KANNADA AUDITORY MEMORY AND SEQUENCING TEST

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INTRODUCTION

Hearing is a complex process that is often taken for granted. As sounds strike the eardrum, the acoustic signals begin to undergo a series of transformations through which the acoustic signals are changed into neural signals. For additional analysis these neural signals are then passed from the ear through complicated neural networks to various parts of the brain, and ultimately, recognition or comprehension takes place. Thus, the ability to detect the presence of sounds is only one part of the processing that occurs within the auditory system. There are many individuals who have no trouble detecting the presence of sound, but who have other types of auditory difficulties, such as difficulties understanding conversations in noisy environments, problems following complex directions, difficulty learning new vocabulary words or foreign languages. This can affect their ability to develop normal language skills, succeed academically, or communicate effectively. Often these individuals are not recognized as having hearing difficulties because they do not have trouble detecting the presence of sounds or recognizing speech in ideal listening situations. Since they appear to "hear normally," the difficulties these individuals experience could be the result of an attention deficit, a behaviour problem, a lack of motivation, or auditory processing problem (Schminky & Baran, 2000). An auditory processing disorder (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).

Auditory processing difficulties become more pronounced in challenging listening situations, such as noisy backgrounds or poor acoustic environments, great distances from the speaker, speakers with fast speaking rates, or speakers with foreign accents (Sloan, 1998). Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioural phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including, temporal resolution, temporal masking, temporal integration and temporal ordering; auditory performance with competing acoustic signals; and auditory performance with degraded acoustic signals (ASHA, 1996). ASHA 2005, has further revised the definition of (central) auditory processing [(C) AP] as perceptual processing of auditory information in the central nervous system (CNS) and the neurobiological activity that underlies that processing and gives rise to electrophysiologic auditory potentials. (C) AP includes the auditory mechanisms that underlie the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination (e.g., temporal gap detection), temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening); and auditory performance with degraded acoustic signals. (Central) Auditory Processing Disorder [(C) APD] refers to difficulties in the perceptual processing of auditory information in the CNS as demonstrated by poor performance in one or more of the above skills. Although abilities such as phonological awareness, attention and memory for auditory information, auditory synthesis, comprehension and interpretation of auditorily presented information, and similar skills may be reliant on or associated with intact central auditory function, they are considered higher order cognitive–communicative and/or language related functions and, thus, are not included in the definition of (C) AP (ASHA, 2005).

According to Schminky and Baran (2000), and Keith (1995, cited in Ciocci, 2002), the common behavioural characteristics seen in children with APD includes:

- Poor listening skills,
- Difficulty learning through the auditory modality,
- Difficulty following auditory instructions,
- Short attention span,
- Difficulty understanding in the presence of background noise,
- Frequently saying "huh" or "what",
- Difficulty with "phonics",
- Poor auditory memory for commands and sequences,
- Tend to recall the last part of a sequence and forget what is said soon after,
- Tend to give slow or delayed responses to verbal stimuli,
- Misunderstands what is said or "mishear",
- Difficulty understanding speech that has been muffled or distorted,
- Poor attention and focusing,
- Easily distracted primarily by noise,
- Reduced tolerance for loud noises,
- Difficulty sorting out information and identifying relevant from irrelevant information,
- Confusion with similar sounding words,
- Require repetition of age level appropriate directions,
- Require clarification of age level appropriate directions,
- Difficulty understanding discussions,
- Confusion of similar sounding words,

- Poor receptive and expressive language and
- Reading, spelling and academic problems.

There is an increasing demand on the audiologist to provide useful clinical batteries for diagnosing auditory processing disorders (APDs) in children using standard audiological test conditions. Children are rarely referred to the audiologist based on auditory processing issues in isolation. Typically, referred children have other problems, such as learning, speech, language, attention and/or reading difficulties. It is likely that most children with APDs have co–morbid conditions and therefore, the audiologist needs to ideally provide a targeted diagnostic battery that will ultimately distinguish auditory processing difficulties from other disorders (Moncrieff, 2002).

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). The quality of 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).

Memory has been viewed, as the flow of information through the mind is one prominent view. Based on this three broad stages of information processing can be distinguished. First, there is the sensory register, a very short–term sensory memory of the event. At the second level is a short–term or working memory and third is long–term memory (Cusimano, 2001). The sensory register concerns memories that last no more than about a second. If a line of print were flashed very rapidly, approximately for one–tenth of a second, all the letters that can be visualized for a brief moment after that presentation constitute the sensory register. This visualization disappears after a second. Trying to recall a telephone number that was heard a few seconds earlier, the name of a person who has just been introduced, or the substance of the remarks just made by a teacher in class, are some of the examples of short–term memory, or working memory. This lasts from a few seconds to a minute; the exact amount of time may vary somewhat. Long–term memory is used to recall general information about the world that has been learned on previous occasions, memory for specific past experiences, specific rules previously learned (Cusimano, 2001).

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. Locke (1968) has suggested that a discrimination impairment seen in auditory processing disorder cases may be a by product of, or coexist with an auditory memory deficit. Probably the most prevalent but most often overlooked leading skill deficiency is auditory memory. These studies indicate different aspects of the development of memory in children. Children gradually acquire knowledge and appreciation of retrieval cues and effective strategies for coding, organizing and retrieving items in memory (Howe & Ceci, 1978).

Weisner, et al., (2000) have also reported evidence of auditory memory deficits in children with learning disabled. This may be of particular importance as it is argued that the phonological loop plays an important role in the acquisition of certain aspects of language and of vocabulary in particular.

According to Cusimano (2001) memory is the retention of information over time. Different types of memories were reported of. Each type was considered to be somewhat independent of the others. It was noted that memory could be assessed by different ways: recall, recognition, and paired associates. The most popularly studied kind of memory is recall. Recollection of a telephone number just heard, a list of items to be purchase at the store, or lists of dates learned in history class are all examples of recall. A second type of memory is recognition, which is generally easier than recall, for example a history teacher gives four dates and learners are to choose the one that goes with the specific historical event. Another kind of memory is called paired associates. It is a child's ability to memorize a list of paired items, such as pictures and names, common objects and nonsense syllables, or words and corresponding visual scenes.

Children with auditory processing problems have difficulties at the level of short–term memory, often called working memory. Problems with short–term memory are mostly noted on long verbal commands. That is, children can remember part of the long command or short command, but get lost trying to remember longer commands it total. According to Cusimano (2001) students with auditory memory weaknesses pick up only bits and pieces of what is being said during a classroom lecture. Hence, they make sense of only a little of what is being said by the teacher. Later they recall only a small amount or none of what was said. Students with auditory memory deficiencies will often experience difficulty developing a good understanding of words, remembering terms and information that has been presented orally, for example, in history and science classes. The children will also experience difficulty processing and recalling information that they have read to themselves. Even in silent reading it is necessary to read, listen and then process information said to oneself. If the children do not attend and listen to the silent input of words, they cannot process information or recall what has been read. Similarly Yathiraj and Mascarenhas (2003) have reported all the children with auditory processing problems whom they evaluated had poorer auditory sequencing ability.

It was opined by Jarold, Baddeley, Heves, Leeke and Philips (2004) that recall 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, which are phonologically dissimilar. In addition, spans are shorter for words of a long spoken duration (example Helicopter and police man) than for words of short–spoken duration (example pig and shoe).

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 is able to test the number of elements the subject is able to retain and retrieve (Lumley & Calhoun, 1934; 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 (Jarold et, al., 2004).

There are various reports on electrophysiological studies related to memory using varying inter-stimulus intervals. It has been reported in these studies that by prolonging the time interval between successive stimuli it is possible to obtain information about the duration of the sensory trace of the standard stimulus provide by the diminution of the MMN amplitude with longer inter-stimulus interval (Mantysalo & Naatanen, 1987; Naatanen, Paavilainen, Alho, Reinikainen & Sams, 1987; Bottcher–Gandor & Ullsperger 1992; Naatanen, 1992, as cited in Ceponiene, 2001).

According to Stockard–Pope, Werner and Bickfird, (1992 as cited in Ceponiene, 2001), Mismatch negativity (MMN) peaks appeared to be sharper in shape and shorter in duration in six month–old infants compared to newborn babies. With increase in inter-stimulus interval the amplitude of MMN diminished for both normal children and children with a learning disability. Pekkonen, Jousmaki, Partanen, and Karhu (1993), tested 27 normal subjects aged 18–85 years using 1 sec and 3 sec inter-stimulus intervals and to 6 young subjects using an additional inter-stimulus intervals of 5 sec. MMN area was quite stable regardless of the age with 1 sec inter-stimulus intervals. With a 3 sec inter-stimulus interval, MMN area was significantly smaller in the old than in the young subjects. This may reflect the shortening of the sensory auditory memory trace with increasing age.

Devi, Sujita and Yathiraj (2006) obtained normative data for an auditory memory and sequencing test in English for children between 6–12 years. The results indicated that auditory memory scores increased with advance in age up to ten years, 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 across gender in two age groups, with the males out performing the females. The normative data, which was obtained, was used to determine whether children with suspected auditory memory deficits could be identified. For this purpose the test was administered on ten children who were diagnosed as learning disabled. The scores were compared with age appropriate normative data. The results revealed that the majority of children with a learning disability had auditory memory deficits.

NEED FOR THE STUDY

There are high percentages of children with auditory memory problems, who ultimately drop out of school, not being able to cope up with the situation. Intensive auditory learning therapy may help these children perform adequately in a school situation without having to use special expensive devises. In order to enable such children to make maximum use of their auditory capabilities, it is necessary to give them intensive auditory learning therapy using appropriate material (Lapish, 1994).

Reviewing the literature it is clear that auditory memory varies with age. Owing to the fact that memory plays an important role for spoken language processing and learning, strengthening memory and sequencing across different age groups is required. In order to determine whether a child requires training to improve memory, it is first essential to evaluate and see whether the child actually has a problem or not. Hence, the need for the present study was felt. Further such a test would provide insight into the utility of a therapy program when pre and post therapy performance on the test are compared.

AIMS OF THE STUDY

The present study aimed at:

1. Developing test material for evaluation of auditory memory and sequencing
2. Obtaining normative data on auditory memory and sequencing in normal children in the age range of 5–12 years and across gender.
3. To indicate the most appropriate protocol that can be used to determine the presence of auditory / sequence problem.
4. In addition it also aims at determining whether children with suspected auditory memory problems could be identified based on the norms obtained.
5. Based on the findings the children can be referred for listening training to improve their auditory memory.
6. The test could be used to monitor the progress made during and after therapy.

METHOD

The present study was conducted in three stages. *Stage one* involved the development of material for diagnostic evaluation of auditory memory problems in children with APD. *Stage two* involved obtaining normative data and *stage three* involved checking the utility of the test on a group of children with a report of a memory problem.

Subjects:

The subjects comprised of 210 normal children and 10 children having difficulty in auditory memory. The subjects were in the age range of 5–12 years.

Subjects for Normative Data:

The tests developed were administered on a group of 210 normal children. The subjects were divided into seven age groups having 30 children in each group. The age groups included were 5years to 5years 11months, 6 years to 6 years 11months, 7 years to 7 years 11months, 8 years to 8 years 11months, 9 years to 9 years 11months, 10 years to 10 years 11months, and 11 years to 12 years. Of the 30 children in each group, fifteen were boys and fifteen were girls. The screening checklist for auditory processing (SCAP) developed by Yathiraj and Mascarenhas (2003) was administered to rule out any auditory processing disorder (Appendix-A). These children were taken from preschool, primary and middle schools in Mysore city. Children who passed the checklist and met the following criteria were selected:

- Were fluent speakers of Kannada and had been exposed to the language from early childhood.
- Had normal IQ as per the Raven's coloured progressive matrices (Raven, 1965).
- Had no history of peripheral hearing loss and no symptoms of auditory processing problems.
- No history of otological and neurological problems.
- No speech problems.
- No report of speech identification problems.
- Normal hearing as per screening pure tone audiometry and immittance audiometry, and
- Normal educational performance as reported by the parents.

Experimental Group:

- The children in the experimental group met all the criteria of the children included for obtaining the normative except they had problems in retaining auditory information, as reported by the parents and school teachers.
- The children who failed the SCAP

Instruments:

- A Pentium 4 computer with Creative Wave Studio software was used to record the developed material.
- A calibrated portable audiometer and immittance meter (MT 10) was used to check for normal peripheral hearing.
- An audio CD player was used (Sony) to present the test material.

Material:

- The “Screening Checklist for Auditory Processing” (SCAP) developed by Yathiraj and Mascarenhas (2003).
- Raven’s coloured progressive matrices (Raven, 1965).
- The “Auditory Memory And Sequencing Test” developed in the project.

Test Environment:

The testing was done in a quite room, which was free from auditory and visual distraction.

Procedure:

The three stages of the study were as described below.

Stage One: Development of material for test.

Meaningful bisyllabic Kannada words were taken from Kannada books of children from preschool, grade1 and grade 2. To confirm that these items were familiar, a pilot study was conducted. Twenty normal children in the age range of four to six years, from different Kannada medium preschools were considered as subjects. Each child was asked to describe the words read out or point to a picture representing the word. The responses were noted as correct or incorrect. The words, which 80–90% of the children could describe or identify, were considered for the test.

The material was recorded onto a Pentium VI computer using Creative Wave Studio software using a sampling rate of 44 kHz. Scaling of the signals was done using the "Audiolab" software to ensure that the intensity of all the sounds was brought to the same level. Four different lists were developed having different inter-stimulus intervals (Appendix-B). The inter-stimulus intervals were 250 msec, 500 msec, 750 msec and 1 sec. The test items were different in each list to avoid any practice effect. It was ensured that the different lists were of equal difficulty. In each list the length of the word sequence increased from a three–word sequence to an eight–word sequence. Each sequence group is referred to as a token. There were two tokens in the three and four word sequences and four tokens each in all the other sequences (i.e., 5, 6, 7 and 8) as described in Table1. Goodness rating of the recorded words was done on ten normal individuals. It was found that all the words were easily identified by these ten individuals, indicating that the quality of recording was good.

Table 1: Sample of the developed test material

3 word sequence	la:ri	se:bu	tʃa:ku					
3 word sequence	mantʃa	bekku	tuTi					
4 word sequence	me:ke	ha:vu	kattu	bi:ga				
4 word sequence	o:Du	lo:Ta	roTTi	maLe				
5 word sequence	Ili	gu:be	mu:ru	ba:la	dzaDe			
5 word sequence	akka	maNNu	ra:Ni	baTTe	to:La			
5 word sequence	la:Du	ba:yi	hagga	mo:Da	ka:su			
5 word sequence	ba:Na	kappu	tʃenDu	mukha	tinDi			
6 word sequence	muLLu	kombe	ga:Di	hu:vu	dzi:pu	pe:sT		
6 word sequence	laiTu	Karu	batta	halli	moTTe	dzinke		
6 word sequence	tʃakra	moLe	adzdzi	ole	ko:lu	nimbe		
6 word sequence	bja:gu	Sihi	guri	da:ra	klippu	vaDe		
7 word sequence	friDdz	enTu	pu:ri	gedzdze	nalli	pinnu	ka:ge	
7 word sequence	dappa	tʃitra	ni:ru	mane	kallu	o:du	bennu	
7 word sequence	ʃa:le	baTlu	aidu	kere	tʃatri	di:pa	hoTTe	
7 word sequence	baLe	hubbu	si:re	bo:Tu	ra:dza	noNa	pho:nu	
8 word sequence	do:Ni	so:pu	bisi	hasu	beTTa	go:li	mora	kaNNu
8 word sequence	huli	dzju:s	nu:ru	katti	ba:vi	ganTe	tʃaTni	braSu
8 word sequence	sonne	dana	pja:nTu	su:rja	biLi	appa	ka:lu	manDi
8 word sequence	o:le	bi:Lu	hoDi	ke:k	mi:nu	kempu	rave	maNi

The interval between the tokens was six seconds for the 3, 4 and 5 word sequences and increased to 12 seconds for the 6, 7 and 8 word sequences.

Stage Two:

Initially the evaluation was done to select the subjects for the study. Those who met the subject selection criteria, were tested using the developed "Kannada Auditory Memory and Sequencing Test".

Procedure for subject selection:

To select subjects, each child was evaluated using the following tests:

- Screening pure tone audiometry,
- Screening immittance audiometry,
- Raven's coloured progressive matrices (Raven, 1965),
- Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarenhas (2003).

To confirm that the children had normal hearing, puretone screening and screening immitttance was carried out. Pure tone screening was done at 20 dB HL. The signal was presented through insert phones and finger raising responses were obtained from the children. Those who obtained thresholds within 20 dB HL were further tested to also rule out the presence of middle ear problems. Children, who obtain 'A' type tympanograms and had reflexes present, were included in the study.

To screen for the presence of normal intelligence, The Raven's colored progressive matrices (RCPM) was used. The three sets A, Ab, B, each with twelve problems constituting the coloured matrices were used to assess the chief cognitive processes of each child less than 11 years of age. The test was administered using the instructions given in the manual. The responses were recorded and scored as per the instructions provided in the manual. The children, whose score were above 25% the percentile point, were considered as subjects for the study. This cut–off score enabled including only those with average and above average intellectual capacity and eliminated those with below average intellectual capacity.

The screening checklist for auditory processing (SCAP) developed by Yathiraj and Mascarenhas (2003) was administered to rule out any auditory processing disorder. The response to the checklist was obtained from teachers who knew the children well.

Procedure for administering the memory test:

The children who passed the above tests were later tested using all the four lists of the developed Kannada auditory memory and sequencing test (KAMST). The lists A, B, C, and D had inter-stimulus interval s of 250 msec, 500 msec, 750 msec and 1sec respectively. The lists were randomized to prevent an order effect. The testing was done in a quite room, which was free from distraction. The signals were presented at a comfortable level through a CD player. Each child was tested individually. The subject was seated one meter away from the player at a zero degree azimuths. 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.

A score of one was awarded for every correct word that was recalled. An addition nil score of one was awarded if the words were recalled in the correct sequence.

Stage Three:

For checking the utility of the test in determining auditory memory problems, ten children who were reported by the school teachers and the parents to have problems in retaining auditory information, were included in the experimental group.

The procedure for subject selection for this group was the same as that used for selecting the subjects for the normative data. This was true for the pure tone, immittance and Raven's colored progressive matrices (RCPM) tests. However only those who failed the screening checklist for auditory processing (SCAP) were included. These children were further tested in a similar manner as the normal children using all the developed KAMST. They were tested with all four inter-stimulus intervals (250 msec, 500 msec, 750 msec and 1sec). Scoring was also done in a similar manner.

RESULTS AND DISCUSSIONS

The raw scores obtained for the Kannada Auditory Memory And Sequencing Tests were tabulated. This was done for the two subtests, seven age groups, and both genders. This data was analyzed using the statistical package SPSS version 10. The results are explained under the following headings:

1.0 Control group

1.1 Effect of gender

- 1.1.1 Effect of gender on the auditory memory subtest
- 1.1.2 Effect of gender on the auditory sequencing subtest

1.2 Effect of age

- 1.2.1 Effect of age on the auditory memory subtest
- 1.2.2 Effect of age on the auditory sequencing subtest

1.3 Effect of inter-stimulus interval (ISI)

- 1.3.1 Effect of inter-stimulus interval on the auditory memory subtest
- 1.3.2 Effect of inter-stimulus interval on the auditory sequencing subtest
- 1.3.3 Analysis of word sequences
- 1.3.4 Comparison of auditory memory scores with sequencing scores across inter-stimulus intervals

2.0 Comparison of the experimental group with the control group on the auditory memory and auditory sequencing subtests

1.0 Control group

Repeated measure ANOVA was done to study the effect of gender, age, and inter-stimulus interval on auditory memory and auditory sequencing in the normal group. The results of these analyses are discussed in the following sections.

1.1 Effect of gender

1.1.1 Effect of gender on the auditory memory subtest:

The means and standard deviations of the auditory memory subtest are given in table 2. The scores for both gender as well as the total are depicted. This is done for each age group across the different inter-stimulus intervals.

Table 2

Mean scores and Confidence interval (CI) of auditory memory subtest for males and females across inter-stimulus intervals for each age group.

Age in Years	Gender	250 m sec		500 m sec		750 m sec		1 sec	
		Mean	CI	Mean	CI	Mean	CI	Mean	CI
5–6	Male	54.6	-	54.6	-	46.1	-	45.5	-
	Female	55.1	-	55.1	-	47.5	-	45.3	-
	Combined	54.9	52-65	54.9	53-69	46.8	44-50	45.4	43-48
6–7	Male	64.0	-	64.0	-	53.0	-	49.9	-
	Female	71.3	-	71.3	-	64.3	-	62.4	-
	Combined	67.7	65-75	67.7	66-71	58.6	54-63	56.1	51-61
7–8	Male	81.8	-	81.8	-	75.4	-	73.2	-
	Female	81.3	-	81.3	-	75.7	-	73.3	-
	Combined	81.5	80-83	81.5	81-83	75.6	74-77	73.3	71-75
8–9	Male	85.2	-	85.2	-	78.6	-	78.3	-
	Female	84.8	-	84.8	-	79.8	-	78.1	-
	Combined	85.0	83-87	85.0	82-85	79.2	78-81	78.2	77-80
9–10	Male	88.8	-	88.8	-	83.3	-	81.7	-
	Female	84.4	-	84.4	-	81.6	-	79.6	-
	Combined	86.6	83-90	86.6	86-91	82.5	80-85	80.6	78-83
10–11	Male	95.1	-	95.1	-	89.4	-	86.8	-
	Female	93.8	-	93.8	-	88.9	-	84.4	-
	Combined	94.5	92-97	94.5	92-99	89.1	87-92	85.6	83-88
11–12	Male	103.0	-	103.0	-	96.7	-	94.3	-
	Female	102.8	-	102.8	-	96.7	-	94.1	-
	Combined	102.9	101-105	102.9	99-104	96.7	95-99	94.2	92-96
Avera ge	Male	81.8	-	81.8	-	74.6	-	72.8	-
	Female	81.9	-	81.9	-	76.3	-	73.9	-
	Combined	81.8	79-83	81.8	79-83	75.5	73-78	73.3	70-77

From table 2 it is evident that both males and females performed in a similar manner on the auditory memory subtest. To check whether these scores were statistically significant, repeated measure ANOVA was carried out. The effect of gender on the overall auditory memory scores was not statistically significant [$F(1, 196) = 1.121$, $p > 0.05$]. There was no significant interaction between gender and age [$F(6, 196) = 3.175$, $p > 0.05$] as well. Also there was no significant interaction between gender and inter-stimulus intervals [$F(3, 588) = 1.491$, $p > 0.05$], as well as between gender, inter-stimulus intervals and age [$F (18, 588) = 1.072$, $p > 0.05$] on the auditory memory subtest. These indicate that irrespective of the age and inter-stimulus interval, males and females performed in a similar manner on the auditory memory subtest.

1.1.2 Effect of gender on the auditory sequencing subtest:

The mean scores and standard deviations of the auditory sequencing subtest for both gender and their total are given in table 3. This information is provided across the seven age groups and four inter-stimulus intervals.

Table 3

Mean scores and Confidence interval (CI) of auditory sequencing subtest for males and females across inter-stimulus interval for each age group.

Age in Years	Gender	250 m sec		500 m sec		750 m sec		1 sec	
		Mean	CI	Mean	CI	Mean	CI	Mean	CI
5–6	Male	9.3	-	9.6	-	5.2	-	3.4	-
	Female	12.3	-	10.2	-	5.6	-	4.0	-
	Combined	10.8	9-13	9.9	8-12	5.4	4-7	3.7	3-5
6–7	Male	24.0	-	18.2	-	10.8	-	6.5	-
	Female	20.3	-	18.4	-	13.3	-	12.1	-
	Combined	22.2	19-25	18.3	16-21	12.1	9-16	9.3	6-12
7–8	Male	47.4	-	45.3	-	34.4	-	29.4	-
	Female	48.5	-	51.4	-	34.6	-	31.9	-
	Combined	48.0	44-51	48.3	44-52	34.5	30-39	30.6	26-35
8–9	Male	46.2	-	44.4	-	31.8	-	29.6	-
	Female	49.4	-	48.2	-	35.4	-	35.8	-
	Combined	47.8	44-51	46.3	43-50	33.6	30-37	32.7	30-36
9–10	Male	53.7	-	57.9	-	46.8	-	44.7	-
	Female	52.4	-	53.4	-	41.8	-	40.6	-
	Combined	53.1	48-57	55.6	53-59	44.3	40-48	42.7	38-48
10–11	Male	67.1	-	65.1	-	54.4	-	54.8	-
	Female	61.1	-	60.9	-	51.1	-	51.0	-
	Combined	64.1	59-69	63.0	59-67	52.7	49-57	52.9	49-57
11–12	Male	82.3	-	75.8	-	69.2	-	65.2	-
	Female	75.4	-	71.6	-	65.8	-	60.6	-
	Combined	78.9	73-85	73.7	69-78	67.5	65-70	62.9	60-66
Average	Male	47.1	-	45.2	-	36.1	-	33.4	-
	Female	45.6	-	44.9	-	35.4	-	33.7	-
	Combined	46.4	44-47	45.0	42-48	35.7	32-41	33.5	30-39

Similar to the auditory memory subtest, only a marginal gender difference was noticed across the different age groups and inter-stimulus intervals. To check whether these scores were statistically significant, repeated measure ANOVA was carried out.

Gender was not found to have any effect on the overall auditory sequencing scores [$F(1, 196) = 0.230$, $p > 0.05$]. This lack of a significant difference between males and females was observed irrespective of the age of the subjects or the inter-stimulus intervals. Thus, it can be construed that males and females performed alike on the auditory sequencing subtest. Devi, Sujitha and Yathiraj (2006), had also reported of no significant difference across gender in the auditory memory test. This was true for the auditory memory as well as sequencing subtests of the test that were carried out in English.

1.2 Effect of age:

1.2.1 Effect of age on the auditory memory subtest

From table 2 it can be noted that with an increase in age there was an increase in the auditory memory scores. This was observed for both genders and at each of the inter-stimulus intervals. The repeated measures ANOVA revealed that the effect of age on the overall auditory memory scores was statistically significant [$F(6, 196) = 251.031$, $p < 0.001$]. To obtain more details, a post hoc test was carried out. The results of Bonferroni's multiple comparison test are shown in table 4.

Table 4
Significance of difference of the overall auditory memory scores across ages.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	SD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

It can be noticed from table 4 that there was a significant difference between all the age groups. Since there was an interaction between age and inter-stimulus interval, a one–way ANOVA was carried out. It was found that at each of the inter-stimulus intervals there was a significant effect of age (p < 001). This was observed immaterial whether the inter-stimulus interval was 250 msec, 500 msec, 750 msec or 1 sec. Duncan's Post-Hoc test was performed to see the pair wise differences of age groups at each inter-stimulus interval. Tables 5, 6, 7, and 8 gives the significance of difference between the different age groups for lists of words having inter-stimulus intervals of 250 msec, 500 msec, 750 msec and 1 sec, respectively.

Table 5

Significance of difference of memory subtest across ages for words having an inter-stimulus interval of 250 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	SD	–		
9–10	SD	SD	SD	NSD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 5 shows no significant difference between the 8-9 year olds and the 9-10 year olds. However, there existed a significant difference across all other age groups. This occurred when the inter-stimulus interval was 250 msec.

Table 6

Significance of difference of memory subtest across ages for words having an inter-stimulus interval of 500 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

When the inter-stimulus interval was 500 msec, no significant difference between the age groups 7-8 years and 8-9 years was present. In contrast there existed a significant difference across all other age groups (Table 6).

Table 7

Significance of difference of memory subtest across ages for words having an inter-stimulus interval of 750 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	NSD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 7 reveals no significant difference between the age groups 7-8 years and 8-9 years as well as 8-9 years and 9-10 years. All other age groups differed significantly from each other.

Table 8

Significance of difference of the memory subtest across ages for words having an inter-stimulus interval of 1 sec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	SD	–		
9–10	SD	SD	SD	NSD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 8 shows no significant difference between the age groups 8–9 years and 9–10 years, while a significant difference was seen between all other age groups.

Thus, in general it can be observed that most of the age groups differed significantly from each other, irrespective of the inter-stimulus interval on the auditory memory subtest. This is evident from tables 5, 6, 7, and 8. Children in the middle groups performed similarly at different inter-stimulus intervals. However, the younger and older children differed significantly from all other age groups. It was generally noted that as the children grew older their scores improved in both males and females. No significant different was observed between only a few age groups. Hence, it is recommended that while assessing auditory memory, the scores should be compared with age appropriate norms.

1.2.2 Effect of age on the auditory sequencing subtest:

From table 3 it can be observed that there was an increase in auditory sequencing scores with increase in age. This was observed irrespective of the genders and inter-stimulus interval. The repeated measure ANOVA revealed that the effect of age on the overall auditory sequencing scores was statistically significant [F (6, 196) = 222.628, $p < 0.001$]. The overall auditory sequencing scores was a total of the scores obtained by the males and females, across all the age group and for all tokens on the auditory sequence subtest. A post hoc test was done for further analysis. The results of Bonferroni's multiple comparison are shown in table 9.

Table 9

Significance of difference of the overall auditory sequencing scores across age groups.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

A significant difference was observed across all age groups with one exception. No significant difference was obtained between the 7-8 years olds and the 8-9 year olds. Since there was an interaction between the inter-stimulus interval and age, a one–way ANOVA was carried out. A significant effect of age ($p < 0.001$) was found at each of the inter-stimulus interval. This was observed at each of the inter-stimulus intervals, 250 msec, 500 msec, 750 msec and 1 sec. To see the pair wise differences, Duncan's Post–Hoc test was performed for all age groups at each inter-stimulus interval. Tables 10, 11, 12, and 13 gives homogenous set of age groups with lists of words having an inter-stimulus interval of 250 msec, 500 msec, 750 msec and 1 sec respectively.

Table 10

Significance of difference of sequencing subtests across ages for words having an inter-stimulus interval of 250 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	NSD	NSD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 10 reveals no significant difference between the scores obtained by the age groups 7-8 years, 8-9 years and 9-10 years. All other age groups differed significantly from each other.

Table 11

Significance of difference of sequencing subtests across ages for words having an inter-stimulus interval of 500 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 11 shows no significant difference between the 7-8 year olds and the 8-9 year olds. However, there existed a significant difference across all other age groups. This occurred when the inter-stimulus interval was 500 msec.

Table 12

Significance of difference of sequencing subtests across ages for words having an inter-stimulus interval of 750 msec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

When the inter-stimulus interval was 750 msec, no significant difference between the age groups 7-8 years and 8-9 years was present. In contrast there existed a significant difference across all other age groups (Table 12).

Table 13

Significance of difference of sequencing subtests across ages for words having an inter-stimulus interval of 1 sec.

Age in Years	5–6	6–7	7–8	8–9	9–10	10–11
5–6	–					
6–7	SD	–				
7–8	SD	SD	–			
8–9	SD	SD	NSD	–		
9–10	SD	SD	SD	SD	–	
10–11	SD	SD	SD	SD	SD	–
11–12	SD	SD	SD	SD	SD	SD

Note: SD = significantly different
NSD = not significantly different

Table 13 shows no significant difference between age groups 7-8 years and 8-9 years, while a significant difference was seen in all other age groups.

It was generally observed that most of the age groups differed significantly from each other irrespective of the inter-stimulus interval (Tables 10, 11, 12 and 13). As the age increased there was an increase in the auditory sequencing scores in all four inter-stimulus intervals (Table 3) as seen in auditory memory scores. The auditory sequencing scores are significantly lowered in the younger age groups compared to the older groups. Children in the middle groups (7-8 years and 8-9 years) showed similar performance at different inter-stimulus intervals. The older children had significant by higher scores compared to the younger age groups. Hence, it is recommended that while assessing auditory sequencing, the scores should be compared with age appropriate norms.

Devi, Sujitha, and Yathiraj (2006), also reported that auditory memory and sequencing scores increases with advance in age. They carried out the study on children using English words. They too noted no significant difference across gender.

1.3 Effect of inter-stimulus interval (ISI)

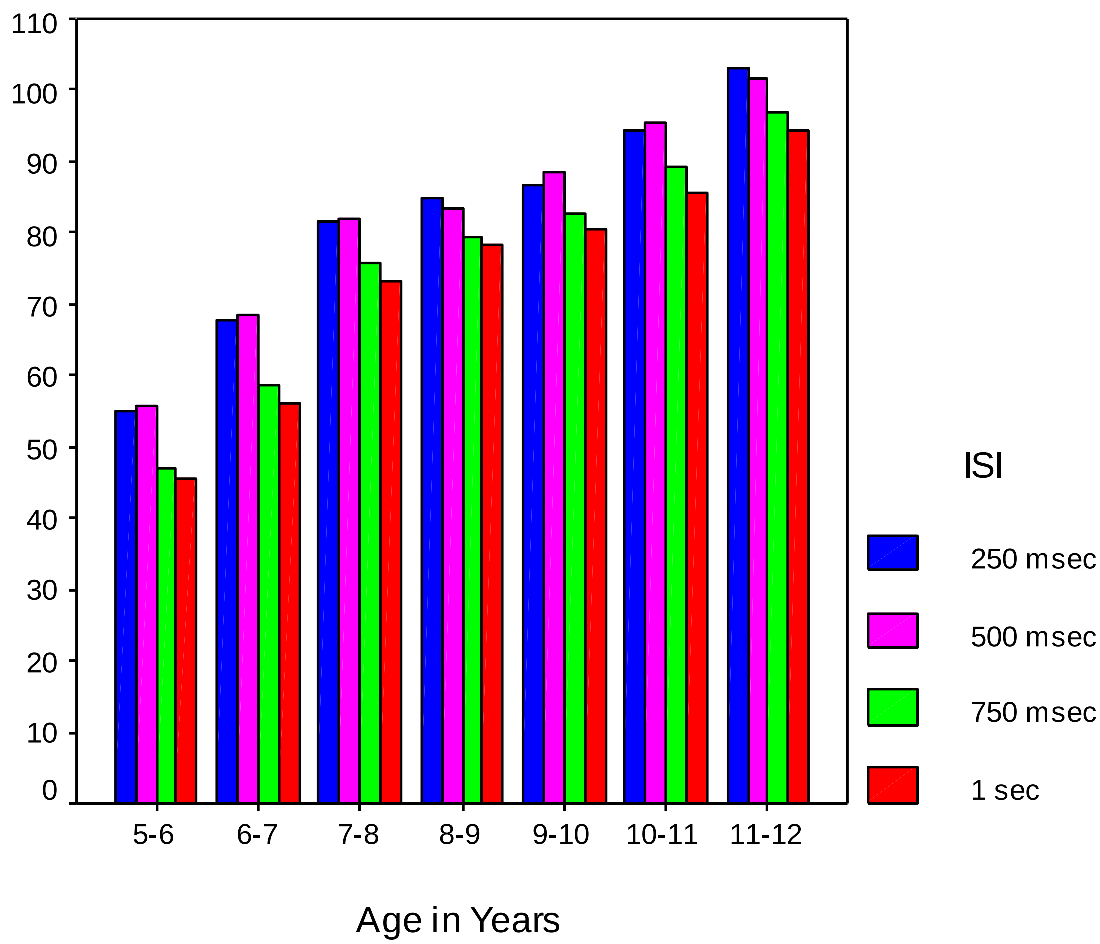
1.3.1 Effect of inter-stimulus interval on the auditory memory subtest:

Repeated measure ANOVA indicated that there was a significant difference between memory scores depending on the inter-stimulus intervals [F (3, 588) = 237.583, P < 0.001]. Since there was significant difference between the scores obtained at the four inter-stimulus intervals (250 msec, 500 msec, 750 msec or 1 sec), Bonferroni's multiple comparison was performed to check for pair–wise differences. It was observed that there was no significant difference between the scores with inter-stimulus intervals of 250 msec and 500 msec. However, there was a significant difference between the other pairs at the 0.05 level.

It was also evident that there was a significant interaction between inter-stimulus intervals and age [$F(18, 588) = 2.666$, $p < 0.001$]. There was however, no significant interaction between inter-stimulus intervals and gender [$F(3, 588) = 1.491$, $p > 0.05$], or between inter-stimulus intervals, age and gender [$F(18, 588) = 1.072$, $p > 0.05$].

Figure I:

Mean scores of the auditory memory subtest for the age groups across inter-stimulus intervals (ISI)



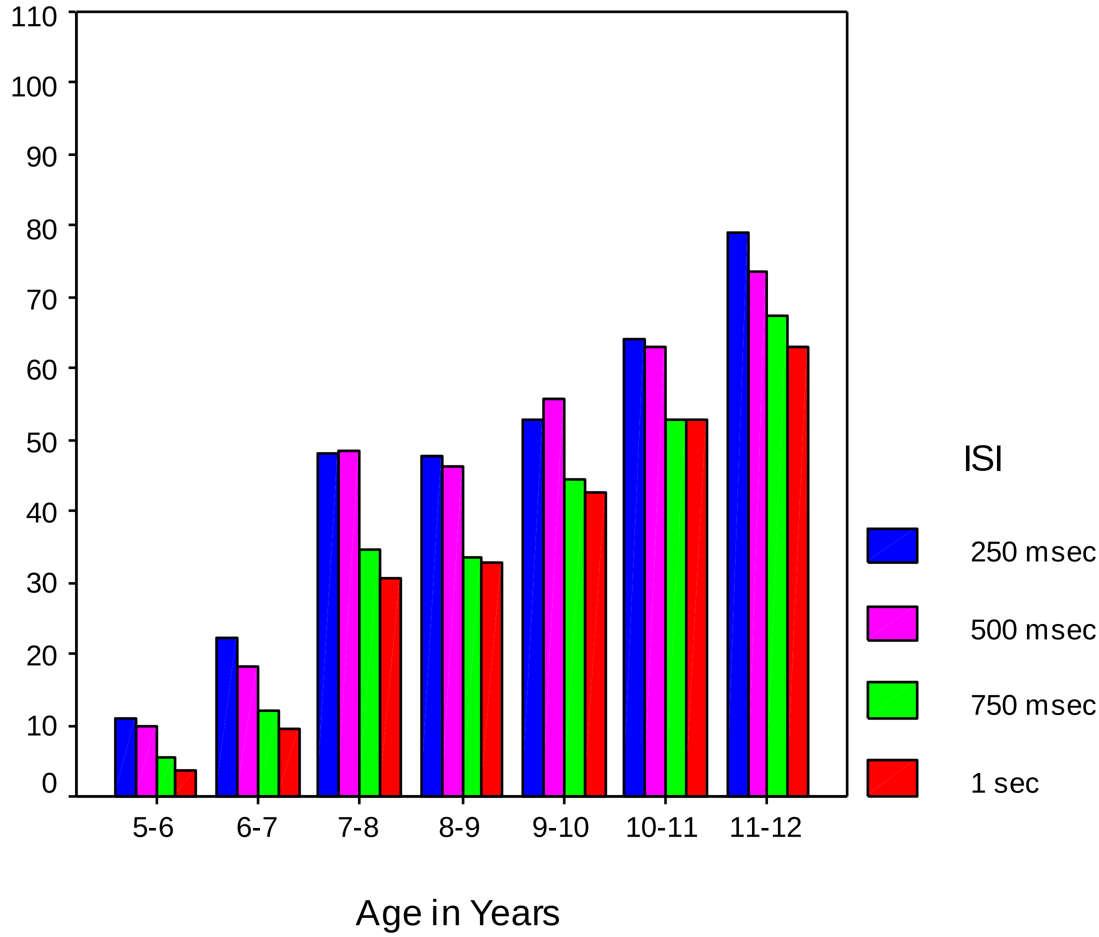
From figure I and tables 5, 6, 7, and 8, it is evident that all the children had scored higher with lists having an inter-stimulus interval of 250 msec and 500 msec when compared to the higher two inter-stimulus intervals. Since the shorter two inter-stimulus intervals did not differ significantly from each other, either of these can be used. This trend was observed across all the seven age groups as well as in both males and females. As the inter-stimulus intervals increased to 750 msec and 1 sec, the auditory memory scores dropped. This occurred for all age groups.

1.3.2 Effect of inter-stimulus interval on the auditory sequencing subtest:

Similar to the auditory memory subtest scores, it was found that there was a significant difference between the inter-stimulus intervals [$F (3, 588) = 227.979$, $p < 0.001$] for the auditory sequencing subtest scores. Since there was a significant difference between the scores, Bonferroni's multiple comparison was performed to see the pair–wise differences. Once again, similar to the auditory memory subtest, there was no significant difference noted between the tokens with inter-stimulus intervals of 250 msec and 500 msec was noted. However, there was a significant difference between all the other pairs at the 0.05 level.

It was also noted that there was a significant interaction between all four inter-stimulus intervals and age groups [$F (18, 588) = 3.718$, $p < 0.001$], but no significant interaction between inter-stimulus intervals and gender [$F (3, 588) =0.840$, $p > 0.05$]. There was no significant interaction between inter-stimulus intervals, age and gender [$F (18, 588) = 0.892$, $p > 0.05$].

Figure II: Mean scores of the auditory sequencing subtest for the age groups across inter-stimulus interval (ISI)



From figure II and tables 10, 11, 12 and 13 it is evident that with inter-stimulus intervals of 250 msec and 500 msec, all the children scored higher when compared to larger inter-stimulus intervals on the auditory sequencing subtest. Similar to the auditory memory subtest scores, the children obtained scores that were not statistically significant for these two shorter inter-stimulus intervals. This trend was observed across all the seven age groups as well as in both males and females. Since they did not differ significantly, either of these two inter-stimulus intervals can be used. As the inter-stimulus intervals increased to 750 msec and 1 sec, the auditory sequencing scores dropped.

Similar findings have also been reported in literature. Pekkonen, Jousmaki, Partanen, and Karhu (1993), studied the effect of inter- stimulus intervals on memory using mismatch negativity (MMN) on 27 normal subjects, aged 18–85 years. These subjects were tested using inter-stimulus intervals of 1 sec and 3 sec. Six young subjects were tested using an additional inter-stimulus interval of 5 sec. MMN area was quite stable regardless of the age when a 1 sec inter-stimulus intervals was used. With 3 sec inter-stimulus intervals MMN area was significantly smaller in the old subjects than in the young subjects. This may reflect the shortening of the sensory auditory memory trace with increasing age. These results has good correlation with the results of Mantysalo & Naatanen, 1987; Naatanen, Paavilainen, Alho, Reinikainen & Sams, 1987; Bottcher–Gandor & Ullsperger 1992; Naatanen, (1992, cited in Ceponiene, 2001), who found by prolonging the time interval between successive stimuli it is possible to obtain information about the duration of the sensory trace of the standard stimulus provide by the diminution of the MMN amplitude with longer inter-stimulus interval.

1.3.3 Analysis of word sequences

An analysis of the different sequence of words was carried out across the four inter-stimulus intervals and seven age groups. Similar to the overall scores it was observed that there was no difference between scores obtained in each of word sequence when the inter-stimulus interval was 250 msec and 500 msec. Also in a similar line to the overall scores, there was significant difference between all other pairs.

Similarly with increase in age there was a steady increase in the scores except for the 3 and 4 word sequences. For the 3 and 4 word sequence there was a significant difference between the youngest two age groups. The maximum score was obtained by most of the children by 7 years of age. Further, with all other sequences, the middle groups (7-8 years, 8-9 years, and 9-10years) generally did not differ from each other. However, all other age groups differed significantly. The above trend was seen for both the auditory memory and auditory sequencing subtests.

1.3.4 Comparison of auditory memory subtest with auditory sequencing subtest across inter-stimulus intervals

Paired sample t–test was performed to see the difference between auditory memory scores and auditory sequencing scores at each inter-stimulus interval. The means and standard deviations of the auditory memory and auditory sequencing subtest across the different inter-stimulus intervals are given in table 14.

Table 14

The means and standard deviations of the auditory memory and auditory sequencing subtest across the different inter-stimulus.

Inter-stimulus Interval	Subtest	Mean	SD
250 msec	AM	81.9	16.3
	AS	46.4	24.3
500 m sec	AM	81.9	15.7
	AS	45.1	23.4
750 msec	AM	75.5	17.7
	AS	35.8	22.2

1 sec	AM	73.4	17.4
	AS	33.6	22.2

Note AM = Auditory memory
AS = Auditory sequencing

From table 14 it can be observed that auditory memory scores are higher than auditory sequencing scores. These scores were statistically different at the 0.001 level at all inter-stimulus intervals.

It has been reported by Cusimano (2001) that different parts of the brain are responsible for processing different aspects of memory. Hence, it is highly possible that the processing of auditory sequencing 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. So, it is recommended that both the subtests be administered and scored separately while evaluating children.

2.0 Comparison of the experimental group with the control group on the auditory memory and auditory sequencing subtests

The scores obtained by the ten children with a learning disability, who were suspected to have an auditory memory problem, were compared with the norms obtained. This was done for the auditory memory as well as for auditory sequencing subtests. The scores obtained by the ten learning disabled children are given in Tables 15, 16, 17, 18 and also explained in figures III to VI.

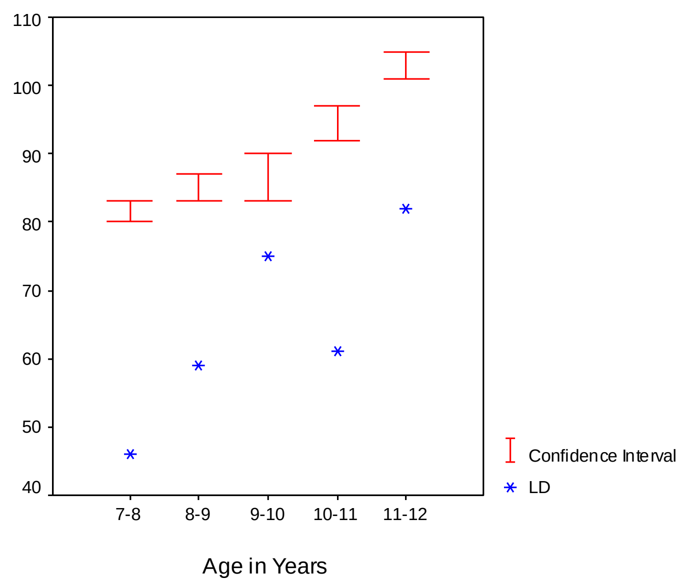
Table15:

Scores of the auditory memory and sequencing subtests for words having an inter-stimulus interval of 250 msec obtained by children with learning disabilities

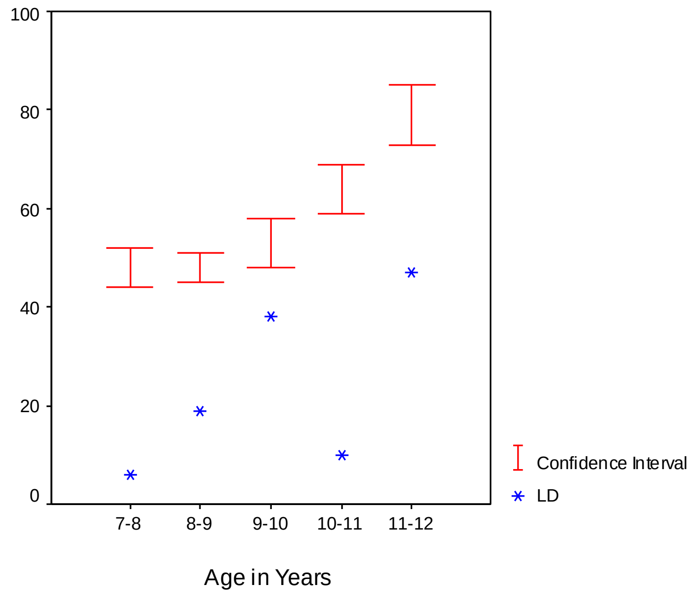
Subject	**Age**	**Sex**	**Auditory Memory Scores**	**Auditory Sequencing Scores**	**Interpretation ***
1	7yrs	F	46.00	6.00	Deviant
2	7yr 9mth	M	68.00	24.00	Deviant
3	8yr 4mth	M	59.00	19.00	Deviant
4	8yr 9mth	F	78.00	37.00	Deviant
5	9yr 4mth	M	75.00	38.00	Deviant
6	9yr 10mth	M	67.00	22.00	Deviant
7	10yrs	M	61.00	10.00	Deviant
8	11yrs	M	82.00	47.00	Deviant
9	11yrs	F	63.00	21.00	Deviant
10	13yrs	M	85.00	45.00	Deviant

* Based on the confidence interval given in Table 2 and 3

Figure III:
Comparison of Auditory Memory (A) scores and Auditory Sequencing (B) scores of children with Learning Disability (LD) with age appropriate norms ages for words having an inter-stimulus interval of 250 msec.



A-Auditory memory subtest



B-Auditory sequencing subtest

Table 16:

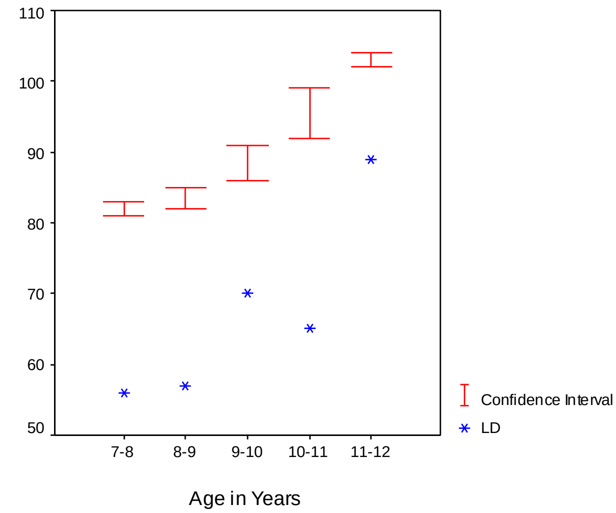
Scores of the auditory memory and sequencing subtests for words having an inter-stimulus interval of 500 msec obtained by children with learning disabilities.

Subject	Age	Sex	Auditory Memory Scores	Auditory Sequencing Scores	Interpretation *
1	7yrs	F	56.00	3.00	Deviant
2	7yr 9mth	M	70.00	16.00	Deviant
3	8yr 4mth	M	57.00	11.00	Deviant
4	8yr 9mth	F	81.00	41.00	Deviant
5	9yr 4mth	M	70.00	14.00	Deviant
6	9yr 10mth	M	79.00	40.00	Deviant
7	10yrs	M	65.00	11.00	Deviant
8	11yrs	M	89.00	46.00	Deviant
9	11yrs	F	82.00	49.00	Deviant
10	13yrs	M	84.00	54.00	Deviant

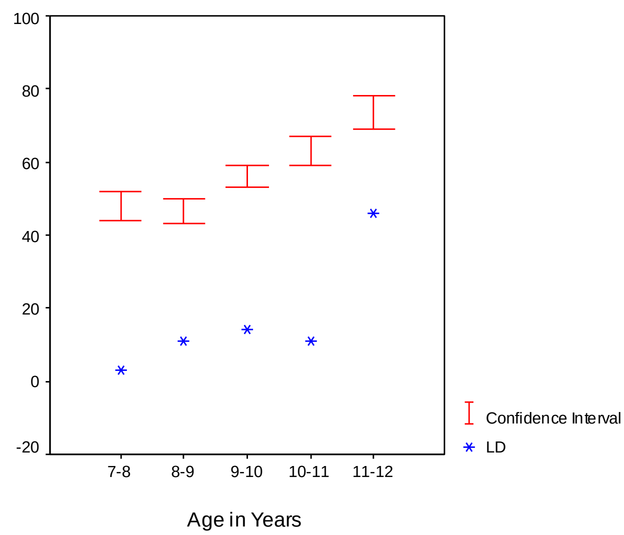
* Based on the confidence interval given in Table 2 and 3

FigureIV:

Comparison of Auditory Memory (A) scores and Auditory Sequencing (B) scores of children with Learning Disability (LD) with age appropriate norms ages for words having an inter-stimulus interval of 500 msec.



A-Auditory memory subtest



B-Auditory sequencing subtest

Table 17:

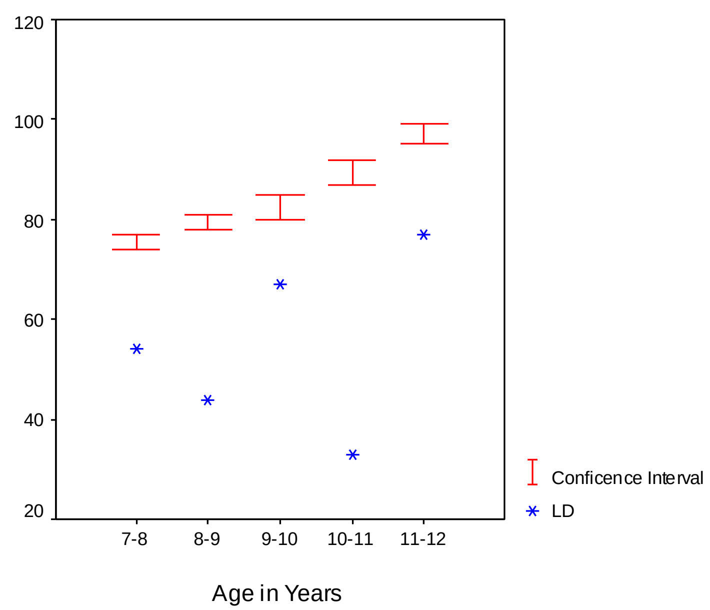
Scores of the auditory memory and sequencing subtests for words having an inter-stimulus interval of 750 msec obtained by children with learning disabilities.

Subject	**Age**	**Sex**	**Auditory Memory Scores**	**Auditory Sequencing Scores**	**Interpretation ***
1	7yrs	F	54.00	1.00	Deviant
2	7yr 9mth	M	74.00	19.00	**Not Deviant
3	8yr 4mth	M	44.00	1.00	Deviant
4	8yr 9mth	F	72.00	33.00	*** Not Deviant
5	9yr 4mth	M	67.00	18.00	Deviant
6	9yr 10mth	M	–	–	Deviant
7	10yrs	M	33.00	3.00	Deviant
8	11yrs	M	77.00	32.00	Deviant
9	11yrs	F	–	–	Deviant
10	13yrs	M	77.00	43.00	Deviant

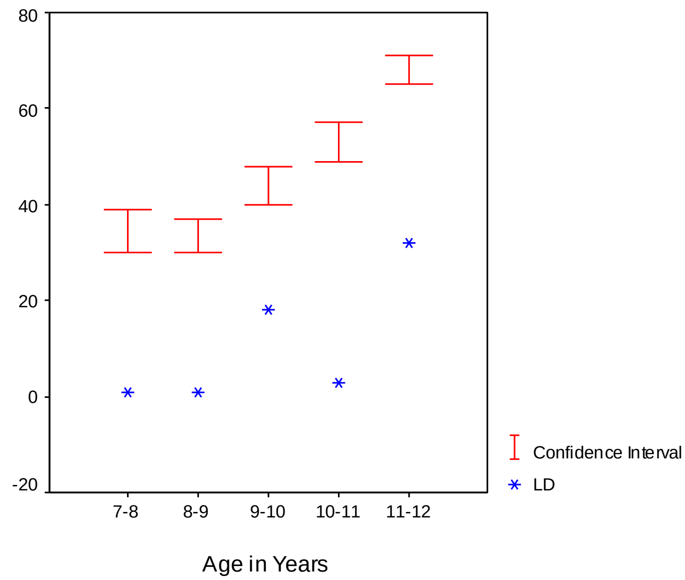
* Based on the confidence interval given in Table 2 and 3
** Not Deviant in auditory memory scores
*** Not Deviant in auditory sequencing scores
– Refused to do the test

Figure V:

Comparison of Auditory Memory (A) scores and Auditory Sequencing (B) scores of children with Learning Disability (LD) with age appropriate norms ages for words having an inter-stimulus interval of 750 msec.



A-Auditory memory subtest



B-Auditory sequencing subtest

Table 18:

Scores of the auditory memory and sequencing subtests for words having an inter-stimulus interval of 1 sec obtained by children with learning disabilities.

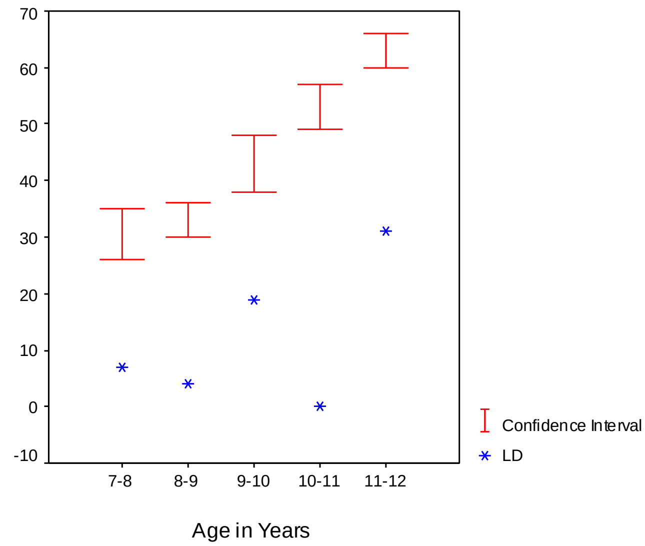
Subject	**Age**	**Sex**	**Auditory Memory Scores**	**Auditory Sequencing Scores**	**Interpretation ***
1	7yrs	F	54.00	7.00	Deviant
2	7yr 9mth	M	62.00	7.00	Deviant
3	8yr 4mth	M	44.00	4.00	Deviant
4	8yr 9mth	F	64.00	17.00	Deviant
5	9yr 4mth	M	65.00	19.00	Deviant
6	9yr 10mth	M	30.00	8.00	Deviant
7	10yrs	M	–	–	Deviant
8	11yrs	M	77.00	31.00	Deviant
9	11yrs	F	39.00	4.00	Deviant
10	13yrs	M	81.00	35.00	Deviant

***** Based on the confidence interval given in Table 2 and 3

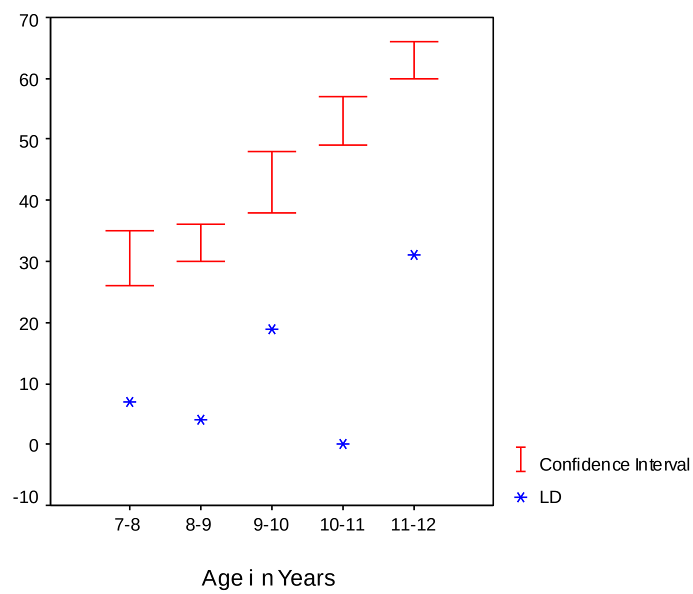
– Refused to do the test.

Figure VI:

Comparison of Auditory Memory (A) scores and Auditory Sequencing (B) of children with Learning Disability (LD) with age appropriate norms ages for words having an inter-stimulus interval of 1 sec.



A-Auditory memory subtest



B-Auditory sequencing subtest

Tables 15, 16, 17, 18 and figures from III to VI indicate that all the learning disabled children performed poorly in both auditory memory and auditory sequencing subtests when compared to age appropriate norms. This was true irrespective of the inter-stimulus intervals. Most of the children with a learning disability performed better on the auditory memory subtest compared to the auditory sequencing subtest, even though not within normal scores.

The results indicate that all ten children had deviant scores in the auditory memory and sequencing subtest when inter-stimulus interval was 250 msec, 500 msec and 1 sec. However with the 750 msec inter-stimulus interval eight of ten children had deviant scores for both the subtests, while two children had deviant scores only on either one of the subtests. In these two children one had deviant auditory memory scores and the other had deviant auditory sequencing scores. From the tables 15 to 18 and figures III to VI it was evidently seen that as the inter-stimulus interval increased the scores in the auditory memory and sequencing reduced in the children with learning disability. Some of the children refused to perform when the tokens with 750 msec and 1 sec was presented as they found the tasks too difficult.

The findings of this present study correlates with the electrophysiological studies reported by Stockard Pope, Werner and Backfired, (1992 cited in Ceponiene, 2001), who also found that with increase in inter-stimulus interval the amplitude of MMN diminished for both normal children and children with learning disability. Apel and Swank (1999) and Nittrouer (1999, cited in Chermak and Museik, 1997) reported that children with reading and writing difficulty have poorer working memory. Similarly it has also been reported by Yathiraj and Mascarenhas (2003) all their subjects with an auditory processing problem had poorer auditory sequencing abilities. Devi, Sujita and Yathiraj (2006) have compared the normative scores of auditory memory and sequencing subtest with age appropriate children with learning disability. The results revealed that the majority of children with a learning disability had auditory memory and sequencing deficits. They have also recommended administering both the subtest separately.

Thus, it can be inferred that the majority of the children with a learning disability do have an auditory memory and sequencing problem. However, not all of them have such a problem on both subtests. Based on this finding, it is suggested that children with a learning disability should be assessed for the presence of an auditory memory and auditory sequencing problem. Appropriate remedial steps should be provided for those who are found to have deviant scores.

CONCLUSION

Present study aimed at developing a test for identifying auditory memory problems in children. The material was developed in Kannada with varying inter-stimulus intervals. Normative data for children aged 5–12 years was obtained. These children were classified into seven age groups. Statistical analysis was done across gender, age, and inter-stimulus intervals for both overall and word sequences analysis for auditory memory and sequencing subtests. Results indicated that there was no significant difference between males and females, while there was a significant difference across the seven age groups and four inter-stimulus intervals both in the auditory memory and sequencing subtests. It was found that with an increase in age, normal children showed an increase in auditory memory and sequencing ability. Overall there was a significant difference in scores between the two subtests.

All the children obtained higher scores with inter-stimulus intervals of 250 msec and 500 msec when compared to the higher two inter-stimulus intervals. This trend was observed across all the seven age groups as well as in both males and females. Since latter these two inter-stimulus intervals did not differ significantly from each other, either of these two can be used while evaluating children. As the inter-stimulus intervals increased to 750 msec and 1 sec, the auditory memory and sequencing scores dropped. This drop in score was statistically significant. It was also observed that normal children reported that the larger two inter-stimulus intervals was too difficult. They required more periods of rest as well as more encouragement while carrying out the tests with these inter-stimulus intervals. Thus, it is not recommended that these two larger inter-stimulus intervals be used.

The utility of the developed test in identifying children with auditory memory problems was confirmed in the present study. The results indicated that eight of the children with a suspected memory problem performed poorly in both auditory memory and auditory sequencing subtests when compared to age appropriate norms, irrespective of the inter-stimulus intervals. Two of the children performed poorly on either one of the subtests. Hence, it is recommended that both the subtests be carried out while assessing children. Overall it was observed that the children with a suspected memory problem performed poorer in the auditory sequencing subtest when compared to auditory memory subtest.

From the findings of the study it can be concluded that the developed test material and obtained norms can be used for diagnosis of an auditory memory problem. It was found that the test was useful in determining whether children with suspected auditory processing problems do have an auditory memory / sequencing problem. The test results can be used to make suggestions for remedial help for children having deviant scores. It is also recommended that it be utilized to determine the utility of management techniques in children with auditory processing problems.

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APPENDIX-A

THE SCREENING CHECK LIST FOR AUDITORY PROCESSING (SCAP)

Yathiraj and Mascarenhas

Developed as part of the project titled "Effect of Auditory Stimulation of Central Auditory Processes in Children with CAPD" at

Department of Audiology
All India Institute of Speech and Hearing
Manasagangothri, Mysore 570006

Name: Age/Sex: Date:

School: Class: Class Teacher:

Medium of instruction:

Languages spoken at home:

Home Address & Telephone no:

Father's occupation: Mother's occupation:

PLEASE PLACE A TICK (√) MARK AGAINST THE CHOICE OF ANSWER THAT IS MOST APPROPRIATE.

Sl No.	Questions	Yes	No
1	Doesn't listen carefully and doesn't pay attention to instruction (requires repetition of instruction).		
2	Has short attention span for listening (approximately 5 to 15 minutes).		
3	Easily distracted by background sound.		
4	Has trouble recalling what has been heard in the correct order.		
5	Forgets what is said in a few minutes.		
6	Has difficulty in differentiating one speech sound from another.		
7	Has difficulty following verbal instructions and tends to misunderstand what is said, which other children of the same age would understand.		
8	Slow or delayed response to verbal instructions or questions.		
9	Has difficulty relating what is heard with what is seen.		
10	Poor performance for listening tasks, but performance improves with visual clues.		
11	Has a pronunciation problem (Mispronunciation of words).		
12	Performance of below average in one or more subjects such as social studies, I/II language.		

APPENDIX-B

KANNADA AUDITORY MEMORY AND SEQUENCING TEST (KAMST)

List ‘A’ with Inter–Stimulus Intervals of 250 msec

3 word sequence	la:ri	se:bu	tʃa:ku					
3 word sequence	mantʃa	bekku	tuTi					
4 word sequence	me:ke	ha:vu	kattu	bi:ga				
4 word sequence	o:Du	lo:Ta	roTTi	maLe				
5 word sequence	ili	gu:be	mu:ru	ba:la	dzaDe			
5 word sequence	akka	maNNu	ra:Ni	baTTe	to:La			
5 word sequence	la:Du	ba:yi	hagga	mo:Da	ka:su			
5 word sequence	ba:Na	kappu	tʃenDu	mukha	tinDi			
6 word sequence	muLLu	kombe	ga:Di	hu:vu	dzi:pu	pe:sT		
6 word sequence	laiTu	karu	batta	halli	moTTe	dzinke		
6 word sequence	tʃakra	moLe	adzdzi	ole	ko:lu	nimbe		
6 word sequence	bja:gu	sihi	guri	da:ra	klippu	vaDe		
7 word sequence	friDdz	enTu	puri	gedzdze	nalli	pinnu	ka:ge	
7 word sequence	dappa	tʃitra	ni:ru	mane	kallu	O:du	bennu	
7 word sequence	ʃa:le	baTlu	aidu	kere	tʃatri	di:pa	hoTTe	
7 word sequence	baLe	hubbu	si:re	bo:Tu	ra:dza	noNa	pho:nu	
8 word sequence	do:Ni	so:pu	bisi	hasu	beTTa	go:li	mora	kaNNu
8 word sequence	huli	dzju:s	nu:ru	katti	ba:vi	ganTe	tʃaTni	braSu
8 word sequence	sonne	dana	pja:nTu	su:rja	biLi	appa	ka:lu	manDi
8 word sequence	o:le	bi:Lu	hoDi	ke:k	mi:nu	kempu	rave	maNi

List ‘B’ with Inter–Stimulus Intervals of 500 msec

3 word sequence	railu	a:ne	lo:Ta					
3 word sequence	a:Ni	pennu	mola					
4 word sequence	To:pi	bassu	ra:dza	kappe				
4 word sequence	su:dzi	mu:gu	ko:Li	hallu				
5 word sequence	kivi	tʃi:la	ha:lu	uppu	pa:tre			
5 word sequence	me:dzu	bleDu	tale	na:ji	ba:Le			
5 word sequence	hakki	langa	mi:se	ba:lu	dappa			
5 word sequence	beNNe	kurtʃi	mara	hattu	simha			
6 word sequence	rave	tʃandra	nadi	la:ri	akka	ba:yi		
6 word sequence	bo:rD	a:To:	ele	se:bu	tinDi	ma:tre		
6 word sequence	kokku	to:Lu	mu:Le	bekku	ra:Ni	pinnu		
6 word sequence	nidre	pe:sT	guLLe	dze:bu	mantʃa	baTTe		
7 word sequence	dzana	ti:vi	ni:li	aNNa	tuTi	magu	si:re	
7 word sequence	laiTu	toDe	gombe	u:Ta	appa	haNNu	kallu	
7 word sequence	tʃiTTe	ʃarTu	a:me	pu:ri	muttu	tʃaDDi	gedzdze	
7 word sequence	o:Du	dimbu	na:lku	kuri	bi:ga	ni:ru	huli	
8 word sequence	hoge	Dabbi	kattu	benki	me:ke	ka:fi	raste	adzdzi
8 word sequence	duDDu	ba:la	kaNNu	pa:pu	ha:vu	kuDi	nela	maLe
8 word sequence	nari	mu:ru	soLLe	katte	friDdz	a:Ta	tʃakra	ili
8 word sequence	fja:n	dzaDe	anna	u:du	roTTi	sonTa	beTTa	gu:be

List 'C' with Inter–Stimulus Intervals of 750 msec

3 word sequence	hu:vu	o:le	da:ra					
3 word sequence	pennu	nalli	tʃatri					
4 word sequence	mane	baLe	ka:ge	hasu				
4 word sequence	ba:vi	kaNNu	su:rja	mi:nu				
5 word sequence	ganTe	tʃaDDi	haNa	bi:dza	manDi			
5 word sequence	tʃaTni	kempu	maNi	si:be	bi:ru			
5 word sequence	hatti	giNi	bennu	mukha	dzi:pu			
5 word sequence	amma	kaDDi	ma:vu	iDli	bo:nu			
6 word sequence	pukka	e:Lu	ko:lu	ni:li	railu	gombe		
6 word sequence	to:Ta	udzdzu	a:ne	u:Ta	halli	go:De		
6 word sequence	va:tʃu	pa:da	gone	Dabbi	muttu	pa:tre		
6 word sequence	nimbe	vaDe	e:Ni	na:lku	ka:fi	tʃa:ku		
7 word sequence	ka:Du	o:du	enTu	tʃutʃtʃu	dzinke	tale	ka:su	
7 word sequence	no:Du	bila	ʃja:mpu	haLLi	To:pi	ma:tre	ka:ru	
7 word sequence	bale	kappu	eNNe	di:pa	noNa	mola	beTTa	
7 word sequence	simha	pe:sT	uppu	ondu	huLu	bassu	fja:nu	
8 word sequence	mara	hoTTe	be:Le	ra:dza	ko:Li	ro:Du	ka:lu	a:ru
8 word sequence	nagu	a:To:	do:se	reppe	hallu	meTlu	kappe	dze:bu
8 word sequence	guDi	ha:ra	bella	akka	su:dzi	kivi	bombe	tʃandra
8 word sequence	so:fa	langa	rakta	mu:gu	drakSi	katte	baTTe	nari

List ‘D’ with Inter–Stimulus Intervals of 1sec

3 word sequence	kombe	tʃenDu	Tivi					
3 word sequence	dzju:s	ga:Di	to:Lu					
4 word sequence	do:Ni	nu:ru	puri	go:li				
4 word sequence	ba:Na	ujju	raste	tʃutʃtʃu				
5 word sequence	ro:Du	moTTe	bja:gu	la:Du	appa			
5 word sequence	biLi	ʃa:le	mo:Da	guri	tʃiTTe			
5 word sequence	karu	dzana	giNi	me:dzu	reppe			
5 word sequence	mi:se	klippu	ba:lu	rakta	go:De			
6 word sequence	braSu	e:Lu	magu	anna	ʃarTu	hagga		
6 word sequence	meTlu	a:Ta	sihi	haLLi	kuri	bi:dza		
6 word sequence	iDli	ma:vu	bo: nu	tʃitra	nagu	katti		
6 word sequence	va:tʃu	bi:ru	amma	ha:ra	dana	kallu		
7 word sequence	ke:k	tʃandra	na:ji	beNNe	moLe	ha:lu	ele	
7 word sequence	drakSi	bombe	so:pu	vaDe	kattu	pa:pu	aidu	
7 word sequence	nidre	roTTi	toDe	kappu	ondu	haNa	bella	
7 word sequence	pukka	batta	hakki	kurtʃi	eNNe	nari	do:se	
8 word sequence	kere	to:Ta	na:lku	baTlu	soLLe	gedzdze	nela	fo:nu
8 word sequence	pja:nTu	mora	kuDi	hattu	ole	so:fa	bisi	dimbu
8 word sequence	benki	sonne	pinnu	u:du	amma	huLu	ka:Du	pu:ri
8 word sequence	tʃi:la	kaDDi	hoTTe	no:Du	pe:sT	ble:Du	si:be	ka:ru

APPENDIX-C Normative Scores

Mean scores and 95% confidence interval of auditory memory subtest across inter-stimulus interval 250 msec and 500 msec for each age group.

Age		250 msec						500 msec					
		3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens	3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens
5-6	Mean	5.2	5.3	11.1	10.8	10.9	11.4	5.1	5.2	10.8	11.2	11.5	11.5
	C-I	5-6	5-6	10-11	10-11	10-12	11-12	5-6	5-6	10-11	11-12	11-12	11-12
6-7	Mean	5.4	6.5	13.3	13.4	13.9	15.0	5.4	6.2	13.6	13.8	14.4	14.9
	C-I	5-6	6-7	13-14	13-14	13-15	14-16	5-6	6-7	13-14	13-14	14-15	14-16
7-8	Mean	6.0	7.6	16.1	16.9	17.1	17.8	5.9	7.8	16.1	16.4	17.5	17.9
	C-I		7-8	15-16	16-17	17-18	17-18	5-6	7-8	15-16	16-17	17-18	17-18
8-9	Mean	6.0	7.8	16.7	17.5	18.0	18.8	6.0	7.6	16.5	17.5	17.7	17.9
	C-I		7-8	16-17	17-18	18-19	18-19		7-8	16-17	17-18	17-18	17-19
9-10	Mean	6.0	7.9	16.6	17.8	18.8	19.4	6.0	7.9	17.1	18.5	19.0	19.8
	C-I		7-8	16-17	17-19	18-20	18-21		7-8	17-18	18-19	18-20	19-20
10-11	Mean	6.0	8.0	18.1	19.9	20.8	21.6	6.0	7.9	18.0	19.5	22.4	21.6
	C-I			18-19	19-21	20-22	21-23		7-8	17-19	19-20	19-26	21-22
11-12	Mean	6.0	8.0	19.4	21.6	23.4	24.4	6.0	7.9	19.3	21.6	23.1	23.8
	C-I			19-20	21-22	23-24	24-25		7-8	19-20	21-22	23-24	23-24
Maximum score		6	8	20	24	28	32	6	8	20	24	28	32

Mean scores and 95% confidence interval of auditory memory subtest across inter-stimulus interval 750 msec and 1 sec for each age group.

Age		750 msec						1 sec					
		3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens	3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens
5-6	Mean	4.4	4.8	9.6	9.4	9.3	9.1	4.5	4.2	9.2	9.2	9.2	9.0
	C-I	4-5	4-5	9-10	9-10	9-10	8-10	4-5	4-5	9-10	9-10	8-10	9-10
6-7	Mean	5.1	5.6	11.7	12.3	11.9	12.0	5.6	5.1	13.2	11.0	10.5	10.5
	C-I	4-5	5-6	11-12	10-16	11-13	11-13	4-7	5-6	10-17	10-12	10-11	10-11
7-8	Mean	5.9	7.3	15.1	15.1	15.7	16.2	5.9	7.2	14.4	14.7	15.3	15.6
	C-I	5-6	7-78	15-16	15-16	15-16	16-17	5-6	7-8	14-15	14-15	15-16	15-16
8-9	Mean	6.0	7.4	15.9	16.3	16.4	17.2	6.0	7.6	15.5	16.0	16.3	16.6
	C-I	5-6	7-8	15-16	16-17	16-17	17-18		7-8	15-16	16-16	16-17	16-17
9-10	Mean	5.9	7.9	15.9	17.1	17.7	17.8	6.0	7.6	15.7	16.6	16.8	17.7
	C-I	5-6	7-8	15-16	16-18	17-20	17-19		7-8	15-16	16-17	16-18	17-19
10-11	Mean	6.0	7.9	17.3	18.6	19.5	19.6	6.0	7.8	16.5	17.6	18.7	18.8
	C-I		7-8	17-18	17-19	19-21	19-21		7-8	16-17	17-18	18-19	18-20
11-12	Mean	6.0	7.9	18.3	20.1	22.0	22.1	6.0	7.9	18.0	19.5	20.9	21.8
	C-I		7-8	18-19	17-21	21-23	21-23		7-8	17-19	19-20	20-22	21-23
Maximum score		6	8	20	24	28	32	6	8	20	24	28	32

Mean scores and 95% confidence interval of auditory sequencing subtest across inter-stimulus interval 250 msec and 500 msec for each age group.

Age		250 msec						500 msec					
		3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens	3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens
5-6	Mean	3.5	1.5	2.7	1.6	.9	.5	2.9	1.5	2.6	1.4	.7	.6
	C-I	3-4	1-2	2-3	1-2	0-1	0-1	2-4	1-2	2-3	1-2	0-1	0-1
6-7	Mean	4.8	3.6	5.4	3.1	2.8	2.2	4.0	3.0	4.8	2.8	2.0	1.4
	C-I	4-5	3-5	4-6	2-4	2-4	2-3	3-5	2-4	4-6	2-4	1-3	0-2
7-8	Mean	5.9	5.8	9.5	9.4	9.0	8.2	5.9	6.2	9.2	8.7	9.7	8.5
	C-I	5-6	5-6	9-10	8-10	8-10	7-10	5-6	5-7	8-10	8-10	9-11	7-10
8-9	Mean	6.0	6.1	10.0	9.0	8.5	7.8	5.9	6.5	9.3	8.7	7.9	7.9
	C-I	5-6	6-7	9-11	8-10	8-9	7-9	5-6	6-7	8-10	8-10	7-9	7-9
9-10	Mean	6.0	7.3	11.1	10.1	11.5	9.0	5.8	7.4	10.6	10.5	12.4	10.4
	C-I		7-8	10-13	9-11	8-11	8-10	5-6	7-8	10-12	10-11	10-12	10-11
10-11	Mean	5.9	7.8	14.1	13.0	17.3	11.7	6.0	7.5	12.8	12.0	14.7	12.2
	C-I		7-8	13-15	12-14	10-13	10-13		7-8	12-14	11-13	11-13	11-14
11-12	Mean	6.0	7.9	18.4	14.7	8.5	14.4	6.0	7.8	15.8	14.7	8.3	14.5
	C-I		7-8	16-21	14-16	13-22	13-16		7-8	15-17	12-16	12-16	13-16
Maximum score		6	8	20	24	28	32	6	8	20	24	28	32

Mean scores and 95% confidence interval of auditory sequencing subtest across inter-stimulus interval 750 msec and 1 sec for each age group.

Age		750 msec						1 sec					
		3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens	3 word tokens	4 word tokens	5 word tokens	6 word tokens	7 word tokens	8 word tokens
5-6	Mean	2.0	.6	1.1	.5	.6	.3	1.7	.4	.8	.3	.2	.1
	C-I	2-3	0-1	0-1	0-1	0-1	0-1	1-2	0-1	0-1	0-1	0-1	0-1
6-7	Mean	3.6	2.3	2.4	1.4	1.3	.9	2.8	1.4	1.8	1.9	.7	.5
	C-I	3-4	1-3	2-3	1-2	1-2	0-2	2-3	1-2	1-3	1-3	0-1	0-1
7-8	Mean	5.7	5.4	7.2	5.8	5.1	5.2	5.7	4.8	6.2	4.6	4.9	4.2
	C-I	5-6	5-6	6-8	5-7	4-6	4-7	5-6	4-6	5-7	4-6	3-6	3-6
8-9	Mean	5.5	5.6	6.9	5.3	5.4	4.8	5.9	4.9	7.5	5.3	4.9	4.1
	C-I	5-6	5-6	6-8	4-6	4-6	4-6	5-6	4-6	7-9	4-6	4-6	3-5
9-10	Mean	5.8	6.8	8.5	7.7	7.6	7.7	5.9	6.1	8.3	7.9	7.2	7.0
	C-I	5-6	6-7	8-9	7-9	6-9	7-9	5-6	5-7	7-9	7-9	6-8	5-9
10-11	Mean	5.9	7.4	10.4	9.7	9.4	9.8	6.0	7.0	10.2	10.0	9.8	9.8
	C-I	5-6	7-8	9-12	9-11	8-10	9-11	5-6	7-8	9-11	9-11	9-11	8-11
11-12	Mean	5.7	7.8	14.4	13.0	12.8	13.2	6.0	7.8	12.9	12.1	11.8	12.3
	C-I	5-6	7-8	14-15	12-14	12-14	12-14	5-6	7-8	12-14	11-13	11-13	11-13
Maximum score		6	8	20	24	28	32	6	8	20	24	28	32