# Auditory Memory and Sequencing in Children Aged 6 to 12 Years

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## Abstract

*Objectives: The study aimed to investigate auditory memory and sequencing ability in typically developing children. The study also compared the performance of children with suspected auditory memory problems with that of typically developing children. Method: Using the Auditory Sequencing Test developed by Yathiraj and Mascarenhas (2003), auditory memory and sequencing abilities were checked on ninety-six typically developing children in the age range of six to twelve years. Ten children with learning disability with suspected auditory memory problems were also tested. Results: The results indicated that auditory memory scores increases with advance in age up to ten years in the normal children, after which a plateau was obtained. There was no significant difference across gender. Auditory sequencing ability was also found to improve with increase in age up to seven years, after which a plateau was attained. A significant difference was obtained for auditory sequencing abilities across gender in two age groups, with the males out performing the females. Also the scores on the ten children with suspected auditory memory problems, was compared with the obtained data. Conclusions: The results revealed that the majority of children with learning disability, who had indications of memory problems, were identified as having auditory memory deficits. Hence, the obtained data on typically developing children can be used to confirm the presence of auditory memory deficit. It could also be used to determine the efficacy of management procedures on children with an auditory memory deficit.*

***Key words: Auditory memory, Auditory sequencing, Auditory processing disorder, Learning disability.***

A (central) auditory processing disorder [(C)APD] is defined as a deficit in the processing of information that is specific to the auditory modality, that may be exacerbated in unfavorable acoustic environments and that may be associated with difficulties in listening, speech understanding, language development and learning (Jerger & Musiek, 2000).

The underlying conceptual and philosophical approach one has regarding auditory processing disorders will determine the testing procedures used for evaluation. The testing procedure can be focused specifically on the auditory processing disorder without the contamination of language, memory, and attention. It can be nonlinguistic stimuli, psychophysical methodology and / or electrophysiological methods used for revaluation. On the other hand, the difficulties experienced in everyday life situations involve various cognitive processes that are intimately intervened to assess memory, attention and decoding (ASHA Task force on Central Auditory Processing consensus development, 1996; Jerger & Musiek, 2000). (C)APD has been defined as a ‘deficit in the neural processing of auditory stimuli that is not due to higher-order language, cognitive or related factors’ (ASHA, 2005). The quality of one’s memory has traditionally been characterized in terms of the quantity of ideas or the number of aspects of events that are recalled (Rhodes & Kelley, 2005).

Chermak and Musiek, 1997 have cited studies providing information regarding memory in children. These studies indicate different aspects of the development of memory in children. They report of a study by Howe and Ceci (1978), which indicated that children gradually acquire knowledge and appreciation of retrieval cues and effective strategies for coding, organizing and retrieving items in memory. In 1979, Howe and

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Celci reported that by age 6 years, most children demonstrate some awareness of the limitations of memory and the factors affecting memory. By age 8 to 10 years the children were found to demonstrate a planned approach for encoding and retrieval, becoming aware of mnemonics and their benefits.

Locke (1968) has suggested that a discrimination impairment seen in those with an auditory processing disorder may be a byproduct of or coexist with an auditory memory deficit. Weisner, Tomblin, Zhang, Buckwalter, Chynoweth and Jones (2000) have noted that auditory memory deficits, seen in children with learning disability, can be attributed to phonological loop impairment. This in turn plays an important role in the acquisition of vocabulary.

According to Cusimano (2001), students with auditory memory deficiencies often experience difficulty in developing a good understanding of words, remembering terms and information that have been presented orally. They also experience difficulty in processing and recalling information that they have read to themselves.

Widely used measures of auditory memory span involve the use of digits, words, sentences, nonsense syllables, paragraphs and stories which are to be recalled following a single presentation, when the number of stimuli presented is increased. The examiner tests the number of elements the subject is able to retain and retrieve (Underwood, 1964). However, there is a limit to the maximum number of items that can be successfully remembered in this way. An individual's auditory memory span is about 6 or 7 items (Roediger, Knight and Kantouwitz, 1977; Jarold, Baddeley, Heves, Leeke & Philips, 2004).

Cusimano (2001) opined that it is important to understand that each aspect of auditory memory is specific unto itself. While one area of the brain involves the intake of a series of unrelated letters, another involves numbers, another word and there are others that involve a contextual series of words, sentences, and whole passages. Hence, students need to be tested to determine if they can recall the number of items in a series proficiently for their age.

Howe (1965) reported that if recall is requested as soon as presentation of a list of items is completed, the items that occur at the beginning of the list are generally found to have become more highly consolidated in memory than the items that occurred later. Memory for the early items in a list is more resistant than that for later items to the disrupting effects of various activities. According to Jarold et al. (2004) it also depends on the nature of the to-be-remembered stimuli. Auditory memory spans are smaller for words, which sound alike or are phonologically similar (example cat, bat and hat) than words, that are phonologically dissimilar. In addition, spans are shorter for multi-syllabic words, that are longer in duration (example Helicopter and police man) than for monosyllabic words, that are shorter (example pig and shoe).

Owing to the fact that memory plays an important role in spoken language processing and learning, strengthening memory may benefit individuals with a learning disability. In order to detect the presence of auditory memory problems, it is essential to evaluate children with an auditory memory and sequencing test. The test should have age appropriate norms to make accurate diagnosis and suggest the necessary rehabilitation strategy. Absence of data in Indian children instigated the present study. The study aims at obtaining age appropriate data on auditory memory and sequencing in typically developing children in the age range of 6-12 years in both boys and girls. In addition, it also aims at determining whether children with suspected auditory memory problems can be identified based on the data obtained on normal children.

## Method

The participants involved in the study comprised of two groups. The study was carriedout initially on 96 typically developing children who were reported to have no academic difficulties as reported by their teachers. Later 10 children with a known history of learning disability were also evaluated to check the utility of the test in determining auditory memory problems. The 96 normal children were in the age range of 6-12 years. The Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarenhas (2003) was administered to rule out any auditory processing disorder. These participants were divided into 6 age groups having 16 children in each group. The age groups were 6 years – 6;11 years, 7 years – 7;11 years, 8 years – 8;11 years, 9 years – 9;11 years, 10 years – 10;11 years, and 11 years – 11;11

years. Of the 16 children in each group, 8 were boys and 8 were girls. These children were taken from primary and middle schools in Mysore city. Children who passed the checklist and met the following criteria were selected:

- Had English as a medium of instruction for at least one year and were familiar with the language,
- Had normal IQ based on Kaufmann assessment battery for children,
- Had no history of hearing and speech problems,
- No history of otological or neurological problems,
- Hearing sensitivity within normal limits (i.e. air conduction threshold of less than or equal to 15 dB HL in the frequency range of 250 to 8 kHz in both ears and air bone gap of less than 10 dB HL at any frequency),
- No report of speech identification problems and,
- No illness on the day of testing.

The second group of participants also met the same participant selection criteria as the first group except that they failed the Early Reading Skills Test (Rae & Pother, 1973) indicating that they had learning disability. These children also obtained less than 50% scores on the Screening Checklist for Auditory Processing (Yathiraj & Mascarenhas, 2003) necessitating further (C)APD evaluation. Further, the children were included in the study only if they failed on at least one item in the SCAP that indicated the possible presence of a memory problem.

**Procedure**

The 'Auditory Sequencing Test' developed by Yathiraj and Mascarenhas (2003) was used as the test material. In this Indian-English test, the length of the word sequence increased from a three-word sequence to an eight-word sequence. Each sequence group was referred to as a token. There were 2 tokens in the 3 and 4 word sequences and 4 token each in all the other sequence (i.e. 5, 6, 7 & 8). The interval between words in each sequence was 500 msec, while the interval between tokens (i.e. between groups of words) was 10 seconds.

The testing was done in a quiet room that was free from distraction. The signals were presented at a comfortable level through a CD player (PHILIPS AZ2160). Each child was tested individually. The participants were seated one meter away from the player at a zero degree azimuth. Each child was instructed to listen to the group of words and repeat them in the correct order. The responses were recorded on a scoring sheet. The children from both groups were tested in a similar manner. A score of one was awarded for every correct word that was recalled. An additional score of one was awarded if the words were recalled in the correct sequence. The maximum attainable score was 104 for the auditory memory subtest. Likewise a similar score was attainable for the auditory sequencing subtest.

The raw scores obtained for the auditory memory and the sequencing subtests were tabulated across different age groups and gender. Descriptive statistics was done to find out the mean and standard deviation. ANOVA and Duncan's post hoc test were carried out to find out the significance of difference between the scores.

## Results and Discussion

The mean and standard deviation values of the auditory memory subtest are depicted in Table 1 and that of the sequencing subtest are shown in Table 2. This information is given for males and females, across the different age groups.

Tables 1, 2 reveal that with increase in age, generally there was a steady increase in auditory memory and auditory sequencing abilities. This increase was more for the auditory memory than for the auditory sequencing subtest. A similar trend was seen in the males as well as females.

| Age | Male | | | Female | | |
|---|---|---|---|---|---|---|
| (in years) | Mean* | SD | CI | Mean* | SD | CI |
| 6–6;11 | 42.12 | 5.59 | 37-47 | 54.37 | 7.24 | 48-61 |
| 7–7;11 | 57.37 | 10.64 | 48-67 | 60.00 | 7.83 | 53-67 |
| 8–8;11 | 61.62 | 4.95 | 57-66 | 58.12 | 6.72 | 52-64 |
| 9–9;11 | 68.37 | 7.68 | 61-75 | 57.37 | 10.35 | 48-67 |
| 10–10;11 | 74.00 | 8.33 | 67-81 | 61.87 | 5.43 | 57-67 |
| 11–11;11 | 73.00 | 4.37 | 69-77 | 70.37 | 10.37 | 61-81 |

**Table 1**: Mean Scores, Standard Deviation (SD) and Confidence Interval (CI) of the Auditory Memory Subtest across gender and age. * Maximum score = 104

| Age (in years) | Male | | | Female | | |
|---|---|---|---|---|---|---|
| | Mean* | SD | CI | Mean* | SD | CI |
| **6 – 6;11** | 22.12 | 7.98 | 15-29 | 25.12 | 10.13 | 16-34 |
| **7 – 7;11** | 32.75 | 9.31 | 24-41 | 27.25 | 7.75 | 20-34 |
| **8 – 8;11** | 33.37 | 10.47 | 24-43 | 23.62 | 3.50 | 20-27 |
| **9 – 9;11** | 34.25 | 9.96 | 25-43 | 26.87 | 8.21 | 20-34 |
| **10 – 10;11** | 43.37 | 16.93 | 29-56 | 27.37 | 5.26 | 22-32 |
| **11 – 11;11** | 39.00 | 5.07 | 34-44 | 33.75 | 12.05 | 23-45 |

**Table 2**: Mean scores, Standard Deviation (SD). and Confidence Interval (CI) of the Auditory Sequencing Subtest across age and gender. * Maximum score = 104

The results of the one-way ANOVA test indicated that the auditory memory scores were highly significant across the age groups [F (6, 96) = 14.071, $p < 0.001$] but it was not significantly different across gender [F (6, 96) = 1.078, $p > 0.05$]. However, auditory sequencing scores were found to be significantly different across ages [F (6, 96) = 3.316, $p < 0.01$] as well as gender [F (6, 96) = 10.32, $p < 0.01$]. Since there was a significant difference, the Duncan's post hoc test was used. The results of the post hoc test on the auditory memory scores and sequencing scores, across age are given in Tables 3 and 4 respectively.

| Age in Years | 6-6;11 | 7-7;11 | 8-8;11 | 9-9;11 | 10-10;11 | 11-11;11 |
|---|---|---|---|---|---|---|
| **6-6;11** | - | | | | | |
| **7-7;11** | SD | - | | | | |
| **8-8;11** | SD | NSD | - | | | |
| **9-9;11** | SD | NSD | NSD | - | | |
| **10-10;11** | SD | SD | NSD | NSD | - | |
| **11-11;11** | SD | SD | SD | SD | NSD | - |

Note: SD = significantly different, NSD = not significantly different.

**Table 3:** Significance of difference between means for the auditory memory subtest across ages.

From Table 3 it is evident that for the auditory memory subtest, the 6 years olds had significantly different scores when compared to all the older age groups. Likewise, the oldest age group (11 years – 11; 11 years) differed significantly from the younger age groups. In general, the older groups did not differ significantly from the adjacent age groups but did so from those who were one to two years younger or older than them. It was generally noted that as the children grew older their auditory memory scores improved (Table 1). This improvement was seen till age ten after which there was a plateau in the responses.

| Age in Years | 6-6;11 | 7-7;11 | 8-8;11 | 9-9;11 | 10-10;11 | 11-11;11 |
|---|---|---|---|---|---|---|
| **6-6;11** | - | | | | | |
| **7-7;11** | NSD | - | | | | |
| **8-8;11** | NSD | NSD | - | | | |
| **9-9;11** | NSD | NSD | NSD | - | | |
| **10-10;11** | SD | NSD | NSD | NSD | - | |
| **11-11;11** | SD | NSD | NSD | NSD | NSD | - |

Note: SD = significantly different, NSD = not significantly different.

**Table 4:** Significance of difference between means for the auditory sequencing subtest cross ages.

In the auditory sequence subtest, the older two age groups (10 years – 10; 11 years and 11 years – 11; 11 years) differed significantly from the youngest age group (6 years – 6; 11 years). There was no significant difference between the other age groups (Table 4). However, there was a steady non significant increase in scores with advance in age, both in the male as well as female participants, as can be seen in Table 2.

The ANOVA test revealed that there was no significant difference across gender for the auditory memory subtest while it was present for auditory sequencing subtest. Further analysis of gender difference for the auditory sequencing for different age groups was done using Duncan's post hoc test. The results revealed that this significant difference was present only in two age groups (8 years – 8; 11 years and 10 years – 10; 11 years). No significant difference was observed for the other age groups. The gender difference probably occurred due to individual variability. The males in these two age groups had a higher standard deviation and confidence interval when compared to the females in the same age groups. Such variability was not seen for the other age groups. This could account for the gender difference in these two age groups.

Comparison between the scores of the two subtests, auditory memory and sequencing, for different ages showed that there was a significant difference between them. In general it was noted that the auditory memory subtest resulted in the children having higher scores when compared to auditory sequencing subtest. Hence, it is recommended that both the subtests be administered and scored separately while evaluating children.

It is highly possible that the processing of auditory sequences takes place in one area of the brain while that of auditory memory taps another area. This could account for difference in scores obtained in the two subtests. This is similar to the findings of Cusimano (2001) who noted that different parts of the brain are responsible for processing different aspects of memory.

The scores obtained by the ten children with learning disability, who were suspected to have an auditory processing problem were compared with the age appropriate scores obtained. This was done for the auditory memory as well as auditory sequencing subtest. The scores obtained by the ten children with learning disability are given in Table 5, Figures 1 and 2.

| Case | Age /Sex | Auditory Memory Scores | Auditory Sequencing Scores | Interpretation* |
|---|---|---|---|---|
| 1 | 7/F | 35 | 13 | Deviant |
| 2 | 8;6/F | 53 | 25 | Not Deviant |
| 3 | 9/M | 74 | 43 | Not Deviant |
| 4 | 10/F | 27 | 18 | Deviant |
| 5 | 11/F | 56 | 17 | Deviant |
| 6 | 12/M | 24 | 15 | Deviant |
| 7 | 12/M | 36 | 18 | Deviant |
| 8 | 12/M | 61 | 24 | Deviant |
| 9 | 12/F | 34 | 15 | Deviant |
| 10 | 12/M | 65 | 26 | Deviant |

*Based on the confidence interval given in Tables 1 and 2.

**Table 5:** Scores of the auditory memory and sequencing subtests obtained by the children with learning disability.

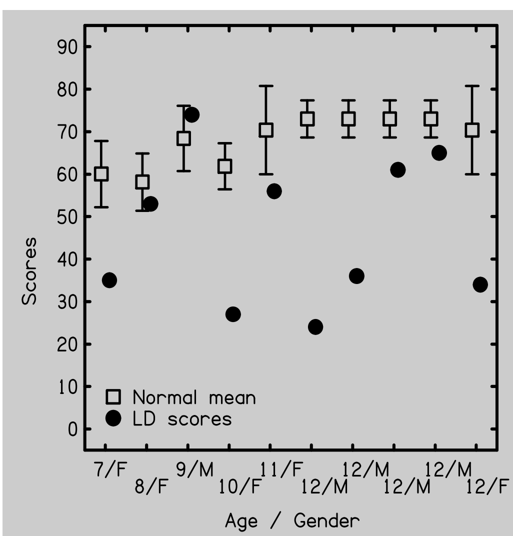


**Figure 1:** Comparison of Auditory Memory scores of children with Learning Disability with age appropriate norms.

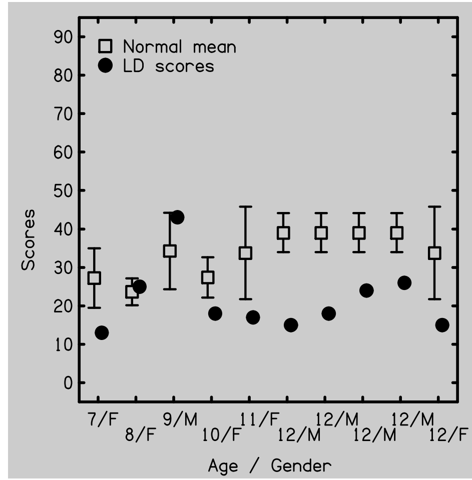


**Figure 2:** Comparison of Auditory Sequencing scores of children with Learning Disability with age appropriate norms.

The result indicates that eight of the ten children had deviant scores in auditory memory and sequencing. Thus, it can be inferred that the majority children with learning disability who have indications of a memory problems based on the SCAP, do have an auditory memory and sequencing problem. However, not all of them have such a problem. Based on this finding, it is suggested that children with a learning disability should be screened using the SCAP or any other (C)APD screening checklist. Those showing an indication of a memory difficulty should be assessed for the presence of an auditory memory or auditory sequencing problem. Appropriate remedial steps should be provided for those who are found to have deviant scores.

## Conclusions

The present study has provided data on auditory memory and sequencing for typically developing children in the age range of 6-12 years. The findings indicated that with an increase in age, the children showed an increase in auditory memory and sequencing abilities. The increase was more significant for the auditory memory subtest when compared to the auditory sequencing subtest. No significant difference across gender was observed for the auditory memory subtest. However, there was a significant gender difference for the sequencing subtest in two of the age groups. This difference was probably on account of the large variability in scores that the males had in these age groups.

It was also found that the test was useful in determining whether children with suspected auditory memory problems as determined through a screening checklist do have an auditory memory / sequencing problem. The test results can be used to make suggestions for remedial help for children having deviant scores.

Thus, the test can be used for diagnosis of auditory memory / sequencing problems in children with suspected auditory memory problems. In addition, it can be used to determine the utility of management techniques in children with auditory processing problems.

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