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Age related changes in auditory processes in children aged 6 to 10 years

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ABSTRACT

Objectives: The study evaluated age related changes in auditory processing (separation/auditory closure, binaural auditory integration abilities, temporal processing abilities) and higher order cognitive function (auditory memory & sequencing abilities) in children. Additionally, the study aimed to assess the effect of gender on the auditory processes/higher cognitive function as well as ear effect for the monaural tests that were administered.
Methods: The cross-sectional experimental study evaluated 280 typically developing children aged 6 to 10 years, divided into five age groups. They were evaluated on auditory processes/higher order cognitive functions reported to be frequently affected in children with auditory processing disorders (Speech-in-Noise Test in Indian-English, Dichotic consonant-vowel test, Duration pattern test, & Revised Auditory Memory and Sequencing Test in Indian-English).
Results: ANOVA and MANOVA revealed no significant gender effect in all four tests. However, a significant age effect was seen, with the rate at which maturation occurred, varying across the tests.
Conclusions: Thus, the findings indicate that different auditory processes have different rates of development. This reflects that the areas responsible for different auditory processes/higher cognitive function do not develop at the same pace.

1. Introduction

Auditory processing is a complex phenomenon and consists of many processes that include auditory closure or separation, binaural integration, and temporal processing. Studies have indicated that children with auditory processing deficits frequently have difficulties in auditory separation or closure [1–3], binaural integration [1,2,4], and temporal processing [2,4]. Additionally, auditory memory, a higher order cognitive function has also been found to be frequently affected in them [2].

Age related changes of these processes or cognitive function in normal children have been used to determine their development. Furthermore, such age related changes have been used in the identification and management of children with auditory processing disorders. These age related changes can be attributed to the maturation of the brain. It has been substantiated that the cortical system is immature in children and continues to develop in adolescents [5–7]. Past research also indicates that different auditory processes do not mature in a similar manner but take different maturational courses [8–13]. A possible reason for the difference in maturation could be on account of the different cortical or brainstem areas that control them.

Perception of speech in noise, an *auditory separation or closure process*, involves perception of spectro-temporal cues to identify the signal as well as ability separate signal from the background noise. Perception of speech in the presence of noise has been observed to result in reduced activity of the left hemisphere along with increased activity in the right hemisphere [14]. It has also been observed that noise entwined with speech results in a neural delay that makes it difficult to segregate the two at the brainstem and cortex [15]. Earlier, Efron et al. [16] implied that the anterior temporal lobe was responsible for perception of speech in the presence of noise since individuals with lesions in this region exhibited difficulty in the task.

Duration pattern test, a test for assessing *temporal processing*, requires discrimination of duration, perception of patterns or

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sequence as well as the ability to indicate the pattern heard. Functioning of both the hemispheres as well as the corpus callosum is required for giving verbal response on this test [17,18]. *Auditory integration*, as assessed by dichotic stimuli, involves the presentation of two different stimuli to the two ears simultaneously, both of which have to be identified by the listener. Dichotic tests are known to assess laterality, specialization of the auditory cortex in addition to the functioning of the two hemispheres and corpus callosum [19]. Likewise, *auditory memory* is reported to depend on the functioning of the hippocampus and amygdala that are located in the anterior temporal region of the brain [20]. The changes with age, in the areas responsible for the development of different auditory processes, may find a parallel with the behavioral development of the same.

Auditory processes have been reported to start developing after birth and continue to develop as the child grows older, in line with the development of the central auditory nervous system. Keith [9] noted that those aged 12 to 50 years performed similarly on the six subtests (2 filtered words subtests, 2 auditory figure-ground subtests, a competing words & a competing sentences subtest) of SCAN-A. It can be construed from these findings that auditory closure or separation matures by 12 years of age. Further, Keith in 2000 reported the mean raw score of SCAN-C increased and the standard deviations decreased with increasing age in children aged 5 years to 11 years and 11 months. This variation in performance with increase in age was considered to reflect the maturation of the central auditory nervous system. Keith [9,10] did not report whether the variation in performance across the ages was statistically significant or not. However, an investigation by Amos and Humes [8] did demonstrate the presence of a statistically significant difference in SCAN scores in children aged 6 and 9 years (first graders & third graders). Thus, these findings substantiate the presence of maturational changes in an auditory closure or separation task.

A review of literature indicates that variation in scores across ages depends not only on the process evaluated, but also on the type of material used while evaluating a particular process. For example, Neijenhuis et al. [11] found no significant difference in a word-in-noise test scores obtained by adolescents (aged 14–16 years) and by adults whereas they observed a significant difference between the two age groups for a sentence-in-noise test. Thus, depending on the type of stimuli used, maturation of auditory closure or separation task varied. Similar to the word-in-noise test performance, Neijenhuis et al. [11] reported of no significant difference between adolescents and adults on a dichotic digit test. Additionally, they also noticed that in children aged 6 to 16 years there was no age effect for a frequency pattern test. However, they reported of an age effect on seven other tests carried out in this age group (words-in noise, filtered speech, binaural fusion, dichotic digits, duration patterns, backward masking, digit span). Based on their findings they concluded that maturation continues to develop even in adolescents.

Similar to the findings of research on auditory closure or separation, the procedure and stimuli has been found to affect the results of tests for temporal processing. Lister et al. [21] observed that performance of 11 to 12 year old children was similar to that of adults on a gap detection test whereas the performance of the 7 to 8 year and 8 to 9 year old children were poorer that of adults. They reported that the developmental effects observed by them were greater than most of those reported previously. Lister et al. [21] attributed this difference to variations in stimuli and procedure used.

Maturational effects up to 12 years have also been documented by Stollman et al. [13], based on the findings of a longitudinal study of 20 children aged 6 years through 7, 8, 10 and 12 years. This was seen for 9 tests (filtered speech test, binaural fusion test, frequency pattern test, duration pattern test, auditory word discrimination test, an auditory synthesis test, an auditory closure test, & a number recall test), but not for a speech-in-noise test. They noticed that in all ages, the children performed significantly poorer than their adult group, indicating that the processes evaluated continued to develop even after 12 years of age. Their findings substantiate the findings of Neijenhuis et al. [11] who also observed that maturation continued through adolescence.

Due to the large variability in results, it has been recommended that tests used for the evaluation of auditory processing should not be administered on children below the age of 7 years [22]. However, Stollman et al. [12] demonstrated that auditory processing tests that evaluated sustained auditory attention, binaural hearing, temporal processing, and phonological coding could be carried out effectively in children aged 4 to 6 years of age. Although no gender difference was observed, the older children were found to perform better than the younger children on the battery of tests. The difference was most prominent for the dichotic word test and the phoneme awareness test.

From the review of literature, it is evident that there exist considerable variations regarding the age related changes of the different auditory processes. This has been attributed to different auditory processes requiring different levels of functioning in the auditory system. There is a need for additional information in the area of age related changes in auditory processing to substantiate the developmental pattern seen in different auditory processes. Thus, the current study was carried out with the aim to determine age related changes in the performance of children on tests assessing different auditory processes or higher cognitive abilities (auditory closure or separation, temporal patterning, binaural integration, & auditory memory and sequencing). Additionally, the study aimed to evaluate the effect of gender as well as the performance across the two ears for the auditory processes or higher cognitive abilities.

2. Methods

Using a cross-sectional experimental design, age related changes on a battery of auditory processing tests were evaluated on 280 normal hearing children who were divided into five age groups. The battery consisted of four different tests that tapped different auditory processes or cognitive ability associated with auditory processing. The tests evaluated monaural auditory separation or closure, binaural auditory integration, temporal patterning, and auditory memory. These aspects of auditory processing were selected since they have been noted to be more frequently affected in children with auditory processing disorder.

2.1. Participant selection

The participants consisted of 280 school-going children (140 male & 140 female) in the age range of 6 to 10 years. The participants were recruited from two different centers in India having similar test facilities, one located in Mysore and the other in Pune. The participants tested in the two centers were matched in terms of gender and age. It was ensured that children were 'not at-risk' for auditory processing disorder, based on the 'Screening Checklist for Auditory Processing' developed by Yathiraj and Mascarenhas [23].

The children were categorized into five age groups (6 to 6;11 years, 7 to 7;11 years, 8 to 8;11 years, 9 to 9;11 years, & 10 to 10;11 years). The youngest age group had 40 children and the four remaining age groups had 60 children each. All the children had average or above average IQ on the Raven's Progressive Colored or standard Matrices [24]. They attended schools where the instruction was in English and were reported by their teachers to be