# Maturational Effect of Pitch Pattern Sequence Test

Register No.02SH0017

An Independent Project submitted as part fulfillment for the first year M.Sc. (Speech and Hearing), Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MYSORE - 570 006

MAY, 2003

# Certificate

This is to certify that this Independent Project entitled **"Maturational Effect of Pitch Pattern Sequence Test"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No. 02SH0017

Mysore
May, 2003

Director "
All India Institute of
Speech and Hearing
Mysore - 570 006

# Certificate

This is to certify that this Independent Project entitled **"Maturational Effect of Pitch Pattern Sequence Test"** has been prepared under my supervision and guidance.

Mysore
May, 2003

Guide
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# Declaration

This independent project entitled **"Maturational Effect of Pitch Pattern Sequence Test"** is the result of my own study under the guidance of **Dr. C.S. Vanaja,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for any other Diploma or Degree.

Mysore

May, 2003

Register No. 02SH0017

Dedicated to

my

Beloved Family

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# INTRODUCTION

Auditory processing is an integral part of communication. ASHA (as cited in Bellis, 1996) describes Central Auditory Processes as the mechanisms and processes of the auditory system that are responsible for the following behavioural phenomena;

- Sound localization and lateralization
- Auditory discrimination
- Auditory pattern recognition
- Temporal aspects of audition including
    - Temporal resolution
    - Temporal masking
    - Temporal integration
    - Temporal ordering
- Auditory performance decrements with completing acoustic signals
- Auditory performance decrements with degraded acoustic signals

A deficiency in any one or more of these phenomena leads to central auditory processing disorders. Recently in Bruton conference a group of scientists agreed that a new label, auditory processing disorders (APD) should replace the older label central auditory processing disorder (Chermak, 2001). Auditory processing disorder is identified by administering a battery of tests with will uniquely stress the auditory mechanisms at various levels of central auditory nervous system function to identify inefficient neural processing.

Prevalence data for APD are sparse, particularly for children, Chermak (2001) has estimated that APD occurs in 2% to 3% of children with a 2:1 ratio between boys and girls. Cooper and Gates (as cited in Chermak 2001) estimated APD in 10% to 20% of older adults. In contrast, Stach, Sprentnjak, and Jerger (as cited in Chermak, 2001) reported APD in 70% of clinical patients over age 60 years.

Temporal processing is one of the processes of central auditory processing. Several tests to asses temporal processing are Frequency Pattern or Pitch Pattern Sequence Test (PPST), Duration Pattern Test (DPT), Psycho acoustic Pattern Discrimination Test (PPDT) (Bellis, 1996). PPST detects both pattern perception and temporal sequencing abilities in the listener (Bellis 1996). The test consists of pattern sequences of 3 tone bursts; two of one frequency and one of another. The subject has to respond by repeating the sequences in which the tones were presented. This test taps the processes of frequency discrimination, temporal ordering and linguistic labeling (Bellis, 1996). The subject/listener can either whistle or hum, say it verbally and point or tap to high-low objects. PPST is useful in detection of disorders of cerebral hemispheres (Pinheiro & Musiek, 1985). It is also sensitive to corpus callosal dysfunction (Musiek, Pinheiro, & Wilson, 1980) and provides information regarding neuromaturation in children with learning disability by indicating the degree of myelination of the corpus callosum.

Individuals with right temporal lobe lesion and corpus callosum lesion show bilateral deficit whereas those with left temporal lobe lesion show significant contralateral and / or bilateral effects. Individuals with brainstem lesions show variable effects whereas those with peripheral lesions show little effect only (Bellis, 1996). Thus, like for other tests (Bellis, 1996), before administering it on clinical population, normative data should be available for PPST also.

*Aims / Objectives **of the** Study*

The following were aims of the present study:

1. To study the effect of age on results of PPST.
2. To compare the scores of humming and verbal responses on PPST in children and adults.
3. To study if there is a difference in performance of males and females.
4. To study the ear effect in PPST.

*Need **for the** Study*

There is a dearth of studies on maturational changes in pitch pattern in children. It is expected that the scores mature with age. The maturation of higher centres and myelination of corpus callosum continues till adolescence (Pinheiro, & Musiek, 1985). So maturation of temporal processing continues till 12 years of age (Bellis, 1996). Therefore, there is a need to obtain age appropriate norms for the test.

The temporal sequencing of auditory patterns require processing by both hemisphere of the brain, i.e., the left hemisphere for the serial ordering of the response and the right hemisphere for the recognition of the pattern Gestalt, since the right hemisphere has been found dominant for pattern recognition (Nebes, 1971). It is known that corpus callosum is the last to mature during the maturation process. Therefore, it can be expected that children obtain better scores for humming response than verbal responses. Hence, there is a need to compare the effect of neural maturation on humming responses and verbal responses.

# REVIEW OF LITERATURE

"Temporal Processing" is one of the processes of Central Auditory Processing (CAP). Temporal refers to time related aspects of the acoustic signal. This function involves the perception and/or processing of two or more auditory stimuli in their order of occurrence in time. This function is usually measured by a judgement of order or the behavioural sequencing of the stimuli (Pinheiro & Musiek, 1985).

Chermak and Musiek (1997) report that temporal processing is responsible for temporal patterning (e.g., Phase locking, Synchronization) of neural discharges and the following behavioural phenomena.

- Temporal resolution (i.e., detection of changes in durations of auditory stimuli and time intervals between auditory stimuli over time).
- Temporal ordering (i.e., detection of sequence of sounds over time)
- Temporal integration (i.e., summation of power over durations less than 200 milli-seconds)
- Temporal masking (i.e., obscuring of probe by pre or post stimulatory presentation of masker).

Temporal processing is critical to a wide variety of every day listening tasks, including speech perception and perception of music (Hirsh, 1959). In speech perception, temporal processing is one of the functions necessary for the discrimination of subtle cues such as voicing and the discrimination of similar words (Bellis, 1996). Analysis of temporal order takes place primarily in the dominant hemisphere, specifically in the temporal lobe and extending posteriorly to Wemicke's area and angular gyrus. (Efron, 1963). One of the tests to assess or check temporal processing is Pitch Pattern Sequence Test. Pinheiro developed this test in 1977. It has versions for both adults and children. The test is also unique in the sense that it is non-verbal and permits evaluation of both pattern perception skill and temporal sequencing ability. The children's version involves having the child report a pattern of 3 tone bursts (500 msec duration each separated by 300 msec intervals between tones). The tone frequencies are 880 Hz (Low) and 1430 Hz (high), which are played in 6 different combinations (HLH, LHL, HHL, LLH, HLL, LHH). The test has provisions for training the subjects with practice items and then each ear may be tested under earphones, with the patterns presented to each ear. However, it may also be presented in sound field. Another feature of the test is that any of several response modes may be employed depending on the ability of the child. Subjects may respond by whistling or humming the pattern perceived, by reporting the pattern verbally, or by pointing to or tapping high and low objects such as blocks which gives us information regarding the interaction of two cerebral hemispheres (Bellis, 1996). The PPST is useful in the detection of disorders of the cerebral hemispheres. (Musiek & Pinheiro, 1987; Pinheiro & Musiek, 1985). The test has been shown to be sensitive to corpus callosal dysfunction in that patient with disruptions in the interhemispheric transfer of auditory information exhibit improvement in performance when the linguistic labeling component of the test is removed by requesting the listener to hum the pattern rather than verbally describe it. (Musiek, et al, 1980). Results of the PPST may provide information regarding neuromaturation in a child with learning disability by indicating the degree of myelination of the corpus callosum (Musiek, Gollegly & Baran, 1984).

A comparison of either verbal, or manual response with hummed responses is valuable in differentiating impairment in perception from impairment in processing the auditory sequences (Pinheiro & Musiek, 1985). The sequential stimuli are non-verbal, the task is a very easy one for normal adults; and various response methods may be tailored to the ability of the subject to respond (Pinheiro & Musiek, 1985). However, Laterally information cannot be obtained from this test. (Bellis, 1996). Test results do not 'localize' the lesion (Pinheiro & Musiek, 1985). It is difficult for normal children also. The PPST probably would not be an appropriate measure for children below the age of 8 years (Bellis, 1996).

***Factors Affecting Temporal Processing:***

Factors Affecting PPST can be broadly divided into: Factors related to procedure and Subject related factors.

**I. *Factors Related To Procedure***

**(1) *Type of Stimuli***

Many different types of stimuli have been utilized in studies of temporal ordering by different investigators. Noise, tones, clicks, speech or speech like sounds, or a combination of some of these have served as stimuli. The auditory signals in a sequence used to investigate the function of temporal ordering should not require the basic function of discrimination between or among acoustic cues not under study. If there is some difference among the signals in frequency, intensity, or duration, the subject should be able to distinguish between them or in isolation easily (Pinheiro & Musiek, 1985).

**(2) *Instrumentation***

Instrumentation has varied from one research laboratory to another. A few investigators have used loud speakers for presentation of stimuli, although most have employed earphones. Some workers have tested subjects using tape loops, while others have generated the signals as they were presented (Pinheiro & Musiek, 1985). Of late, the material is recorded on a CD. These factors must be taken into account when studies of temporal ordering are compared.

**(3) *Number of Components***

The number of components in a sequence obviously influences the difficulty of the psychophysical task. The task of ordering three elements is different from that of ordering only two elements or from that of ordering more than three elements. In fact, it is possible that the number of stimuli affect the manner of processing in a temporal ordering task. (Pinheiro & Musiek, 1985).

**(4) *Duration of Components***

The duration of the individual components in a sequence also affects perception of the sequence and the task of ordering it, Divenyi and Hirsh (1974) summarized duration requirements for the components of a contiguous sequence necessary for judgements of temporal order. They reported that in repeated sequences of four contiguous components, each component must be of 125 to 700 msec duration. (A naive subject required 700 msec for such a task). If the four components sequence was presented only once, each component had to be 200 msec in duration Warren & Obusek (as cited in Piheiro & Musiek, 1985). For sequences of 3 components, each component needed duration of 50 msec (Peters & Wood, 1973). If the subject had to judge which of two components came first, each components required a duration of 20msec (Hirsh, 1959). In order to discriminate between two separate sequences, each component needed to be 90 msec in duration (Leshowitz & Hanzi, 1972). Absolute identification of the temporal order of four different contiguous sounds required a duration of at least 200 msec for each sound Waren (as cited in Pinheiro & Musiek, 1985).

Gengel (1973) studied temporal effects in frequency discrimination by hearing impaired listeners. Five college students with sensori neural hearing loss having impairment with site of lesion presumably in cochlea were tested. Three subjects with normal hearing were also taken. Standard frequencies tested were 500, 1.5 kHz and 3 kHz. Comparison frequencies were higher than their respective standard frequencies. Nominal frequencies were accurate to within 0.4 Hz Difference Limens for Frequency (DLF) was obtained for 50 and 500 msec signals that were delivered monaurally by TDH-39 earphones at comfortably loud levels to hearing impaired. Normal subjects were tested at 95 dB SPL. White noise of 80 dB SPL was used to mask the contralateral ear. Speech discrimination was measured with 2 types of tests - vowel discrimination and consonant discrimination with a signal to noise ratio of+30 dB. Results indicated a wide range in the size of DLF among subjects. Hearing impaired subjects showed DLF's that generally were larger than the DLF's with subjects with normal sensitivity. All subjects DLF were larger for 50 msec signals than for the 500 msec signals, even though the temporal effects on frequency discrimination seemed to be similar. They found a significant rank order correlation between frequency discrimination at 3 kHz and phoneme discrimination i.e., S1 had the smallest DLF and the highest phonemic discrimination score. While S5 had the largest DLF the lowest discrimination score. They have taken normal subjects for comparison. Modified procedure was used to obtain DLF and speech discrimination was measured for both vowels and consonants. However, the numbers of subjects taken were less.

**(5) *Duration of silent interval***

The duration of silent interval also has been found to be important (Peters & Wood, 1973). The components of sequences themselves, or both have been separated in time by silent intervals, and performance has improved. (Thomas, Cetti & Chase, 1971). Some researchers have used overlapping stimuli with different onset times. (Pinheiro & Musiek, 1985).

**(6) *Type of Patterns***

Investigators have employed patterns that were binary and others have presented sequences in which all components differed. Some sequences have been unidirectional in tonal presentation, while others have not. Some sequences have been presented in pairs, some presented only once, and some repeated continuously on a tape loop. Sequential stimuli have also been presented to subjects monaurally, binaurally, diotically, dichotically in alternating ears and in sound fields. (Pinheiro & Musiek, 1985). Speech and speech like sounds have been found to be sequenced into temporal order more easily than non-speech stimuli (Thomas, Hill, Carroll & Barcia, 1970).

**(7) *Response Task***

The type of temporal order judgement the subject is asked to make also influences the results of studies in temporal sequencing Warren & Obusek (as cited in Pinheiro &

Musiek, 1985). Some responses require a higher level of cognitive processing than others. In some investigations, subjects have been required to determine whether overlapping stimuli were simultaneous or successive in onset times. In other investigations, subjects have had to decide which of a pair of overlapping sounds began first in time. Subjects have been asked to judge whether two sequences were the same or different. Some have used tracking procedures in which the subjects tried to respond to or identify each component of a sequence as it occurred. In some studies, subjects have been required to identify a particular pulse in a series of pulses as different or changed. Another method used was to have the subject adjust the frequency of one component in the sound sequence of a pair of sequences to match the same component in the first sequence. Some judgements required matching a sequence pictured on a response button to the sequence heard. The most difficult type of judgement of temporal order appears to be a description of a sequence or actual ordering of the components by labeling them verbally or pointing to or pressing buttons in a sequence that matches the sequences heard, or repeating the actual order of the components of the sequence in some other form of response. Preusser (as cited in Pinheiro & Musiek, 1985).

Hummed responses for tonal sequences or pitch patterns have also been investigated and found to be an imitative type of response involving less cognitive processing than a verbal a manual response (Pinheiro, 1978). Different response modes were also investigated Pinheiro & Tinta (as cited in Pnheiro & Musiek, 1985) i.e., manual, verbal and hummed, but all responses except the latter, which was initiative, required actual temporal ordering of a sequence presented a single time. There were no differences among response modes for normal subjects. There were no significant differences between ears for any response modes as for ears across response modes.

**(8) *Intensity Level***

The intensity level or sensation level at which the auditory sequences are presented may also influence results. The psychophysical variable has not been adequately investigated. Ptacek and Pinheiro (1971) reported that lower levels of presentations decreased performance for sequences of 3 noise or tone bursts involving a frequency or intensity difference within the sequence (Pinheiro & Musiek, 1985).

Musiek (1994) compared compact disc versions of the frequency (pitch) and duration pattern tests. Subjects taken were 150 young, normal hearing adults. The frequency pattern consisted of three 150 msec tones (10 msec rise fall times) and two 200 msec intertone intervals. The two frequencies used were 880 Hz and 1122 Hz CD contained 60 frequency patterns that had approximately 6 sec inter pattern interval. Tones were presented at either 20 dB HL (ANSI, 1989) on 50 dB HL. Subjects were asked to repeat by verbalizing the tonal patterns and were encouraged to guess if they were unsure of the pattern. Results showed no effect of presentation on level or performance, as mean scores were essentially the same at both levels used for both types of patterns. Mean scores for both tests were approximately 90% correct, with less variability at the lower presentation levels. A cut-off score of 78% was obtained. This CD version of frequency pattern test provides a high fidelity measure of auditory pattern identification that can be administered easily. However, this particular experimental design did not seek to determine ear differences.

**(9) *Rate and Manner of Presentation***

Very brief stimuli presented at a rapid rate are thought to be judged by spectral differences, whereas longer components presented at a slower rate are usually perceived as individually different or separate sounds, Nickerson & Freeman (as cited in Pinheiro & Musiek, 1985). Very rapid rates of presentation do not permit, actual temporal ordering of the stimuli, although rapid rates have been used for other types of temporal ordering tasks that employ simpler judgements needing less cognitive processing. The manner of presentation interacts with the rate of presentation (Pinheiro & Musiek, 1985).

A study by Tallal (1980) in which reading impaired and control children were given an experimental battery of nonverbal auditory perceptual tests, examined discrimination and temporal order perception. Twenty reading disabled children (4 girls and 16 boys) age 8-12 years and age and sex matched normals were taken for the study. Auditory perceptual test included repetition test which had subtests such as association, sequencing, rapid perception (where the interstimulus interval of two-element stimulus was decreased and presented to the subjects) and same different discrimination test. Stimuli used were tones. Nonsense word reading was also carried out. Results showed no significant differences between groups on tests in which stimuli were presented at slow rates. However, when the same stimuli were presented more rapidly, the reading impaired group made significantly more errors than the controls. Performances of all subjects were virtually errorless on the same different discrimination test when the two tones to be discriminated were separated by the relatively long interval.

## II. *Subject related factors*

### (1) *Subject Training:*

The amount of training necessary depends on both the complexity of the stimulus and the difficulty of the psychophysical task. Warren (as cited in Pinheiro & Musiek, 1985) felt that training of subjects was not necessary for sequences in which the components had duration of at least 200 msec each on some temporal ordering tasks. Efron (1963) pointed out that a naive subject performs significantly more poorly than a trained normal subject on certain temporal ordering tasks. Whether or not subjects should be trained may depend on the type of data that is being collected. (Pinheiro & Musiek, 1985).

Soderquist and Moore (1970) studied the effect of training on frequency discrimination in primary school children. Frequency differential limens (DLF) were measured for 3 groups of children (ages 5, 7, 8 and 9) and specific frequency discrimination training was given to half of each group. Results indicated a decrease in DLF as a function of age up to approximately 7 years old. In addition; the training resulted in significant decrease in mean DLF for each of the three groups. The 7-year-old group also was subjected to a re-evaluation of their frequency DLF after approximately one year. The results revealed significant differences between these children who had been previously exposed to the training procedure and those who had not. The results were explained in terms of perceptual learning. Here they have compared trained group with those who were not trained and have considered maturation as an aspect. However, only specific frequency discrimination training was earned out. Thus, subject training helps in reducing the DLF and in turn helps in temporal patterning tasks.

**(2)** ***Music Training***

Early studies indicated that musicians perform better than non-musicians on frequency and duration pattern tasks. DeFosse (as cited in Pinheiro & Musiek, 1985) studied dichotic pitch patterns in musicians and non-musicians, with the finding that the former performed better across different response modes and report conditions. In addition, the two groups seemed to process the stimuli differently i.e., non-musicians were left ear-dominant, whereas musicians performed equally well for both ears.

**(3)** ***Attention and Recall***

It is difficult to separate the variables of attention and recall because the attention of the subject obviously affects recall of the sequence. Recall is a powerful variable that affects all types of judgements of temporal order, since the response must follow the stimulus after some brief period of time. In tracking, the responses the subject has to recall only one component at a time. In other response paradigms the subjects has to remember pairs of sequences or a single sequence with several or more components. If recall is inaccurate, not even the simplest type of temporal order judgement can be made correctly (Pinheiro & Musiek, 1985).

**(4)** ***Frequency discrimination***

Although a few studies are available on young infants, there is a dearth of literature on frequency discrimination for infants between the ages of 4 months and 3 years. However, some data on children's frequency discrimination abilities are available, although not extensive, beyond the age of three, Duel and Anderson (as cited in Pinheiro & Musiek, 1985). These latter data suggest some interesting trends. First, difference

limen frequency (DLF) for young children are, as would be expected, larger than adult values at the same point on the frequency spectrum. Second, DLF are inversely related to age (up to approximately 8 years). Third, frequency discrimination for young children may be improved through training. In particular, four hypothesis concerning frequency discrimination in primary age children are suggested (a) DLF prior to frequency discrimination training will show a tendency to decrease as a function of age.
(b) Children trained in frequency discrimination will have significantly smaller DLF in contrast with children who receive no training (c) Frequency discrimination will improve (DLF will decrease) as a function of training and this improvement will result in equivalent DLF for three different age levels (5, 7 and 9 years olds) (d) DLF will continue to decrease as a function of time (decrease as the individual child grows older) and children who have been given training in frequency discrimination will remain superior to children who have not received training. (Soderquist & Moore, 1970).

Andrews and Madeira (1977) assessed pitch discrimination ability in young children. They tested the hypothesis that some tasks used in assessing pitch discrimination ability may instead be assessing children's ability to deal with relational language. Five tasks were given to thirty-six normal children who were equally divided unto 3 age groups, 6 to 6 1/2 years, 7 to 7 1/2 years and 8 to 8 1/2; years. Task 1 involved a training procedure to assess the children's ability to hear the difference in the pitch of two tones, which were an octave apart. A simple motor response was required. Task 2 assessed the children's ability to label these tones as high or low. Task 3 assessed their ability to compare two tones and label the second as higher or lower than the first. Task 4 examined their ability to label as high or low the position of a man on a ladder.

Task 5 examined their ability to compare the positions of two men on two ladders and say whether the second man was higher or lower than the first. Results indicated that children who make pitch discriminations as demonstrated by nearly perfect scores on Task 1 often fail to demonstrate those discriminations on tasks requiring relational language. A comparison of tasks 2 and 3 to tasks 4 and 5 suggests that children in the age range studied are less proficient in applying high - low and higher - lower to pitch than to spatial relations. Here pitch discrimination is assessed with different tasks. Also pitch comparisons are related to spatial comparison for better understanding in children. However, there is no higher age group say 10 or 12 years for comparison of the performance of these children with older group children.

Wier, Jesteadt and Green (1977) studied frequency discrimination as a function of frequency and sensation level. Frequency discrimination was measured for frequencies from 200 to 8000 Hz and for sensation levels from 5 to 80 dB, using pulse sinusoids as stimuli in an adaptive two interval forced choice psychophysical procedure. Stimuli were 500 msec square gated tone bursts with a 500 msec silent interval between observation intervals. After gating, the sinusoids were filtered through a 200 Hz pass band centered on the signal frequency. Stimuli were presented monaurally in low-level broadband noise. Each block of 100 trails started with a stimulus difference well above the anticipated threshold. Two consecutive correct responses led to a decrease in the stimulus difference and one incorrect response led to increase. The mean of the turn-around points were used as the threshold estimate. An analysis of variance indicated significant effects of frequency and sensation levels and of the interaction between frequency and sensation levels. The effect of sensation level was greatest at low frequency and decreased at high frequency being quite small at 8000 Hz. The data are used to evaluate the predictions of current theoretical models. Here, special types of earphones were used. An adaptive two interval forced choice psycho physical procedure was used. However, age range of subjects was not provided and stimuli duration taken was 500 msec. Other stimuli duration was not considered. Frequency discrimination is the prerequisite for the perception of pitch patterns. Therefore, performance on PPST will depend on the individual's ability for frequency discrimination.

(5) ***Ear Differences***

Several studies talk of no ear difference in PPST (Bellis, 1996;Musiek, 1994, Musiek, Baran & Pinheiro, 1990;Musiek & Geurkink, 1982). The only pitch pattern study in which a difference between the two ears reached significance was one in which pattern components alternated randomly between ears. Sequences that began in the right fear were more readily put into the correct temporal order. There was no significant deterioration in performance of normal subjects when pitch patterns were presented with either competing piano music or competing discourse at equal sensation level (SL) in the same or opposite ear Pinhiero, Weidner, Suren and Gaydos (as cited in Pinheiro & Musiek, 1985).

**(6) Age/Maturation**

The effect of age on tests of temporal patterning may be inferred from studies of patients with corpus callosal involvement. (Musiek et.al.,1980). Performance on temporal patterning tasks involving linguistic labeling of non-speech stimuli would not be expected to reach adult values until neuromaturation of the neural structures critical to the task, particularly the corpus callosum is complete.

Based on their outstanding work on the developing brain, Yakovlev and Lecours (as cited in Pinheiro & Musiek, 1985) suggest that myelination of the coipus callosum may not be complete until 10 years of age. The optimal function (organization and synchronization with other neural units from various complex analyses) of these neural developed myelin sheaths may take even longer.

The development of temporal processing abilities appears to follow the course of neuro maturation, with skills improving as a function of age until approximately 12 years of age. In addition, the effect of age upon temporal processing will depend on the task selected and to some degree, on attentional factors (Bellis, 1996).

Normative data was obtained by Bellis and others (1996), using 30 items half lists and collected from 150 listeners ages 7 through adults. Their normative values (two standard deviations below the mean) are as follows;

8 years to 8 years 11 months - 42%

9 years to 9 year 11 months - 63%

10 years to 10 year 11 months - 78%

11 years to 11-year 11 months - 78%

12 years to adults - 80%

These results indicate that the scores improve till age of 10 yrs. However, DLF matures earlier.

Cranford, Thompson and Hoyer (1999) studied brief tone frequency discrimination by children. They investigated maturational changes in children's ability to discriminate the frequency of short duration tone pulses. Frequency difference limens (DLF) were measured for digitally generated 1000 Hz tones with pulse durations of 200, 50 and 20 msec using a two alternative, two - interval, forced choice procedure. Participants were sixteen, 5 year old children, ten children each in age categories of 7,9 and 11 yrs and a control group often young adults. Eleven of the 5 yr old children were unable to learn the experimental task. All children in the three older groups and the adults successfully completed the study. The five, 5 years old children who completed the task performed similarly to the 7 year old children. All groups of participants showed an inverse relationship between duration of the signal and the size of the DL. The DLF at all of three durations were significantly larger for the 7-year-older children and adults. There were no significant differences in DL size among the 9-year-old, 11 years old and adult subjects at any tone duration. These findings suggest that the sensory and/or cognitive skills required to discriminate the frequency of brief duration tones may not reach maturity until after age 7 years. Comparison is done with older group also. Different brief duration was taken. However, only one frequency of 1 kHz was considered.

(7) *Pathology*

Musiek, et. al., (1980) studied auditory pattern perception in split-brain patients. Three right-handed subjects who had complete sections of the corpus callosum were tested on auditory pattern sequencing tasks. Subjects 1 & 2 were tested approximately 10 days after surgery while subject 3 was tested prior to his commissurotemy, 10 days after surgery, and again 1 year later. All subjects had normal pure tone audiometric thresholds (250 Hz to 8 kHz), normal speech recognition thresholds as well as speech discrimination scores in both ears after the commissurotomy. Pitch patterns consisting of 2 different frequencies (1, 122 Hz and 880 Hz). Intensity patterns consisted of soft and loud sounds of 1 kHz tone (differences of 7 dB HL). 30 frequency and 30 intensity patterns were presented at 40 dB HL above the SRT. Subjects were asked to respond both verbally and humming. Post operatively, all 3 subjects exhibited great difficulty in verbally sequencing both intensity and pitch patterns presented to either ear. Right ear verbal performance tended to be poorer than left ear performance. Subject 2 and 3 were able to hum the pitch patterns postoperatively. Subject 2 performed within the normal range for stimuli presented to both ears while subject 3 scored only slightly below normal in both ears. Results indicated that sectioning the corpus callosum dramatically affects the ability to verbally report both intensity and frequency patterns. However, the ability of the subjects to correctly hum frequency patterns was not impaired. In this investigation, detailed testing was done both before and after the surgery for comparison. However only 3 subjects were taken.

Cranford, Stream, Rye and Slade (1982) studied detection versus discrimination of brief duration tones in subjects with temporal lobe damage. Standard audiometric examination involving air conduction, pure tones and speech recognition threshold (SRT) was carried out. Absolute detection threshold and difference limens were found for 1 kHz tones over a range of seven signal durations 500, 200, 100, 50, 20, 10 and 5 msec. Presentation level was 40 dBHL above subject's threshold. Total of 10 subjects with unilateral damage to neocortical substance were tested. Seven subjects sustained damage involving primary auditory receptive zones. (Brodman's areas 41 &42) in the anterior and posterior transverse temporal gyri or Heschl's convolutions, whereas 3 subjects had unilateral damage confined to areas outside the parietotemporal region. Results indicated a similar behavioural dissociation for seven subjects with temporal lobe damage in brief tone tests. All the subjects exhibited normal detection threshold in conjunction with substantially elevated frequency difference lamina. Here, individual detailed case study was carried out. Subjects were divided into 2 groups based on site of lesion. Comparison was made with normal group and repeated testing was done in cases of more than 1 surgery. But subject's physical motor involvement might have affected their responses. u,

Tallal (1980) observed that there were no significant differences between scores of reading disabled and 4 children in which stimuli were presented at slow rates. However, when the stimuli were presented more rapidly, the reading impaired group made significantly more errors than the controls. All subjects' performances were virtually errorless on the same - different discrimination test when the two tones to be discriminated were separated by the relatively long interval. The reading impaired children's ability to use phonics' skill (nonsense word reading) was also examined. There was a high correlation between the number of errors made on the phonics-reading test and the number of errors made in responding to the rapidly present stimuli in the auditory perceptual tests. Here the several subtests included almost all components. This study supports the hypothesis that some reading impairments are related to two level auditory perceptual dysfunction that affects the ability to learn to use phonics skills adequately.

Lowe and Campbell (1965) investigated the ability of eight normal and eight aphasoid children to perform tasks involving judgements of succession and order. Stimulus used was pulse tone. Subjects were matched according to age, were from 7 to 14 years of age. Some aphasoid subjects had possible minimal hearing losses. Each child was presented the succession task first, then the ordering task. All pulses were presented at 50 dBre thresholds established prior to the experiment on normal adults. Time between pulse onsets was varied to determine the minimum time separation necessary for the subject's to place the pulses in their proper order of pitch. In both tasks, a subject's score was the time separation at the 75% level of accuracy with a two alternative, forced choice paradigm. Results showed no statistically significant difference between the aphasoid and normal children on the succession task. Although, some degree of peripheral hearing loss may have existed in the aphasoid group, this result indicates that the effects of such losses were minimal. The order task yielded a significant difference between the two groups at the 0.05 levels. They have compared aphasoid with normal children. Such information would appear to have diagnostic, therapeutic and theoretical value. However, only a few subjects were taken for the study.

The summary of the effects of different lesions on PPST given by Bellis (1996) is given in Table 1.

**Table 1: Effect of lesions of the CANS on Temporal Processing**

| Site of Lesion | Effect(s) on Temporal Processing |
|---|---|
| Right Temporal Lobe | Contralateral deficit in two tone ordering or gap detection, bilateral deficit on temporal patterning tasks involving more than 2 stimuli |
| Left Temporal Lobe | Significant contra lateral and /or bilateral deficits |
| Corpus Callosum | Bilateral deficit on temporal patterning tasks involving more than 2 stimuli. |
| Brainstem | Variable, depending upon site of lesion and type of task. |
| Peripheral | Little effect on temporal patterning performance. |

Normal child does not achieve maturation of the corpus callosum until 10 years of age or older, the LD child may require an even longer period of time for complete myelination. Thus, it seems logical to assume that not all children have similar myelination rates and perhaps those slower in this respect of maturation manifest processing problems related to poor interhemispheric transfer and integration.

Further support for this idea was revealed in a brain autopsy report by Drake (1968). He performed a detailed pathological analysis on the brain of a 12 years old boy with a well documented psycho-educational history of learning disability. Drake found marked thing of the corpus callosum and malformation of the deep gyri of the brain. This type of neuro-pathological condition could be consisted with lack of myelination of the corpus callosum and interhemispheric dysfunction (Musiek, Gollegly & Baran, 1984).

Musiek, et. al., (1984) investigated myelination of the corpus callosum and auditory processing problems in children. Central auditory test results from four individual cases as well as mean data from a group of sixteen LD children have been highlighted. These selected children demonstrate the auditory disconnection profile or ADP. The ADP requires not only normal performance on low-redundancy monotic speech tests, such as LPFs, marked left ear deficits for dichotic speech tasks and bilaterally poor performance on the frequency pattern test by verbal report but also the ability to hum patterns correctly. This profile is commonly observed in adult split brain subjects and implicates the corpus callosum as the anatomical site of dysfunction.

Musiek, et. al., (1984) had proposed the theory that some LD children have poor interhemispheric auditory processing and subsequently demonstrate the ADP. The hypothetical basis for this disrupted interhemispheric function is that the children are delayed in the myelination of the corpus callosum. This theory is supported indirectly by neuropathological, electrophysiological and behavioural data that indicate that myelination of the corpus callosum may not be complete until age 10 years or older. It also is possible that the myelination rate is not the same for all children. Therefore, some children may have delayed myelin development and demonstrate the Auditory Disconnection Profile, which may contribute to their overall learning disability. Hence individual case studies are taken and each detail history is taken. Have derived theory also from their study and based on other related information. Have also explained the concept of ADP. However, only 4 subjects were taken for the study and also the performance of LD children was not compared with that of normal children of that age.

Thus, these are the several factors, which affect the task of temporal processing, of which age is an important factor. Hence, it is essential to study the effects of age on PPST before using it on clinical population.

# METHOD

***Subjects***

A total of ninety subjects were divided into three groups with equal number of subjects in each of these three groups.

| | | | | | | |
|---|---|---|---|---|---|---|
| I | group | - | 9.1 to 10.0 years | - | Thirty children |
| II | group | - | 10.1 to 11.0 years | - | Thirty children |
| III | group | - | 17.1 to 35.0 years | - | Thirty subjects |

Equal numbers of male and female subjects were taken. The subjects selected for the study met the following criteria.

- No known history of hearing loss
- No chronic otologic problem
- No history of neurologic problems or trauma to the brain
- No previous experience with pitch pattern sequencing task
- No difficulty in understanding speech in presence of noise
- Pure tone thresholds less than 15 dB in both ears in the frequency range of 250 Hz-to 8 kHz for air conduction and 250 Hz to 4 kHz for bone conduction.

A checklist was used to rule out any indications of APD. Checklist is given in Appendix A.

**Test Material**

PPST, child version was developed and recorded on a CD at the department of Audiology, All India Institute of Speech and Hearing, Mysore. It consisted of 30 test items and 21 practice items (consisting of 16 two - tone patterns and 5 three-tone patterns). Each test item had pattern of 3 tone bursts of 500 msec duration each, separated by 300 msec intervals between tones. The tone frequencies were 880 Hz (Low) and 1430 Hz (High). The tones were recorded in 6 different combinations (HLH, LHL, HHL, LLH, HLL and LHH). Single sinusoids of 880 Hz and 1430 Hz were recorded on a computer using the software, Sound Generator. Pitch pattern sequences were developed using the software 'Audio lab Version-2'. These sequences were then transferred to a CD using a CD writer.

***Equipment***

A CD R-80, 40 x with PPST recorded on it was used which was played in Philips DVD 729 K DVD/Video CD/CD player. The CD player was connected to GSI-61 clinical audiometer. GSI-Tympstar immitance meter was used for screening subjects to rule out any type of middle ear problems.

***Test Environment***

The testing was carried out in acoustically treated two rooms situation.

***Procedure***

The subjects were made to sit comfortably in the sound treated room with head phones placed on his/her ears. Subjects were trained to discriminate high and low tones with practice trials by demonstrating the humming and verbal tasks. The test items were presented through the audiometer using external input from DVD player with a patch cord connecting it to the audiometer. The audiometer was calibrated according to the ANSI, 1996 Standards (as cited in Wilber, 1994).

Initially the calibration tone was presented to the subject's ear through TDH 50-P earphones and the V-U meter was adjusted to show "0" reading. Each ear was tested under headphones at 40 dB SL (Ref. 1 kHz threshold) with 30, 3 -tone patterns presented to each ear separately. Two types of responses were taken. Subjects were asked to respond by humming when stimuli were presented once, and then verbally for next presentation. Half of the subjects were tested for humming responses first and another half for verbal responses. The test was administered twice and the order was randomized. The responses were recorded and total numbers of correct responses were calculated. Score of 1 was given for each correctly repeated pattern and 0 was given for incorrect responses. Reversals were considered as errors. Both humming and verbal responses were scored for each ear separately. Mean and standard deviation was calculated for each of the different groups and t-test was administered to find the relationship between different variables.

# RESULTS

The data obtained was analyzed using different statistical procedures. These included mean, and the standard deviation (S.D). Paired t -test (Garrett and Woodworth, 1979) was used to check the significance of difference between the various parameters analyzed. Table 2 gives the mean, range, S.D. and percentage values across different age groups for the 2 types of response.

**Table 2 - Performance of different age groups for humming and verbal responses**

| Age | Response | Mean and Percentage | Range | S.D. |
|---|---|---|---|---|
| 9 years | Humming (n=60) | 23.38 (77.94%) | 12-30 | 5.21 |
| | Verbal (n=60) | 12.58 (41.94%) | 2-29 | 6.93 |
| 10 years | Humming (n=60) | 23.75 (79.16%) | 10-30 | 6.13 |
| | Verbal (n=60) | 15.32 (51.05%) | 0-30 | 9.32 |
| Adults | Humming (n=60) | 27.23 (92.27%) | 20-30 | 3.81 |
| | Verbal (n=60) | 27.77 (92.55%) | 17-30 | 2.85 |

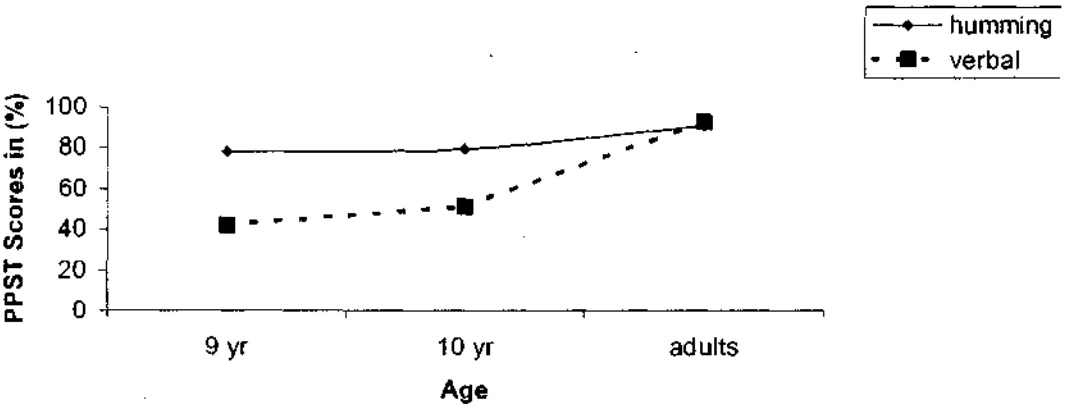


**Fig.1 Maturation of scores across age**

Totally ninety-eight subjects were taken. Eight children did very poor for humming and verbal tasks and hence were not included for analysis. So, statistical analysis was carried out for 90 subjects. As seen from table 2 and figure-1, scores improved with increase in age. Humming scores were better than verbal scores for children i.e., 9 yrs and 10 yrs whereas for adults scores were almost similar. One child obtained verbal better than humming, however, one adult subject could not hum at all and 3 other subjects did very poor for humming task. The difference between humming and verbal scores was high for 9 yrs and 10 yrs old children whereas for adults the difference was negligible. Range of scores was wider for verbal responses when compared to humming responses, for all the age groups, indicating greater degree of variation for verbal than humming response. Score of humming responses for 9 yrs and 10 yrs subjects were almost similar whereas for adults, score was higher. Score of verbal response showed an increasing trend with increase in age, the difference being less between 9 yrs and 10 yrs. children whereas more for adults. Also, there was more variation or scatter of scores in 9 yrs and 10 yrs old children as compared to adults.

Paired t-test was carried out further, to study the effect of different parameters in each age group as well as between different age groups.

**I. *Results of Adults:***

Analysis was carried out to check gender, ear and response mode on the performance of the subjects.

**Table 3: Effect of gender and types of response on the scores for adults**

| Parameters Compared | | | Mean | SD | t-value | Significance |
|---|---|---|---|---|---|---|
| Gender and type of response | Male | Humming (n=30) | 27 97 | 1906 | 0.264 | Non Significant |
| | | x Verbal (n=30) | 27 83 | 2 911 | | |
| | Female | Humming (n=30) | 274 | 2.361 | 0 585 | Non Significant |
| | | Verbal (n=30) | 277 | 2.807 | | |
| Type of response and gender | Humming | Male (n=30) | 27 97 | 1.906 | 1.323 | Non Significant |
| | | Female (n=30) | 27.4 | 2 361 | | |
| | Verbal | Male (n=30) | 27 83 | 2 911 | 0 253 | Non Significant |
| | | Female (n=30) | 277 | 2.807 | | |

As seen from Table 3, there was statistically no significant difference between humming and verbal scores for both males and for females. The SD values or the variation was more for verbal responses than for humming responses. The mean scores were slightly higher for males as compared to females. The SD values or the variation was more for females than for males for humming responses. However the difference was not statistically significant for humming as well as verbal responses.

Table 4 shows that there was statistically no significant difference between humming and verbal scores for right as well as for left ear. Also, there was statistically no significant difference between right and left ears scores for humming as well as verbal responses. The mean scores for right and left ears were almost similar, left ear score was slightly better than right for humming response and right ear score was slightly better than left for verbal response. The SD values were almost similar though it was little higher for verbal responses of left ear.

**Table 4: Effect of ear and type for responses on the scores for adults**

| Parameters Compared | | | Mean | SD | t-value | Significance |
|---|---|---|---|---|---|---|
| Ear and type of response | Right | Humming (n=30) | 27.5 | 2.277 | 1.462 | Non Significant |
| | | Verbal (n=30) | 28.13 | 2.363 | | |
| | Left | Humming (n=30) | 27.87 | 2.029 | 0.794 | Non Significant |
| | | Verbal (n=30) | 27.4 | 3.241 | | |
| Type of response and ear | Humming | Right (n=30) | 27.5 | 2.277 | 1.0 | Non Significant |
| | | Left (n=30) | 27.87 | 2.029 | | |
| | Verbal | Right (n=30) | 28.13 | 2.363 | 1.233 | Non Significant |
| | | Left (n=30) | 27.4 | 3.241 | | |

**II.** ***Results Of Children**:*

Analysis was carried out to check gender, ear and response mode on the performance of the subjects.

**Table 5: Effect of age, gender and type of response on the scores obtained in children**

| Parameters Compared | | | Mean | SD | t-value | Significance |
|---|---|---|---|---|---|---|
| Age and type of response | 9 yrs | Humming (n=60) | 23.383 | 5.212 | 9.651 | 0.01 |
| | | Verbal (n=60) | 12.583 | 6.926 | | |
| | 10yrs | Humming (n=60) | 23.75 | 6.128 | 5.9 | 0.01 |
| | | Verbal (n=60) | 15.316 | 9.316 | | |
| Type of response and age | Humming | 9 yrs (n=60) | 23.383 | 5.212 | 0.353 | Non Significant |
| | | 10 yrs (n=60) | 23.75 | 6.128 | | |
| | Verbal | 9 yrs (n=60) | 12.583 | 6.926 | 2.274 | 0.05 |
| | | 10 yrs (n=60) | 15.316 | 9.316 | | |
| Gender and Type of response | Male | Humming (n=60) | 23 | 5.468 | 7.082 | 0.01 |
| | | Verbal (n=60) | 14.75 | 9.022 | | |
| | Female | Humming (n=60) | 24.133 | 5.852 | 11.381 | 0.01 |
| | | Verbal (n=60) | 13.15 | 7.472 | | |
| Type of response and gender | Humming | Male (n=60) | 23 | 5.468 | 1.605 | Non Significant |
| | | Female (n=60) | 24.133 | 5.852 | | |
| | Verbal | Male (n=60) | 14.75 | 9.022 | 1.658 | Non Significant |
| | | Female (n=60) | 13.15 | 7.472 | | |

It is evident from Table 5 that statistically significant difference was obtained between humming and verbal scores of both 9 year and 10-year-old groups. This was true for males as well as for females. Humming scores were higher than verbal scores. However, the SD values were more for verbal than humming responses. Statistically there was no significant difference between scores of 9 year and 10 year olds for humming response though the scores for 10-year-old children were slightly better than that of 9-year-old children. But there was statistically significant difference (0.01) between scores of 9 year and 10 year olds for verbal response. There was no significant difference between scores of males and females for humming as well as for verbal responses. The mean values were almost similar but the SD variation was more in male when compared to females for verbal responses.

Inspection of Table 6 reveals that there was statistically significant difference between humming and verbal scores of both the ears for 9 yrs as well as 10 yrs children similar to that observed for adults. Humming scores were better for left ear in both age groups whereas verbal scores were better for right ear for 9 yrs but not so for 10 yrs. There was statistically no significant difference between right and left ear scores for humming and verbal response in 9 yr as well as 10 yr old children. The SD value was more for verbal than humming response, higher for 10 yr than that for 9 yr old children.

**Table 6: Effect of age, ear and type of response on the scores obtained in children**

| Parameters Compared | | | Mean | SD | t-value | Significance |
|---|---|---|---|---|---|---|
| Age across ear and type of response | 9yrs Right | Humming (n=30) | 22.73 | 5.183 | 7.252 | 0.01 |
| | | Verbal (n=30) | 12.7 | 7.573 | | |
| | Left | Humming (n-30) | 24.03 | 5.161 | 10.197 | 0.01 |
| | | Verbal (n=30) | 12.467 | 6.211 | | |
| | l0yrs Right | Humming (n=30) | 23.73 | 6.016 | 4.994 | 0.01 |
| | | Verbal (n=30) | 15.17 | 9.39 | | |
| | Left | Humming (n=30) | 23.77 | 6.238 | 4.923 | 0.01 |
| | | Verbal (n=30) | 15.47 | 9.233 | | |
| Age across type of response and ear | 9yrs Humming | Right (n-30) | 22.73 | 5.183 | 1.380 | Non Significant |
| | | Left (n=30) | 24.03 | 5.161 | | |
| | Verbal | Right (n=30) | 12.7 | 7.573 | 0.205 | Non Significant |
| | | Left (n=30) | 12.467 | 6.211 | | |
| | lOyrs Humming | Right (n=30) | 23.73 | 6.016 | 0.035 | Non Significant |
| | | Left (n=30) | 23.77 | 6.238 | | |
| | Verbal | Right (n=30) | 15.17 | 9.39 | 0.178 | Non significant » |
| | | Left (n=30) | 15.47 | 9.233 | | |

**III.** ***Comparison between children and Adults***

In this section, comparison is made of effect of age, gender and response mode on performances in children and adults.

**Table 7: Effect of type of response and age on the scores obtained in children and adults**

<table>
<tr><th colspan="3">Parameters Compared</th><th>Mean</th><th>SD</th><th>t-value</th><th>Significance</th></tr>
<tr><td rowspan="4">Type of response and age</td><td rowspan="2">Humming</td><td>9yrs (n=60)</td><td>23.38</td><td>5.212</td><td rowspan="2">7.825</td><td rowspan="2">0.01</td></tr>
<tr><td>Adults (n=60)</td><td>27.23</td><td>3.814</td></tr>
<tr><td rowspan="2">Verbal</td><td>9yrs (n=60)</td><td>12.58</td><td>6.926</td><td rowspan="2">41.389</td><td rowspan="2">0.01</td></tr>
<tr><td>Adults (n=60)</td><td>27.77</td><td>2.850</td></tr>
<tr><td rowspan="4">Type of response and age</td><td rowspan="2">Humming</td><td>l0yrs (n=60)</td><td>23.75</td><td>6.128</td><td rowspan="2">7.073</td><td rowspan="2">0.01</td></tr>
<tr><td>Adults (n=60)</td><td>27.23</td><td>3.814</td></tr>
<tr><td rowspan="2">Verbal</td><td>l0yrs (n=60)</td><td>15.316</td><td>9.316</td><td rowspan="2">33.935</td><td rowspan="2">0.01</td></tr>
<tr><td>Adults (n=60)</td><td>27,77</td><td>2.850</td></tr>
</table>

A glance at Table 7 shows that there was statistically significant difference between scores of 9 yr old children and adult for both humming as well as verbal responses. Similarly, statistically significant difference was seen between scores of 10 yr old and adults for humming and verbal response. Adults' scores were higher than that of 9 yr and 10 yr old children, the difference in scores being more for verbal than humming responses. The variation in scores was more for verbal than humming responses, higher for 9 yr and 10 yr old children as compared to that of adults.

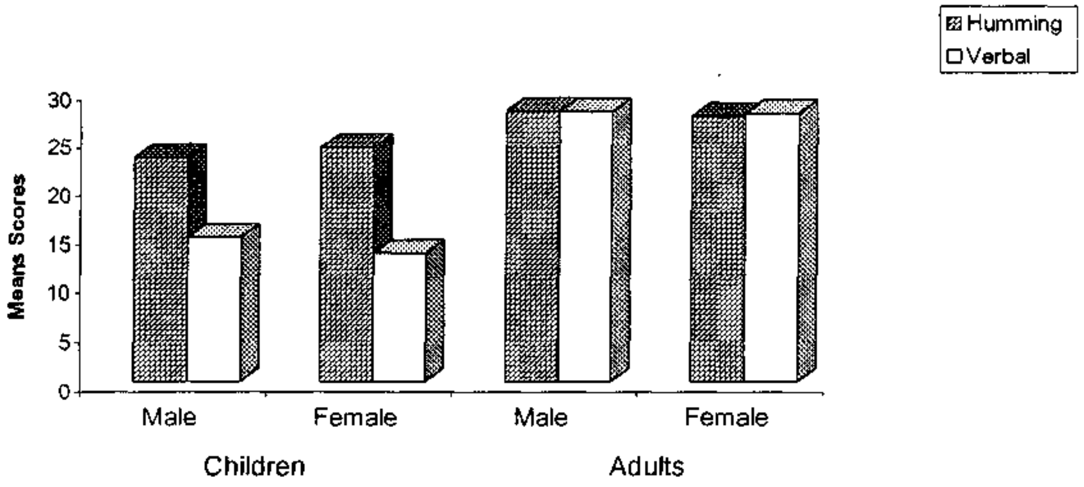


**Fig.2 Effect of gender on scores of PPST in children and adults**

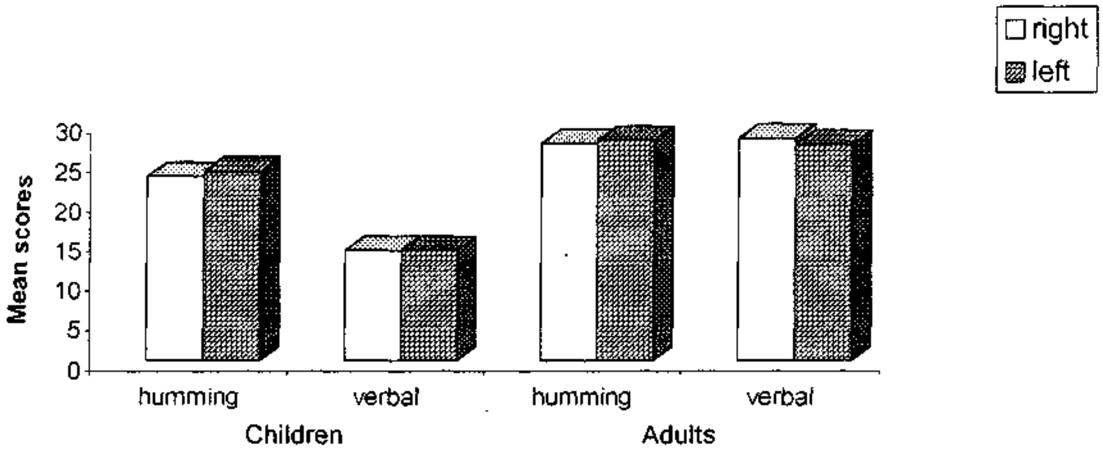


**Fig.3 Effect of Mode of respone on scores of PPST in children and adults**

As shown in figure 2, there was statistically significant difference obtained between humming and verbal responses of both the ears for both males and for females in children but not in adults. Comparison of mean values in boys and girls showed that humming response was higher in girls whereas mean value for verbal response was higher in boys. Whereas in adults, both the mean values for verbal and humming responses was higher in males than females. Variations were seen more for children than adults, more for verbal than for humming response. It is evident from figure 3; there was no statistically significant difference between scores of right and left ear for humming as well as for verbal responses both for children and adults. However, the mean values for left ear slightly better than right ears for humming and verbal response for both children as well as adult subjects. Variations were again more in children than adults more for verbal than for humming response.

# DISCUSSION

The results showed significant difference in scores from one age group to another. The scores matured with increasing age. It was reflected in both humming as well as verbal responses. This supports the theory of maturation and myelination. The development of temporal processing abilities appears to follow the course of neuromaturation with skills improving as a function of age until approximately 12 years of age(Bellis, 1996).

The results also showed significant difference between humming and verbal scores of children, which indicates that humming responses were better than verbal responses. It supports the fact that the temporal sequencing of auditory patterns require processing by both hemispheres of the brain, i.e., the left hemisphere for the serial ordering of the response and right hemisphere for the recognition of the pattern Gestalt, since the right hemisphere has been found to be dominant for pattern recognition (Nebes, 1971). Hence the interaction of the two hemispheres and role of corpus callosum is important for this interaction.

A significant difference between humming and verbal responses for males as well as females subjects was observed for both ears. This was true with both age groups of children i.e., 9 year and 10 year whereas for adult group there was no significant difference between humming and verbal responses for any of the conditions. There was also no significant difference obtained between scores of 9 years and 10 year olds for humming responses even though the mean for 10 year subjects was slightly higher than 9 year subjects. However, there was a significant difference between scores of 9 year and 10 year olds for verbal responses. This again supports the fact that maturation of corpus callosum is important for verbal responses. The results of the present study indicate that the maturation of corpus callosum and myelination is complete in adults and thus they obtain almost equal scores on humming and verbal responses.

Table 9 gives a comparison of results obtained in present study with that of results obtained in the previous study. Since the variation in score was very high for 9 yr and 10 yr old children, the data of subjects who scored less than 10 were deleted and mean and S.D. was recalculated. One of the reasons for the discrepancy in results could be attributed to scoring of the results. Pinheiro (as cited in Musiek, Geurkink & Kietel, 1982) does not consider reversals e.g., (low-high-low for high-low-high) as errors. In the present study, such reversals were also considered as errors, as suggested by Musiek, Geurkink and Kietel, 1982. However, a lot of reversals were observed in children. This could have resulted in much lower scores in 9 yr and 10 yr olds. It is not known whether Bellis, 1996 considers reversals as errors or not. The sensitivity and specificity of PPST has to be checked for both the criteria of scoring (with and without reversals as errors).

Norms obtained for adults in this present study are in agreement with the findings of earlier investigations (Musiek, 1994; Bellis, 1996 & Pinheiro, 1980). However, the norms (lower cut off scores) obtained for 9 yr and 10 yr old children in the present study are much lower than that reported in earlier studies.

**Table 8: Comparison of the scores of the present study with that of the earlier studies.**

| Author | Low Cut Off Scores | | |
|---|---|---|---|
| | 9 years | 10 years | Adult |
| Pinheiro(1980) | 79% (verbal) | 79% (verbal) | Not available |
| Musiek(1994) | Not available | Not available | 78% (Verbal) |
| Bellis (1996) | 63% (Verbal) | 78% (verbal) | 80% (verbal) |
| Present study (2003) | 43.20% (Hum)<br>n=60<br>24.73 % (Verbal)<br>n=35 | 50.5 % (Hum)<br>n=54<br>26.26% (Verbal)<br>n=36 | 77.85% (Hum)<br>n=60<br>73.49% (Verbal)<br>n=60 |

The results also indicated the difference in mean values for verbal responses are much more than that for humming responses for all the age groups. This again supports the neuromaturation theory and the myelination of corpus callosum. This may be due to the reason that corpus callosum does not play any role for obtaining humming responses but plays a significantly important role in obtaining verbal responses and thus the scores for verbal response mature with maturation of corpus callosum.

The results indicated no statistically significant difference between right and left ear scores for all the three age groups. This finding is in agreement with the study by Bellis (1996). Similar findings have also been reported by other investigations (Musiek, 1994, Musiek, Baran & Pinheiro, 1990;Musiek & Geurkink, 1982). The only pitch pattern study in which a difference between two ears reached significance was one in which pattern components alternated randomly between ears. Sequences that began in the right ear were more readily put into the correct temporal order (Pinheiro & Tinta, as cited in Pinheiro & Musiek, 1985). There was no significant difference between scores of males and females for humming as well as verbal response.

Thus, the results of the present study revealed that the scores improve with increase in age. Humming scores were better than verbal scores for children whereas for adults humming and verbal scores were almost similar. There were no ear or gender differences found in the study.

## SUMMARY AND CONCLUSIONS

Pitch pattern sequence test (PPST) is one of the tests to assess temporal processing. It detects pattern perception as well as temporal sequencing abilities. It provides information regarding neuromaturation in children by indicating the degree of myelination of the corpus callosum. It also helps in identification of lesion at peripheral, brainstem and temporal lobe levels. Both procedural as well as subject related factors affect the results of PPST. However, information of laterality or localization of lesion is not obtained from this test.

There are only a few studies on maturational changes in pitch pattern in children. Temporal processing of auditory patterns matures till 12 years of age (Bellis, 1996) and requires processing by both hemispheres. Also it is known that corpus callosum is the last part of the central nervous system to mature. Hence, there is a need to see the effect of neuromaturation on the various types of responses obtained for PPST. This study was aimed to study the effect of age on results of PPST and to compare scores of humming and verbal responses for PPST in children and adults. This study also aimed to study gender difference and ear effects in PPST.

In this study, data was collected from ninety subjects, thirty subjects each in 9 year, 10 year and adult age group. Thirty test items, three tones burst of frequencies 880 Hz (Low) and 1430 Hz (High) were recorded on a CD with 500 msec duration for each tone burst, separated by 300 msec intervals between tones. These items were recorded in 6 different combinations (HLH, LHL, HHL, LLH, HLL and LHH) and were presented through the headphones of audiometer using external input from CD player. Each ear was tested separately at 40 dBSL (reference 1 kHz threshold). Subjects were tested for verbal response as well as humming response and were scored separately. The data was statistically analyzed (mean, standard deviation, percentage and t-test was administered) and the following results were obtained:

- There was significant effect of age on scores of PPST for both humming and verbal responses.
- There was significant difference between humming and verbal scores in children irrespective of gender or ear.
- There was no significant difference between humming and verbal scores in adults.
- There was no significant difference between scores of the two ears for any of the age groups.
- There was no significant difference between scores of male and female in any of the age groups.

The trend of maturation and increase in scores with age observed in this study were similar to that of the previous studies.

***Implications of the Study***

1. This study provides the normative data for PPST, which can then be used for clinical population.
2. It also provides information regarding the neuromaturation of temporal processes in normal children.

***Suggestions for Further Research***

- Studies can be done for other age groups after 10 years to see the ceiling age for maturational effect.
- Studies comparing the score of adults with children by using adult and child version of the test can be carried out.
- Investigations can also be done to study the factors that affect the results/ scores in the PPST.
- Further studies can be done by changing the criteria of scoring.

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# APPENDIX - A

## CHECKLIST FOR SCREENING AUDITORY PROCESSING DISORDER

Place a check **mark** before each **item that** is considered **to** be **a** concern by you.

1. Has short attention span.
2. Easily distracted by background sounds.
3. Problems with sound discrimination.
4. Trouble in recalling any sequence heard.
5. Forgets what is said in a few minutes.
6. Misunderstands verbal instructions.
7. Takes long time to answer questions regarding familiar concepts.
8. Performance is below age in one or more subjects.
9. Problems in understanding when somebody speaks fast.
10. Reverses numbers, words, tones etc.