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Original Article:

Development of Auditory Memory and Sequencing Test for Marathi Speaking Children

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Abstract: Objectives: Aims of the study were to develop test material for evaluation of auditory memory and sequencing in Marathi; to compare scores in children across the age and among children with and without symptoms of Central auditory processing disorders (CAPD). Methods: The test material consisted of 20 sequences. The number of words in a sequence ranged from three to eight. All tokens were audio recorded and played through a laptop computer. The participants were instructed to repeat the words heard in the same sequence. Data were collected from a total of 60 typically developing children, in the age range of 5 to 5;11; 6 to 6;11 and 7 to 7;11years. Twelve children with symptoms of CAPD, were compared with typically developing children. The responses were scored using two scoring methods. In Method I, which is based on Yathiraj and Vijayalakshmi (2006) and in Method II, memory and sequencing span was determined based on the recommendation of Vaidyanath and Yathiraj (2014). Results: Results of item analysis suggest that the developed auditory memory and sequencing test has good reliability. There was no significant effect of gender, whereas significant age effect was observed for auditory memory and sequencing scores as well as span, there was a difference in the trend. Children with CAPD had poor auditory memory and sequencing score and span, however a significant difference was observed in some age groups while it was not observed in other age groups. Auditory sequencing score and span could identify more number of children with CAPD. Conclusion: Auditory memory and sequencing test has good internal consistency and reliability. Significant age effect for both auditory memory and sequencing was observed for 5 to 8 year old children. There was no gender effect. Children with symptoms of CAPD showed poor performance on these tests. The results obtained varied depending on the methods of scoring. Auditory sequencing task was more difficult than auditory memory both in typically developing children and those with symptoms of CAPD.
Key Words: Memory span, CAPD, Auditory maturation

Introduction:
Memory is one among the wide range of mental structures and processes used for cognition(1).Cognition refers to the process by which the sensory input is transformed, elaborated, stored, recovered and used(2), while memory is defined as the representation of stored information which involves a process of encoding, storing, memorizing and retrieving the information(3). Ability to retain information in the correct temporal order is called sequencing(4).
Auditory memory and sequencing plays vital role in the spoken language processing. The act of processing what is heard is very complex and involves successful intertwining of auditory, cognitive and language mechanisms. Processing of spoken language signals are reported to have several abilities or skills such as sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition such as temp oral integration, temporal discrimination (e.g. temporal gap detection), temporal ordering, temporal masking, as well as auditory performance with degraded acoustic signal memory, sequencing, auditory attention, phonological awareness, auditory linguistic integration(5). A deficit in any of these processes has been found to result in spoken language processing disorder. Hence, auditory memory need to be assessed in persons with spoken language processing disorder or central auditory processing disorder (CAPD).
Auditory memory, described as the ability to process information heard auditorily, which is analyzed mentally and stored to be recalled later (6), can be short term or long term. Studies reported in literature have used different techniques to assess auditory short term memory. Some of the techniques that have been used are free recall, paired association task, recognition task, and probe discourse task (7). Varied techniques such as conditioned recall (8) and story repetition (9) have been used to assess auditory sequencing. Auditory sequencing abilities have also been assessed by testing

participant's ability to follow multistep related/unrelated commands (10).

It has been well established that the auditory memory and sequencing abilities of children improve with age. Tam et. al. (11) reported that the performance of 8 year old children was better than that of 6 years old children (16.23 Vs 12.78) on word recall. Leclercq et. al. (12) studied longitudinal development of serial order short term memory and vocabulary. They examined serial order short term memory of 4 and 5 year old children using animal race task(13) and delayed item repetition using a single nonword delayed repetition task adopted from castle task(13). Results indicated that for serial order reconstruction and single nonword delayed repetition children scored 5.76 and 13.62 respectively at age of 4 years, also when children tested at 5 years they scored 9.04 and 20.96 respectively. Visu-Petra et. al. (14) studied Digit span of preschool children tested using Wechsler Intelligence Scale for Children(WISC-III) and word recall task in two age groups (3 to 5 years and 5 to 6 years). The evaluations were repeated after 8 months. In 8 months, the scores of younger age group on word recall increased from 3.41 to 3.84 for word recall while it increased from 3.87 to 4.04 for digit recall task. Similarly the scores of 5 to 6 age group increased from 3.89 to 4.31 for word recall task and 4.32 to 4.45 for digit recall task when tested after 8 months. Colenso et al. (15) studied effect of socio-economic variable on immediate memory span in children of age range 10 to 12 years, using PGI Memory scale (16) which include digit recall span. Their results did not reveal a difference in the scores of 10 year old and 11 year old children. Anuroopa et al.(17) evaluated auditory memory using tasks such as e digit forward recall and word recall as a part of Cognitive Linguistic Protocol. The results revealed an improvement in scores with increase in age. Children in the age range 4 to 5 years could recall three words or digits, 5 to 6 years could recall 4 words or digits, 6 to 7 years can recall 5 words and 4 digits, and 7 to 8 year old children could recall 7 words and 5 digits. Similar results were reported by Yathiraj et al. (18) who developed Auditory Memory and sequencing test in Kannada and obtained normative for age range of 5 to 12 years. However, Yathiraj et al.(19) reported that the auditory memory and sequencing scores improve with age but the development was not uniform across age range of 6 to 10 years. They observed that the growth in auditory memory and sequencing scores was gradual from 5 to 8 years; there was a rapid increase in scores from 8 to 9 years and again a gradual increase from 9 to 10 years of age.

Thus, a review of literature shows that auditory memory and sequencing abilities have been tested using a variety of procedures. The results indicate a developmental change in the performance of children. However, the procedure used for testing and scoring can influence the performance. Effect of scoring method of auditory memory was investigated by Vaidyanath et al. (20). In a retrospective study they compared two scoring methods for evaluating auditory memory for children in the age range 5 to 9 years. Auditory memory and sequencing score was calculated using original method described by Yathiraj et al. (18) and an alternate scoring method developed in the study. Yathiraj et al. (18) recommended giving a score of one to each correct word repeated irrespective of the sequence and adding the scores to get a total score while Vaidyanath et al. (20) calculated auditory memory span and sequencing span. Memory span was determined by noting the longest word token which could be recalled 50% of the time irrespective of sequence. The longest word token which was recalled in correct order, 50% of the time was noted as sequence span. They observed a high significant correlation between the two scoring methods, but the testing time was reduced with alternate method of scoring.

In a multilingual country like India, tool to assess auditory memory and sequencing are required in different languages. Even though Hindi is national language of India, there are 22 official languages (21). Marathi which is one among them, is an Indo-Aryan language, rooting from Sanskrit (21). It ranks 19th in the list of most spoken language in the world(22). It is official language in the state of Maharashtra which is second largest state in population of India. also it is co-official language of state of Goa(21). A few other states of western and south India also has Marathi speaking population(23,24). In all, around 73 Million people in the world speak Marathi (22). To the best of the researchers' knowledge, an auditory memory and sequencing test is not available in Marathi. It is very difficult test auditory memory and sequencing in Marathi speaking children without a standard test. Auditory memory and sequencing test in Marathi would help in assessment and planning intervention for children with learning disability, CAPD, specific language impairment. Hence, there is a need to develop a tool to assess auditory memory and sequencing in Marathi and to obtain age specific normative. So, the aim of the present study was to develop a test for evaluation of auditory memory and sequencing in Marathi. This study investigated the maturation of auditory memory and sequencing skills in Marathi speaking children. An attempt was made to investigate the auditory memory and sequencing abilities of children who are 'at-risk' and 'not at-risk' for central auditory processing disorder (CAPD).

Method

Present study was conducted in two phases. In the first phase, an auditory memory and sequencing test in Marathi was developed. In the second phase, the developed test was administered on typically developing children in the age range of 5 to 7;11 years. Current study was approved by ethical committee, and the ethical rules of Bharati Vidyapeeth Deemed University Medical College were followed while conducting the study.

Phase One: Development of Auditory Memory and sequencing Test in Marathi

The test was developed by adopting the method given by Yathiraj et al. (18). A total of 176 meaningful monosyllabic and bisyllabic Marathi words were selected from preschool Marathi books. The familiarity of these words was tested on thirty children in the age range 5 years to 5;11 years. The words were presented through auditory mode and the children were instructed to describe the meaning of the word or point to a picture representing the word. The responses were noted as correct or incorrect. Each child was tested individually and only those words that were familiar to 85% of the children were selected for construction of the test.

The selected words were audio recorded in an audio recording studio using an Apple Mac Intel Computer, digital audio workstation software Pro Tools 10 and M Audio Nova condenser microphone with sampling rate of 192 kHz. The recorded signal was edited using Audacity-win-2.1.2 software to ensure that the sample is free from noise and the intensity of the recorded audio signal was normalized. Ten Marathi speaking adults and children were instructed to rate the intelligibility of the recorded signal using a three-point rating scale. Words rated below 2 were rerecorded.

The words were grouped to form tokens and the number of words in a token ranged from three-word sequence to an eight-word sequence. Inter stimulus interval between two words within a word token was 500 ms. A total of 20 tokens were formed including two token of three word sequence; two tokens of four word sequence; four token each five, six, seven and eight words sequences. Inter stimulus interval between two tokens varied depending on the length of the preceding word sequence. There was a silent interval of five seconds after 3 words sequences while it was six seconds after four and

five words sequences. The silent interval was 10 seconds after six words sequences whereas it was to 12 seconds after 7 and 8 words sequences. A 1 kHz calibration tone was recorded at the beginning of the list.

Phase Two: Administration of Auditory memory and sequencing test in Marathi

Participants: Children from preschools and primary schools in Buldana district of Maharashtra, India served as participants. Two groups of participants were considered for the study. Group I included 60 typically developing children, in the age range of 5 years to 7;11 years. There were 20 children each in the three age groups, 5 to 5;11 years, 6 to 6;11 years and 7 to 7;11 years, with equal number of males to females. All the children were native speakers of Marathi. All the children had hearing sensitivity within normal limits. The screening checklist for auditory processing (SCAP) (25) was administered for children who were above 6 years to screen for central auditory processing problem. Teachers of younger children were interviewed by the researcher to ensure that the children did not have any symptoms of CAPD. All the children had average or above average academic performance as reported by the teacher. There was no history of neurological, psychological/emotional disturbance or attention deficits disorders.

Group II, included 12 children who were 'at-risk' for CAPD, who either did not pass SCAP or had signs and symptoms of central auditory processing disorder as reported by their teacher. There were 4 children each in the three age groups, 5 to 5; 11 years, 6 to 6;11 years and 7 to 7;11 years, with equal number of males to females. All the children had hearing sensitivity within normal limits. There was no history of neurological, psychological/emotional disturbance or attention deficits disorders. Children who scored below average intelligence on Raven's Coloured Progressive Matrices (CPM) were not included in the study.

Procedure

Teachers of older children (above 6 years) were requested to complete the Marathi version of SCAP(25) and teachers of younger children (less than 6 years) were interviewed by the researcher for signs and symptoms of central auditory processing disorder for each participant. Hearing screening was carried out using pure tones at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz presented through laptop DELL INSPIRON N5010 at an intensity equivalent to 25 dB HL in a quiet room. The pure tones were generated using the software Audacity-win-2.1.2 software and the intensity was measured and adjusted using a sound level meter.

Auditory memory and sequencing test in Marathi was administered on children in a quiet room, which was free from distraction. The recorded test material was presented at a comfortable level using DELL INSPIRON N5010 laptop. The participants were instructed to listen to each word-sequence and repeat the words heard in the same order. Their responses were recorded in written form and scored by the administrator. The responses were scored using two scoring methods. In Method I, which is based on Yathiraj et al. (18) a score '1' was given for each correctly recalled word for auditory memory, while calculating auditory sequencing score, score of '1' given to each word repeated in the correct order. Both auditory memory and auditory sequencing were scored separately with maximum score of 118. In Method II, which memory and sequencing span was determined based on the recommendation of Vaidyanath et al. (20). In this method, Auditory memory span determined by noting the longest word token that could be recalled 50% of the time irrespective of the sequence. The longest word token which was recalled in correct order, 50% of the time was noted as the auditory sequence span.

Statistical analyses of the data were carried out using SPSS 16.0 statistics software. The mean and standard deviation was calculated separately for the data obtained from children who are 'at-risk' and 'not at-risk' for CAPD. Item analysis was carried out to check internal consistency and reliability of test. Non-parametric tests were carried out to investigate the aims of the study.

Results

Item analysis was carried out to study internal consistency and reliability of test. The Conbach's alpha for the auditory memory test was 0.82 and sequencing test was 0.86. Split half reliability analysis revealed a Spearman-Brown Coefficient of 0.79 for auditory memory test and 0.81 for sequencing test.

The mean, median, standard deviation and range of the auditory memory scores and auditory memory span are given in Table 1 and Table 2 gives the auditory sequencing score and auditory sequencing span. The scores across gender for the three age groups as well as the combined scores are tabulated separately. Shapiro Wilk test showed that the data were not normally distributed. Hence non parametric tests were performed to investigate the objectives of the study. Mann-Whitney U test was used to investigate the effect of gender on auditory memory and sequencing scores as well as auditory memory and sequencing span. Results indicated that there was no significant difference between the performance of boys and girls on both auditory memory and sequencing test (Table 3).

Table 1: Mean Score, standard deviation, median and range of auditory memory score and auditory memory span for males and females across three age groups.

Age in years	Gender	Auditory Memory Scores				Auditory Memory Span			
		Mean	S.D.	Median	Range	Mean	S.D.	Median	Range
5-5;11	Male	45.36	9.69	45	32-60	1.84	1.81	3	0-4
	Female	44.09	7.21	44	32-55	2.92	1.03	3	0-4
	Combined	44.72	8.36	44.5	32-60	2.38	1.55	3	0-4
6-6;11	Male	49.90	7.87	49	40-63	3.38	1.19	4	3-5
	Female	48.36	12.34	46	35-79	3.30	1.18	4	3-5
	Combined	49.13	10.13	47.50	35-79	3.34	1.16	4	3-5
7-7;11	Male	50.90	7.60	52	35-61	3.16	1.19	3	3-4
	Female	56.90	9.95	58	38-71	3.92	0.75	4	3-5
	Combined	54.04	9.22	55	35-71	3.56	1.04	4	3-5

Maximum Auditory Memory Scores: 118, Maximum Auditory Memory Span: 8.

Table 2: Mean Score, standard deviation, median and range of auditory sequencing score and auditory sequencing span for males and females across three age groups.

Age in years	Gender	Auditory Sequencing Scores				Auditory Sequencing Span			
		Mean	S.D.	Median	Range	Mean	S.D.	Median	Range
5-5;11	Male	11.45	8.14	11	2-30	1.38	1.85	0	0-4
	Female	13.36	7.57	12	3-30	2.92	1.03	3	0-4
	Combined	12.40	7.73	11.5	2-30	2.15	1.66	3	0-4
6-6;11	Male	21.00	12.65	19	7-53	3.00	1.47	3	0-5
	Female	18.18	10.43	17	5-43	3.23	1.16	3	3-5
	Combined	19.59	11.41	18	5-53	3.11	1.30	3	0-5
7-7;11	Male	24.20	6.92	25	15-36	3.16	1.19	3	3-4
	Female	27.27	9.26	25	17-39	3.92	.75	4	3-5
	Combined	25.80	8.18	25	15-39	3.56	1.04	4	3-5

Maximum Auditory Sequencing Scores: 118, Maximum Auditory Sequencing Span: 8.

Table 3: Results of Mann-Whitney U test to investigate the gender effect

z/*p* values	Auditory Memory score	Auditory sequencing score	Auditory Memory span	Auditory sequencing span
z value	0.09	0.26	1.28	1.84
p value	0.93	0.79	0.2	0.07

Table 4: Results of Kruskal-Wallis test to investigate the age effect				
	Auditory Memory score	Auditory sequencing score	Auditory Memory span	Auditory sequencing span
z value	9.99	21.36	9.69	8.92
p value	0.01	0.00	0.01	0.01

Table 4 shows the results of Kruskal-Wallis test carried out to study the age effect on auditory memory and sequencing. There was a significant main effect of age for auditory memory and sequencing scores as well as auditory memory and sequencing span. Hence pair wise comparison was carried out using Mann-Whitney U test.

Auditory memory score did not show a significant difference between children of 5 to 5;11 and 6 to 6;11 age group (z =1.39, *p*=0.17), whereas scores of auditory memory span showed a significant difference (z=2.78, *p*=0.01). Comparison of 5 to 5;11 and 7 to 7;11 year age groups showed a significant difference for both memory score (z=3.03, *p*=0.00) and memory span (z= 2.54. *p*=0.01). Children of 6 to 6;11 and 7 to 7;11 years, showed a significant difference for scores obtained using memory score (z=1.98, *p*=0.05) but not for memory span (z= 0.19, *p*=0.85).

Similar trend was observed for the scores of auditory sequencing. Children of 5 to 5;11 and 6 to 6;11 age group did not show significant difference for auditory sequencing scores (z =2.33, *p*= 0.2) whereas a significant difference was observed for sequencing span (z= 2.24, *p*= 0.03). A significant difference was observed between scores obtained for children of 5 to 5;11 and 7 to 7;11 years age groups for both auditory sequencing score (z= 4.46, *p*= 0.00) and span (z=2.76, *p* = 0.0). Children of 6 to 6;11 and 7 to 7;11 age group showed significant difference for sequencing scores (z=2.58, *p*=0.01) but not for sequencing span (z=0.67, *p*= 0.51).

The data obtained from children who are 'at-risk' for CAPD were compared with the data obtained from typically developing children who are 'not at-risk' for CAPD. The comparison was done with respective age groups as a significant age effect was observed for the scores of the typically developing children. It can be observed from the results of Mann-Whitney U test shown in Table 5 that for the auditory memory span, a significant difference was noticed between the two groups only for children in the age range 6 to 6;11 years whereas for auditory scores did not show significant difference for any of the age groups. Auditory sequencing scores showed significant difference for children in the age range of 5 to 5;11 and 6 to 6;11 years. Auditory sequencing span, showed a significant difference for only for children of 6 to 6;11 year age group.

Table 5: Results of Mann-Whitney U on comparison of children with and without symptoms of CAPD.					
Age in years	z/*p* values	Auditory Memory score	Auditory sequencing score	Auditory Memory span	Auditory sequencing span
5-5;11	z value	1.82	1.96	1.29	0.98
	p value	0.07	0.05	0.25	0.38
6-6;11	z value	1.82	2.81	2.70	2.32
	p value	0.07	0.00	0.01	0.03
7-7;11	z value	0.45	1.08	0.28	0.28
	p value	0.70	0.30	0.80	0.80

Individual data of children who are 'at-risk' for CAPD were inspected to compare the scores with those of typically developing children in the same age group. Scores were considered as abnormal if the score was less than mean minus 1 SD of the score obtained by typically developing children. Five out of twelve children who are 'at-risk' for CAPD obtained abnormally low score for both auditory memory scores and span and also on auditory sequencing span whereas eight children showed poor performance on auditory sequencing score.

Discussion

Auditory memory and sequencing skills plays important role in the auditory processing. Poor auditory memory and sequencing skill may result in CAPD or spoken language processing disorder. Children with CAPD have been found to have poor self-esteem(26,27), logic problems (27) and difficulty in social interactions (28). Children experiencing auditory processing difficulty have deleterious impact on school performance(27,29-31). It has been reported by that 2-3% of the population has CAPD (29,31), making it necessary to identify the condition early.

There is a debate as to whether auditory memory should be considered as a part of central auditory processing (CAP). Tolerance fading memory is proposed as one of the subtypes CAPD by Katz (32) and reported it as the second most common CAPD subtype in the general population. Individuals with TFM are reported to exhibit significantly weak short-term memory, difficulty in understanding and tolerating in noise (33). A review of literature suggests that auditory memory is affected in children with CAPD (19,29,31,34,35). Hence it is important to assess auditory memory and sequencing.

The present study developed a tool to assess auditory memory and sequencing in Marathi as it was not available in that language which is spoken by a large population in India. Item analysis of the tool was done to assess the quality of tokens in the test and the test as a whole. Results of item analysis suggest that the auditory memory and sequencing test has very good reliability. Cronabch's alpha obtained in the present study has been considered as having good reliability by the earlier investigators. Field,(36) reported that the Chronbach's alpha value should be above 0.7 for good reliability while Chawla et al. (37) opined that the Chronbach's alpha value between 0.80 to 0.95 is considered as very good reliability. Gliem et al. (38) reported in their study that Cronbach's alpha reliability coefficient above 0.7 is acceptable whereas coefficient above 0.8 is good. Spearman Brown coefficient value of split half reliability obtained in the present study is also considered as indicating good reliability by earlier researchers (e.g., Grover et al.(39)). Thus, the developed auditory memory and sequencing test can be considered as having good internal consistency and reliability.

Results of this study indicate that, typically developing boys and girls performed in a similar manner for auditory memory and sequencing tasks. These results support the findings of the earlier investigators (18,19,40,41). Age effect was observed in the present study. Both auditory memory and sequencing scores improved with age. Similar results were reported by previous investigators(18,19,40,41). In a study investigating cognitive linguistic skills in Kannada speaking children in the age range of 4 to 8 years, Anuroopa,et al, (17) observed that the number of items recalled increased with increase in age for digit forward recall, word recall and digit backward recall. The improvement observed can be correlated to neuro maturation in hippocampus and auditory processing pathway(42,43).

Relationship between memory abilities and hippocampal volumes are studied by various investigators. Daugherty et al. (42) found different magnitudes and patterns of age related changes in subfield volumes show dynamic microstructural factors which may implicate in increase in memory span. Longitudinal studies showed that hippocampus volume stabilizes in children as early as 4 years(44).

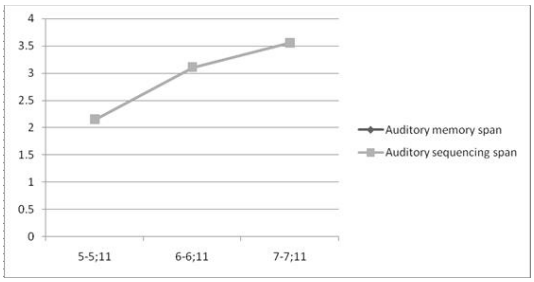

Fig. 1. Mean auditory memory and sequencing score across three age groups

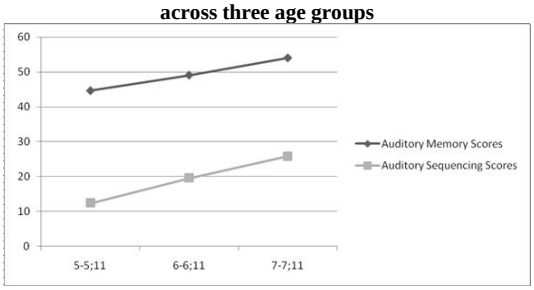

Fig. 2. Mean auditory memory and sequencing span across three age groups

Though an age effect was observed for auditory memory and sequencing scores as well as span, there was a difference in the trend. It can be observed from Figure 1 and 2 that there was a gradual improvement in auditory memory and sequencing scores while auditory memory and sequencing span improved rapidly from 5 to 6;11 years after that it improved gradually. This indicates that scoring method used for auditory memory and sequencing has an effect on the results obtained. Vaidyanathan et al (20) also observed that the trend in age effect varied depending on the method of scoring.

In children who are 'at-risk' for CAPD, significantly poorer auditory memory span was noticed when compared to the typically developing children who are 'not at-risk' for CAPD in both the age groups. Children who are 'at-risk' for CAPD in the age group of 6 to 6;11 years also showed significantly poorer performance than typically developing children on both auditory sequencing scores and span. There was no significant difference in the other age groups. However, these results need to be interpreted with caution as the sample size of children who are 'at-risk' for CAPD was very less. There is dearth of studies investigating auditory memory scores in children who are 'at-risk' for CAPD. Yathiraj et al. (19) reported that children with CAPD had poor auditory memory and sequencing score, however a significant difference was observed in some age groups while it was not observed in other age groups. Yathiraj et al. (35) studied correlation between SCAP and screening test for auditory processing disorders. Moderate significant correlation was noticed for auditory memory.

Inspection of individual revealed that auditory sequencing score and span could identify more number of children who are 'at-risk' for CAPD. Similar results were observed by Yathiraj et al. (19). In typically developing children also, it was observed that auditory memory scores were higher than the auditory sequencing scores in all the age groups. Similar findings were observed by earlier investigators(18-20)and this has been attributed to greater load required for remembering in the sequence when compared to memory.

Conclusions

A test was developed to assess Auditory Memory and Sequencing Abilities in Marathi speaking children. The developed test has good internal consistency and reliability. Data obtained from typically developing children showed a significant age effect for both auditory memory and sequencing abilities in the 5 to 8 year old children. There was no gender effect. Children who are 'at-risk' for CAPD showed poor performance on these tests. The results obtained varied depending on the methods of scoring. Auditory sequencing task was more difficult than auditory memory both in typically developing children who are 'not at-risk' and 'at-risk' for CAPD. Comparison of auditory memory and sequencing scores versus auditory memory and sequencing span in present article may act as stepping stone for further research.

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