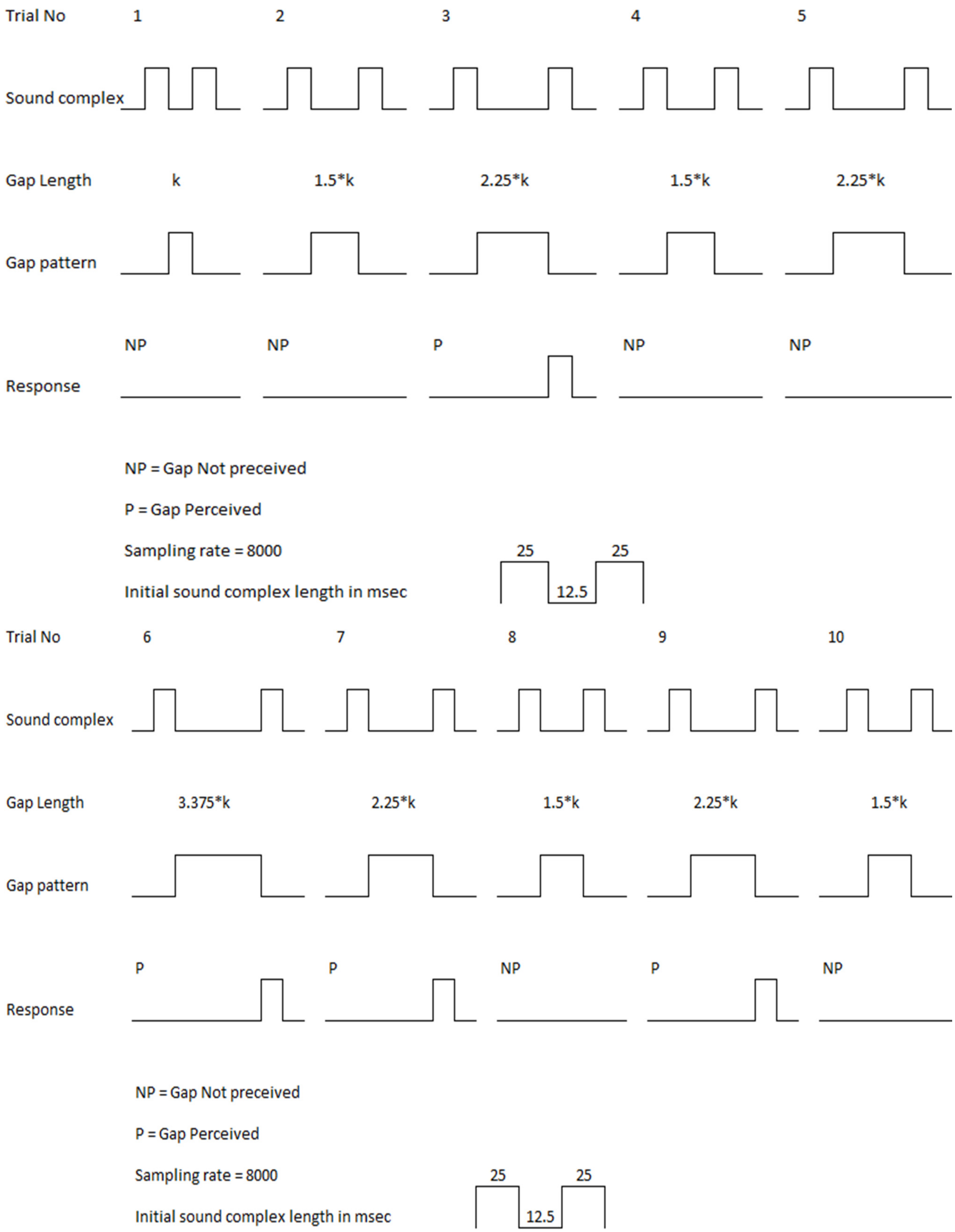

Figure 3: The timing diagram for the Gap detection Test protocol illustrated for a sample case of 10 trials

4. RESULTS AND DISCUSSION

The Gap Detection paradigm is used to assess the GDT of the subject with respect to age, in the present case. Once the GDT of an individual is obtained, as per the protocol mentioned prior, it is tabulated with respect to age. Every individual is made to undergo three trials and the GDT obtained for every trial is averaged. The averaged data is mentioned in this section. Table 1 provides the information about the statistical analysis performed for the GDT values with respect to age as the discriminating factor, for both males and females combined with respect to age alone.

Table 1
Overall analysis - age wise (both males and females combined)

Age (Years)	*N*	*Range*	*Mean*	*Std. Deviation*	*Variance*	*Kurtosis*		*Mean Ranks Friedman Test*	*Chi square*
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Std. Error*		
20 – 30	44	3.52	4.3839	.99930	.999	–1.295	.702	1.05	64.682
30 – 40	44	3.86	7.1789	.88805	.789	2.427	.702	2.25	
40 – 50	44	6.99	7.8143	1.34354	1.805	1.817	.702	2.70	

Table 2 provides the statistical analysis of the results of GDT obtained for males segregated with respect to age. Table 3 provides a similar statistical analysis for the results obtained for females with respect to age.

Table 2
Overall analysis – age wise for males

Age (Years)	*N*	*Range*	*Mean*	*Std. Deviation*	*Variance*	*Kurtosis*		*Mean Ranks Friedman Test*	*Chi square*
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Std. Error*		
20 – 30	22	2.31	4.25	.76125	.580	–1.603	.953	1.00	33.091
30 – 40	22	3.86	6.8523	.94423	.892	4.783	.953	2.05	
40 – 50	22	3.48	7.54	1.18539	1.405	–1.701	.953	2.55	

Table 3
Overall analysis – age wise for females

Age (Years)	*N*	*Range*	*Mean*	*Std. Deviation*	*Variance*	*Kurtosis*		*Mean Ranks Friedman Test*	*Chi square*
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Statistic*	*Std. Error*		
20 – 30	22	3.52	4.5136	1.19581	1.430	–1.782	.953	1.09	34.636
30 – 40	22	2.93	7.5055	.70694	.500	5.163	.953	2.45	
40 – 50	22	6.99	8.0805	1.46377	2.143	2.797	.953	2.86	

5. CONCLUSIONS

The most important inference that could be drawn from the present results is that ***the GDT increases with age***. This means that the ability of a human being to perceive and detect the silence interval between sound complex decreases with age. Also the auditory perception is better in males than in females. This simply suggests that the temporal resolution is superior in males than in females and that the ability to temporally resolve decreases with age in both males and females.

6. FUTURE DIRECTIONS

While one could easily conclude on the GDT of an individual using this paradigm, the present test can also be used to see if there is an indicative result in sports professionals such as those involved with table tennis and volley ball. If there shows a clear GDT variation between those playing these sports professionally and the control subjects, then definitely GDT can be used as a discriminating parameter in the assessment of sports rehabilitation and conditioning. Also the same can be applied for those working in chemical industries and mechanical industries. GDT can be a easy and a definite parameter to verify the variations in the hearing perception of the subjects exposed to occupational noise and thereby aid in the occupation based rehabilitation as well as to plan the preventive actions to be taken to avoid a permanent damage to the auditory functions of such individuals.

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REFERENCES

[1] Beverly A. Wright, Linda J. Lombardino, Wayne M. King, Cynthia S. Puranik, Christiana M. Leonard and Michael M. Merzenich, "*Deficits in auditory temporal and spectral resolution in language-impaired children*", Nature, Vol. 387 (1997), 176 – 178.

[2] Chaubet, Juliana, Liliane Pereira, and Ana Paula Perez. "*Temporal Resolution Ability in Students with Dyslexia and Reading and Writing Disorders*", International archives of otorhinolaryngology*,* Vol. 18.2 (2014), 146-149.

[3] Fuente, Adrian, Bradley McPherson, and Felipe Cardemil, "*Xylene-induced auditory dysfunction in humans*", Ear and Hearing, Vol. 34.5 (2013), 651-660.

[4] Fuente, Adrian, Bradley McPherson, and Louise Hickson, "*Auditory dysfunction associated with solvent exposure*", BMC Public Health*,* Vol. 13.1 (2013), 13-39.

[5] Camarinha CR, Frota SM, Pacheco-Ferreira H, Lima MA, "*Auditory temporal processing assessment in rural workers exposed to organophosphate pesticides*", Jornal da Sociedade Brasileira de Fonoaudiologia, Vol. 23.2 (2011), 102-106.

[6] Fooladi, Marjaneh M. "*Involuntary and persistent environmental noise influences health and hearing in Beirut, Lebanon*." Journal of environmental and public health 2012 (2011).

[7] Uppunda Ajith Kumar, A. V. Sangamanatha, and Jai Vikas, "*Effects of Meditation on Temporal Processing and Speech Perceptual Skills in Younger and Older Adults*," Asian Journal of Neuroscience, Vol. 2013, Article ID 304057, 8 pages, 2013. doi:10.1155/2013/304057

[8] Sanjay H S, Arundathi Hazare, Sharanya, Dr Bhargavi S. "*EEG based GAP perception in human beings*." International Journal of Advances in Engineering Research 10.2 (2015): 92-101.

[9] Prithvi B S, Sanjay H S, Deeksha Hegde, Bhargavi S, "*Novel Software Solution to Diagnose the Hearing Disabilities In Human Beings*", International Journal of Recent Innovations & Trends in Computing & Communication, 4.4 (2016): 593-597

[10] Sanjay H S, Anusha G. and Lalitha B. S. "*Auditory perception of random gaps in human beings*." International Journal of Biomedical Engineering and Consumer Health Informatics 4.2 (2012): 29-31.