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# Performance of Typically Developing Children on Duration Pattern Test

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## Abstract

**Introduction:** Temporal patterning is one of the important aspects in auditory processing and it not only tells us about one's ability to sequence auditory events in the correct order by retaining them but based on the mode of response can give substantial information regarding the processing at the interhemispheric level. It has major implications in terms of auditory sequencing; perception of prosodic as well as musical aspects.

**Aim:** This study aims at assessing temporal patterning abilities in typically developing children using Duration Pattern Test (DPT).

**Methods:** DPT was administered on 150 normal hearing children (chronological age 6 years to 11 years) under headphones (closed field) and sound field conditions using verbal mode of response. Scores were calculated in percentage under each condition and for each ear separately.

**Results and Discussion:** Results showed an improvement in the performance of normal hearing children as a function of age. Also, a significant right ear advantage was observed. However, no significant difference was seen between headphones and sound field conditions.

**Conclusion:** Neuro-maturation along with other higher order factors significantly affect temporal patterning abilities of typically developing children with evident right ear advantage/left hemisphere dominance.

**Aim and Objectives:** This study aimed at assessing temporal patterning abilities in 6 years to 11-years-old typically developing children using Duration Pattern Test (DPT) in order to analyze the effect of age, ear and listening condition (under headphones *vs.* sound field condition).

**Keywords: Temporal patterning; Duration Pattern Test (DPT); Normal hearing; Neuro-maturation**

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## Introduction

The ASHA task force on Central Auditory Processing (ASHA) defined Central Auditory Processing as the auditory system mechanisms and processes responsible for the following behavioral 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 with competing acoustic signals; auditory performance with degraded acoustic signals [1].

Temporal processing is one of the central auditory processes that are required even for simple everyday listening tasks, speech perception and even music perception [2]. CAPD and temporal processing has been extensively studied. Bellis et al. [3] explained deficits in temporal processing as prosodic deficits where difficulty in perceiving and recognizing nonverbal information such as tonal patterns is observed. Temporal processing deficits involves deficits in any of its aspects such as temporal resolution which is the shortest duration of time in which an individual can discriminate between two auditory signals; temporal integration that results from the summation or aggregation of neuronal activity as a function of the additional duration of sound energy [4]. Another aspect in temporal processing is temporal masking that occurs when the threshold of one sound shifts due to the presence of another sound which precedes or follows it. Each of these temporal processes assesses different aspects such as auditory discrimination and identification in the presence of noise, prosodic aspects etc. However, except for temporal patterning none of the above-mentioned processes are required for interhemispheric connections.

Children with temporal patterning deficits exhibit difficulty in extracting key words from a spoken message. They could be flat or monotonous readers and sequencing of elements within a message or individual speech sounds within a word could be an issue. This critical role of temporal patterning abilities in speech perception has made it a highly investigated phenomenon in terms of clinical practice [5-8].

Performance on temporal patterning tasks involving linguistic labeling of non-speech stimuli would not be expected to reach adult values until neuro-maturation of the relevant neural structures, especially the corpus callosum is complete. This was supported by Musiek et al. [9-13] and colleagues in a series of experiments studying the effects of surgical sectioning of corpus callosum on frequency pattern test in both the linguistic labeling and humming conditions. Following the surgical sectioning, the linguistic labeling of the tonal patterns was affected; however, their ability to hum or sing the patterns was intact. Berwanger et al. [14] found out that children younger than 7 years had difficulties performing the task of temporal ordering successfully.

Several clinical tests are available; however, are not incorporated as a part of the clinical protocol. The most widely used clinical tests of temporal ordering are the Frequency Pattern Test (FPT) and Duration Pattern Test (DPT) [15]. The Frequency Pattern Test (Pitch Pattern Test) (FPT/PPT) was initially designed to investigate both pattern perception and temporal sequencing abilities [16,17]. It detects disorders of the cerebral hemispheres although laterality information cannot be obtained [13,18,19]. It may provide information regarding the neuro-maturation in the child with learning disability by indicating the degree of myelination of the corpus callosum [20]. It has been established as an excellent tool to use with young children, ages 8 years and older [21]. The DPT appears to be sensitive to cerebral lesions while remaining unaffected by peripheral hearing loss as long as the stimuli are presented at a frequency and intensity that can be perceived by the listener [22]. The DPT assesses the processes of duration discrimination, temporal ordering and linguistic labeling. Mean performance of normal-hearing young adults for both tests (FPT and DPT) was approximately 90 percent with no effect of the presentation levels that was used [21]. Therefore, the commercially available disc versions of these tests provide a highly feasible and accurate measure of temporal patterning and can be successfully administered as well.

A systematic review of literature by Delecrode et al. [23] in Brazil described the development of temporal processing aspects and the clinical use. These developments in Brazil were found to be recent, yet a remarkable increase in publications was seen over the last few years due to its clinical relevance and its role in speech perception. The present study involves assessing temporal patterning of typically developing children in under headphones and sound field conditions using DPT. Temporal patterning represents ability to sequence auditory events in the correct order by retaining them and mode of response gives substantial information regarding the processing at the inter hemispheric level. These deficits can be present even in children with normal hearing and no speech or language delay yet experience some academic difficulties or impaired auditory comprehension and hence could be missed very easily. Temporal patterning unlike other temporal aspects involves more than one process at a time with multiple implications in speech perception due to its role in discrimination and identification of prosodic aspects that may or may not be attributed to any hearing loss.

## Materials and Methods

The current study was a survey design with purposive sampling.

### Tool

The tool used for this study was the Duration Pattern Test which included recorded tracks of 37 practice items followed by 30 test items [24]. Each test item consists of a pattern of 1 kHz long and short tones which are 500 msec and 250 msec in duration respectively with an inter-tone interval of 300 msec. Each of these patterns is a combination of three long and short tones. There are 6 possible combinations namely- Long, Long, Short (LLS), LSS, LSL, SSL, SLS, SLL. This test was administered monaurally; at 50 dB SL of PTA in both closed field as well as sound field. The CD version of the test was used for the study.

### Participants

Children in the age range 6 years to 11 years with normal motor and speech milestones; normal otoscopic findings with no history of middle ear infection; pure tone thresholds of ≤ 20 dB HL at frequencies 250 Hz to 8 kHz in both ears; pass on Screening Checklist for Auditory Processing (SCAP); no associated impairments of any type such as mental sub-normality, visual impairment, developmental delay, neuro-motor disabilities, attention deficit hyperactivity disorder and pervasive developmental disorders; both boys and girls were included as participants for the study [25]. A total of 150 children with 30 participants in each of the five sub-groups or age groups (6 years ± 7 years, 7 years ± 8 years, 8 ± 9 years, 9 years ± 10 years and 10 years ± 11 years) were included. The details of the participants are shown in Table 1.

### Instrumentation

Otoscope (Welsh Allyn); GSI 38 immitance audiometer; GSI 61 Audiometer connected to speakers; TDH 39 Supra-aural headphones, connecting cord; Laptop and CD version of DPT [24].

### Preliminary examination

Informed parent consent was obtained and detailed case history was taken. All participants went through a preliminary evaluation followed by administration of DPT. SCAP screening was done prior to this preliminary evaluation and all children passing this screening were taken up for the preliminary audiological evaluation.

SCAP (Screening Checklist for Auditory Processing) in children was developed by Yathiraj et al. [26]. It was designed to be administered by a class teacher. It has 12 questions that tap different aspects of auditory processing such as auditory separation/closure, auditory memory, and auditory attention. It is scored on a 2-point rating scale and children who obtain more than the 50% score (a score ≥ 6) are considered at risk for auditory processing deficits. A modified version of this checklist called SCAP- A was developed by Vaidyanath et al. [27] as a tool to screen adults.

A total of 167 children were recruited for the study of which 10 referred on the SCAP screening; so, 157 underwent preliminary evaluation. The preliminary stage of evaluation included an Otoscopic examination using a hand-held Welch Allyn otoscope in order to check for any external ear abnormalities like excessive wax or foreign bodies; tympanic membrane perforation or ear discharge. Following this pure tone audiometry was conducted for the participants in a sound treated room with ambient noise levels within permissible limits according to ANSI standards (ANSI S3.6/ISO 389) [28]. Air

**Table 1:** Details of participants.

| Age group | Mean age (y &m) | Number | Gender | |
|---|---|---|---|---|
| | | | M | F |
| **6+ to 7 years** | 6.46 (6 years 6 months) | 30 | 13 | 17 |
| **7+ to 8 years** | 7.57 (7 years 6 months) | 30 | 16 | 14 |
| **8+ to 9 years** | 8.42 (8 years 5 months) | 30 | 18 | 12 |
| **9+ to10 years** | 9.6 (9 years 8 months) | 30 | 20 | 10 |
| **10+ to 11 years** | 10.64 (10 years 7 months) | 30 | 20 | 10 |

conduction thresholds were determined using GSI 61 audiometer with calibrated TDH 39 earphones (ANSI S3.6/ISO 389) at octave frequencies from 250 Hz to 8 Hz using the modified Hughson Westlake procedure [28]. Immitance audiometry was performed to ensure normal middle ear functioning using GSI 38 immitance audiometer calibrated as per ANSI S3.6/ISO389 [28]. Tympanometry was done to determine the static acoustic admittance and ear canal volume. Reflexometry was done at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz to ensure the presence of ipsilateral and contralateral acoustic reflexes. Of the 157 children, 7 children failed the preliminary evaluation and hence 150 children were eventually included in the actual administration of DPT and for analysis of the same.

### Administration of the duration pattern test

Since participants were young children, the concept of long and short tones was explained to them and then they were instructed to identify each pattern of three tones by saying it aloud e.g. LLS (Long, Long, and Short). The test was administered in a sound treated, two room set up where the laptop was connected to the GSI 61 audiometer using a connecting cord and the output was routed through the headphones and/or speakers. The presentation level was set both on the laptop and the audiometer. The laptop volume was set to 50% of the total volume and on the audiometer the level was set to 50 dB SL of the pure tone average obtained in both the ears during preliminary testing. After instructing the subject and before administering the actual test, a practice session including 5 items of three tone pattern was given to ensure that the participants have understood the task properly.

DPT was administered in two conditions-under headphones and sound field. While using headphones, the laptop was connected to the audiometer and the output was routed through the headphones. In sound field condition, the output was routed through the speaker. The speaker was placed at an azimuth of 0° with the subject, i.e. the subject was exactly in front of the speaker. Randomization of the ear was done while testing in headphone and sound field conditions i.e. the order of administering the test in right ear, left ear and sound field was randomized to avoid the bias. The 30 items were administered in right and left ear each as well as in the sound field condition.

The actual test included 30 test items with gaps recorded in between arranged randomly thereby giving enough time for the participant to listen to the pattern and identify it. While administering the test, after every test item, enough time was given to the participant to identify the pattern. The total time taken for the entire procedure was approximately 45 min to 1 h per participant. If the participant identified the pattern correctly, then a score of 1 was given, an incorrect response was given a score of 0. Since 30 items were administered, a maximum score of 30 could be obtained for each ear and for the sound field testing. Once the total score was obtained, percentage of correct responses was calculated for both listening conditions.

### Statistical analysis

Descriptive statistics (Mean, Standard Deviation (S.D), Standard Error (S.E), maximum and minimum) were obtained for each of the subgroups. Statistical analysis was done using one-way ANOVA followed by Post Hoc analysis using the Multiple Comparisons Bonferroni test to analyze the effect of age. Paired t test was done to analyze the right ear advantage by comparing the scores in each ear.

## Results and Discussion

### Analysis of scores obtained in the under headphones and sound field condition

Table 2-4 show analysis of scores obtained using headphones for right ear, left ear and in the sound field condition respectively.

Figure 1 shows the minimum scores (31.05%) and maximum score (74.99%) obtained for children in the age group of 6 to 7 year and 10 to 11 years for the right ear; minimum scores (27.16%) and maximum scores (69.77%) for the left ear and minimum scores (32.10%) and maximum scores (70.99%) obtained in sound field. A major increase in the scores was observed from 6 to 9 years, however beyond 9 years, scores have continued to increase but with a reduced margin.

**Table 2:** Descriptive statistics for scores obtained in the right ear.

| Age Group (Years) | Mean Score % | Mean Score | S. D | S. E | Maximum | Minimum |
|---|---|---|---|---|---|---|
| **6+ to 7** | 31.05 | 0.3105 | 0.149 | 0.02 | 0.83 | 0.1 |
| **7+ to 8** | 43.44 | 0.4344 | 0.147 | 0.02 | 0.73 | 0.16 |
| **8+ to 9** | 55.77 | 0.5577 | 0.211 | 0.03 | 0.93 | 0.23 |
| **9+ to 10** | 63.55 | 0.6355 | 0.202 | 0.03 | 1 | 0.33 |
| **10+ to 11** | 74.99 | 0.7499 | 0.183 | 0.03 | 1 | 0.36 |

**Table 3:** Descriptive statistics for scores obtained in the left ear.

| Age Group (Years) | Mean Score % | Mean Score | S. D | S. E | Maximum | Minimum |
|---|---|---|---|---|---|---|
| **6+ to 7** | 27.16 | 0.2716 | 0.132 | 0.02 | 0.7 | 0.1 |
| **7+ to 8** | 41.33 | 0.4133 | 0.135 | 0.02 | 0.73 | 0.23 |
| **8+ to9** | 47.66 | 0.4766 | 0.207 | 0.03 | 0.83 | 0.16 |
| **9+ to 10** | 58.99 | 0.5899 | 0.218 | 0.03 | 0.96 | 0.23 |
| **10+ to 11** | 69.77 | 0.6977 | 0.221 | 0.04 | 1 | 0.2 |

**Table 4:** Descriptive statistics for scores obtained in the sound field condition.

| Age Group (Years) | Mean Score % | Mean Score % | S. D | S. E | Maximum | Minimum |
|---|---|---|---|---|---|---|
| **6+ to 7** | 32.1 | 0.321 | 0.153 | 0.02 | 0.8 | 0.1 |
| **7+ to 8** | 45.43 | 0.4543 | 0.152 | 0.02 | 0.76 | 0.16 |
| **8+ to 9** | 53.66 | 0.5366 | 0.214 | 0.03 | 0.93 | 0.16 |
| **9+ to10** | 65.77 | 0.6577 | 0.207 | 0.03 | 1 | 0.3 |
| **10+ to 11** | 70.99 | 0.7099 | 0.221 | 0.04 | 1 | 0.36 |

**Table 5:** Result of paired t test for comparison of right ear *vs.* left ear scores.

| SUBGROUPS | Mean Difference | Obtained p Value | Level of Significance | Statistically Significant or not |
|---|---|---|---|---|
| **6+ to 7** | 0.038 | 0.027 | p=0.05 | YES |
| **7+ to 8** | 0.021 | 0.263 | p=0.05 | NO |
| **8+ to 9** | 0.081 | 0 | p=0.05 | YES |
| **9+ to 10** | 0.045 | 0.025 | p=0.05 | YES |
| **10+ to 11** | 0.052 | 0.004 | p=0.05 | YES |

An evident and consistent increase in the mean scores was seen as the age increases from 6 to 11 years, indicating that the performance on DPT i.e. temporal patterning abilities improve as a function of age for children with normal hearing. This is in agreement with results obtained by Bellis [3] in listeners ranging from 7 to 11 years in which cut offs for DPT were 7% to 10% lower than those for frequency pattern test and these cut offs were consistently found to increase as a function of age. Higher order functions like binaural auditory integration abilities, temporal processing and sequencing abilities are influenced by age especially in children ranging from 6 to 10 years. Different auditory processes develop at different rates and hence the corresponding areas performing those cognitive functions develop in accordance [29].

Neuro-maturation plays a significant role in development of auditory processing abilities in young children up to an age of 12 years in which an evident increase in their performance on auditory processing abilities is seen and these abilities then tend to stabilize after this age achieving a plateau [24,30-32]. This is in agreement with the results obtained by Stollman et al. [33] who studied the development of auditory processing in young children of ages 6 years, 7 years, 8 years, 10 years and 12 years with normal cognitive and language.

Normative data for Duration Pattern Test on ages 8 years to 35 years was developed by Gauri et al. [24]. The mean score for 8 to 9 years was 20.46% whereas for 12 years increased to 78.20 % and for adults it was 96.81%. Statistical analysis at 0.01 level of significance also showed a significant difference across the subgroups from 8 to 12 years as well as 12 years and the highest age group. Therefore, a gradual increase in the scores was seen from 8 to 12 years of age and adult like scores were achieved beyond 12 indicating that scores improve with the neuro-maturation.

In the present study, ceiling scores were not obtained even for the highest age group i.e. at 11 years of age indicating that temporal patterning abilities continue to improve after 11 years of age to achieve adult like scores. A similar effect was seen for children as well as adults for Frequency Pattern Test and Duration Pattern Test by Missouri [34]; Neijenhuis et al. [35]; thereby stating that maturation of auditory processing abilities takes place even during adolescence. Performance on temporal patterning tasks involving linguistic labeling of non-speech stimuli would not be expected to reach adult

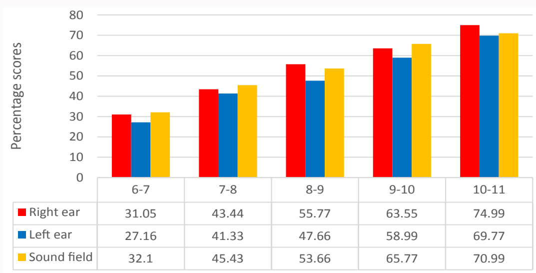


**Figure 1:** Mean scores in % for right ear, left ear and sound field across 5 age groups.

values until neuro-maturation of the relevant neural structures, especially the corpus callosum is complete. This is because, verbal labeling requires processing in the right hemisphere and then transfer via the corpus callosum to the left hemisphere for linguistic labeling [36].

One-way ANOVA was done for right ear, left ear and sound field conditions. Obtained p-value was 0.00 which was less than 0.05 for scores in all listening conditions therefore, difference between the means across 5 subgroups was statistically significant in both conditions. Furthermore, post hoc analysis was done using unpaired t test and applying Bonferroni corrections for right ear, left ear and sound field. A significant difference was seen across all pairs except for three pairs (subgroups) 7+ to 8 and 8+ to 9; 8+ to 9 and 9+ to 10; 9+ to 10 and 10+ to 11 for both the ears.

In the present study, children between 6 years to 8 years scored less than 50%. Further, children below 8 years of age were able to perform the test but required repetition and reinstructions at times. Mean scores in all the conditions for children below 8 years of age was <50% whereas with all the other groups scored >50% and required less repetitions. Also, there were several children below 8 years of age who despite fulfilling the inclusion criteria were not included in the study as they did not understand the instructions. The variability in the scores for children between 6 years to 8 years of age could be seen from the wide range of scores wherein children in 6+ to 7 year group (right ear) have scored as low as 10% and high as 83%. On the other hand, the least score for 7+ to 8 year is 16% and maximum is 76%. This variability is seen under headphones as well as sound field conditions. This variability could be attributed to other factors such as

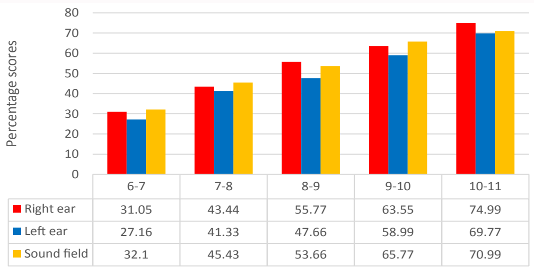


**Figure 2:** Scores in % for right ear *vs.* left ear across 5 age groups.

attention, memory, concentration and mode of response.

Children below 8 years of age tend to have reduced attention and concentration thereby yielding such scores. Also, linguistic labeling of nonverbal stimuli is a complex task which is achieved only when the relevant structures have developed enough. As the age increases, these structures develop more, and the interference of other higher order factors is reduced yielding better scores.

Above 8 years of age, all other groups have shown less variability and a consistent increase in both the minimum and maximum scores. This high degree of variability and relatively poor results for very young children was noted by Bellis [36] owing to which she stated that both Frequency Pattern Test and Duration Pattern Test are difficult for children under 8 years of age. Performance of typically developing children improves as a function of age on DPT. Nonverbal response can be seen in children as young as 7 years of age along with a significant increase in scores especially between 8 years to 10 years of age [37-39]. This is supported by Frederigue-Lopes et al. [40] where PPT and DPT was administered on children between 7 to 12 years and a significant age effect was seen for both the tests.

### A comparison of left *vs.* right ear scores was also done

Left hemisphere is dominant for speech and has a preferential role in processing of temporal aspects of acoustic stimuli [41]. Mean scores obtained in the right ear were consistently higher than those obtained in the left ear for all the subgroups indicating performance of children to be better in the right ear than the left ear. Results of paired t test (Table 5) obtained $p<0.05$ for all the groups except subgroup 7+ to 8 years. The range of scores for 7+ to 8 group was highly overlapping i.e. 16 % to 73% (right ear) and 23% to 73% (left ear) which is quite a wide range of scores and hence mean was still found to be slightly better for right ear, however statistically significant difference was not seen for this group (Figure 2).

Zatorre et al. [42] used Positron Emission Tomography (PET) to study the spectral and temporal variation in auditory cortex and found out that left hemisphere is specialized for rapid temporal processing, thereby emphasizing major left hemisphere role in analyzing temporal aspects of acoustic stimuli. Left hemisphere has a major role to play in processing non-verbal stimuli [43]. Functional magnetic resonance imaging revealed responses to increased temporal variation lateralized to the left hemisphere. Therefore, increased right ear scores could be attributed to the left hemisphere specialization in processing of temporal aspects of the auditory stimuli.

However, several studies contraindicating these findings have stated that no significant difference was seen for right ear *vs.* left ear for DPT [13,24,44-46]. However, these studies are either reported on adults or on limited number of children. Small sample size could be a reason for no statistically significant differences between right and left ear scores. Therefore, it can be concluded that right ear scores are better than left ear in challenging tasks like temporal patterning mainly due to left hemisphere dominance for temporal processing.

A significant age effect was seen in both headphones and sound field condition, however, performance in the left ear was consistently lower than right ear as well as sound field across all subgroups with an overlap between right ear and sound field.

## Conclusions

Temporal patterning abilities in children are highly influenced by neuro-maturation with a greater degree of variability in performance especially for children below 8 years of age due to presence of other higher order factors as well. Temporal patterning abilities improve as a function of age due to better comprehension of task as well as better attention; but adult like scores may not still be achieved even by 11 years but rather they continue to improve beyond 11 years. Also, left hemisphere dominance for temporal processing was seen on DPT with a significant difference in the DPT scores obtained for right ear *vs.* left ear for children.

## Implications and Limitations

The present study was done on children as young as 6 years thereby encouraging its use on the younger population with a little practice. Performance on DPT using nonverbal mode of response could be evaluated along with verbal mode considering the younger population. DPT can be used as a quick tool for identifying any temporal processing deficits in school going children. DPT could be used to assess the performance of children using hearing aids as well as cochlear implants.

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## References

1. American Speech Language Hearing Association. Central auditory processing: Current status of research and implications for clinical practice. Am J Audiol. 1996;5(2):41-54.

2. Hirsh IJ. Auditory perception of temporal order. J Acoust Soc Am. 1959;31(6):759-67.

3. Bellis TJ. Assessment and management of central auditory processing disorders in the educational setting: From science to practice. 2nd ed. Toronto, Ontario, Canada: Thomson Delmar Learning. 2003.

4. Gelfand S. Hearing: An introduction to psychophysical and physiological acoustics. 3rd ed. New York: Marcel Dekker. 1998.

5. Fu Q. Temporal processing and speech recognition in cochlear implant users. Neuroreport. 2002;13(13):1635-9.

6. Hirsh I. Information processing in input channels for speech and language: The significance of serial order on stimuli. In: Milliman CF, Darley, editors. Brain mechanisms underlying speech and language. New York: Grune & Stratton. 1967;22-38.

7. Neff W. Neural mechanisms of auditory discrimination. In: Rosenblish W,

editor. Sensory communication. Cambridge: MIT Press. 1961;259-77.

8. Pichora Fuller Mk, Souza P. Effects of aging on auditory processing of speech. Int J Audiol. 2003;42(S2):2S11-6.
9. Musiek FE, Reeves AG, Baran JA. Release from central auditory competition in the split-brain patient. Neurology. 1985;35(7):983.
10. Musiek FE, Kibbe K, Baran JA. Neuroaudiological results from split-brain patients. Semin Hear 1984;5(3):219-29.
11. Musiek FE, Reeves AG. Asymmetries of the auditory areas of the cerebrum. J Am Acad Audiol. 1990;1(4):240-5.
12. Musiek FE, Wilson DH, Pinheiro ML. Audiological manifestations in "split brain" patients. J Am Aud Soc. 1979;5(1):25-9.
13. Pinheiro ML. Auditory pattern perception in patients with right and left hemisphere lesions. Ohio J Speech Hear. 1976;12:9-20.
14. Berwanger D, Wittmann M, von Steinbuchel N, von Suchodoletz W. Measurement of temporal-order judgment in children. Acta Neurobiol Exp (Wars). 2004;64(3):387-94.
15. Emanuel DC. The auditory processing battery: survey of common practices. J Am Acad Audiol. 2002;13(2):93-117.
16. Pinheiro ML, Ptacek PH. Reversals in the perception of noise and tone patterns. J Acoust Soc Am. 1971;49(6):1778-83.
17. Ptacek PH, Pinheiro ML. Pattern reversal in auditory perception. J Acoust Soc Am. 1971;49:493-8.
18. Musiek FE, Pinheiro ML. Frequency patterns in cochlear, brainstem and cerebral lesions. Audiology. 1987;26(2):79-88.
19. Pinheiro ML, Musiek FE. Sequencing and temporal ordering in the auditory system. In: Wiliams, Wilkins, editors. Assessment of central auditory dysfunction: Foundations and clinical correlates. Baltimore. 1985;219-38.
20. Musiek FE, Gollegly KM, Baran JA. Myelination of the corpus callosum and auditory processing problems in children: Theoretical and clinical correlates. Semin Hear. 1984;5(3):231-41.
21. Musiek FE. Frequency (pitch) and duration pattern tests. J Am Acad Audiol. 1994;5(4):265-8.
22. Musiek FE, Baran JA, Pinheiro ML. Duration pattern recognition in normal subjects and patients with cerebral and cochlear lesions. Audiology. 1990;29(6):304-13.
23. Delecrode CR, Cardoso ACV, Frizzo ACF, Guida HL. Pitch pattern sequence and duration pattern tests in Brazil: Literature review. Rev CEFAC. 2014;16(1):283-93.
24. Gauri T, Manjula P. Development of norms on duration pattern test. Unpublished Independent project. University of Mysore. 2003.
25. Yathiraj A, Mascarenhas KE. Effect of auditory stimulation in central auditory processing in children with CAPD. Project carried out at the department of Audiology. All India Institute of Speech and Hearing: Mysore. 2003.
26. Yathiraj A, Mascarenhas K. Auditory profile of children with suspected auditory processing disorder. J Ind Speech Hear Assoc. 2004;18:6-14.
27. Vaidyanath R, Yathiraj A. Screening checklist for auditory processing in adults (scap-a): Development and preliminary findings. J Hear Sci. 2014;4(1).
28. American National Standards Institute. Specifications for Audiometers. ANSI: New York. 1989.
29. Yathiraj A, Vanaja CS. Age related changes in auditory processes in children aged 6 to 10 years. Int J Pediatr Otorhinolaryngol. 2015;79(8):1224-34.
30. Irwin RJ, Ball AK, Kay N, Stillman JA, Rosser J. The development of auditory temporal acuity in children. Child Dev. 1985;56(3):614-20.
31. Jutras B, Gagné JP. Auditory sequential organization among children with and without a hearing loss. J Speech Lang Hear Res. 1999;42(3):553-67.
32. Balen SA. Recognition of auditory patterns of frequency and duration: Performance of schoolchildren aged 7 to 11 years. Sao Paulo: University of Sao Paulo. 2001.
33. Stollman MH, van Velzen EC, Simkens HM, Snik AF, van den Broek P. Development of auditory processing in 6-12-year-old children: A longitudinal study. Int J Audiol. 2004;43(1):34-44.
34. Auditec TM, Auditec. Evaluation manual of pitch pattern sequence and duration pattern sequence. Missouri: United States of America. 1997.
35. Neijenhuis K, Snik A, Priester G, van Kordenoordt S, van den Broek P. Age effects and normative data on a Dutch test battery for auditory processing disorders. Int J Audiol. 2002;41(6):334-46.
36. Bellis TJ. Assessment and management of central auditory processing disorders in the educational setting: From science to practice. San Diego: Singular Publishing group; 2011.
37. Phillips DP. Central auditory system and central auditory processing disorders: Some conceptual issues. Semin Hear. 2002;23(4):251-61.
38. Schochat E, Rabelo CM, Sanfins MD. Central auditory processing: Tonal frequency and duration tests in normal individuals aged 7 to 16 years. Pro-Fono. 2000;12(2):2-7.
39. Chermak GD, Musiek FE. Managing central auditory processing disorders in children and youth. Ame J Audiol. 1992;1(3):61-6.
40. Frederigue-Lopes NB, Bevilacqua MC, Sameshima K, Costa OA. Performance of typical children in free field auditory temporal tests. Pró-FonoRevista de Atualizaçao Científica. 2010;22(2):83-8.
41. Penhune VB, Zatorre RJ, MacDonald JD, Evans AC. Interhemispheric anatomical differences in human primary auditory cortex: Probabilistic mapping and volume measurement from magnetic resonance scans. Cereb Cortex. 1996;6(5):661-72.
42. Zatorre RJ, Belin P. Spectral and temporal processing in human auditory cortex. Cereb Cortex. 2001;11(10):946-53.
43. Jamison HL, Watkins KE, Bishop DV, Matthews PM. Hemispheric specialization for processing auditory nonspeech stimuli. Cerebral cortex. 2006;16(9):1266-75.
44. Pinheiro M, Godbey N. Perceptual Reversals of temporal patterns with co-varying acoustic cues. Presented at the annual meeting of the American Speech and Hearing Association. Detroit: MI. 1973.
45. Musiek FE, Geurkink NA. Auditory brainstem response and central auditory test findings for patients with brainstem lesions: A preliminary report. Laryngoscope. 1982;92(8):891-900.
46. Pengilly L. Normative studies on the auditory duration patterns test. In: Unpublished thesis, University of New Mexico: Albuquerque. 1992.