Lexical processing among children with hearing impairment using cochlear implant

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***Abstract*: Lexical processing is a complex process array of mechanisms namely encoding, search and retrieval. Stored information about a lexicon is a mental representation. Lexical processing helps in the decoding of words and comprehends meaning from linguistic system. It can be assessed through with lexical decision task. DMDX-5 software is a helpful tool that can be used to calculate the decoding speed. Lexical decoding is an important aspect of language. It is important to study lexical decoding in children with hearing impairment. A total 30 participants were included in the present study. Group A included 20 typically developing children based on language age evaluated on Receptive Expressive Emergent Language Scale. Ten children with hearing impairment using cochlear implant based on the language matched using REELS were included in Group B. Lexical processing test in Marathi was used to evaluate lexical processing abilities. The responses were analysed using the DMDX-5 software. Correct or incorrect responses along with the reaction time were calculated for all stimuli. Scores for identification of words and nonwords improves with age, whereas reaction time for identification of words and nonwords reduces with age. The data obtained in the present study serve as pilot norms. Children with hearing impairment showed poor performance on the lexical processing of words and nonwords. Further studies are required on the large number of clinical populations.**

***Index Terms*: lexical processing, reaction time, hearing impairment, cochlear implant, and semantics**

Introduction

Lexical decoding is a vital aspect in spoken language processing [1]. Lexical processing helps in decoding words and comprehending meaning from linguistic system. Lexical processing is a complex process array of mechanisms namely, encoding, search and retrieval. Stored information about a lexicon is a mental representation [2,3]. Mental lexicon/lexical memory include information about articulation, information linkage of words and words, words and concepts, and concepts and concepts [4]. Mental representation in the mental lexicon is expressed from analysing the levels of lexical processing. Lexical access or lexicalization is a process by which speakers retrieve and encode words for expression. Word recognition task can assess lexical decoding ability. It can be assessed through lexical decision task [5]. In auditory lexical decision task, the participants need to classify auditory stimuli presented as words or nonwords. Time taken to decide whether stimuli presented is word or non-word can be considered as decoding speed [6]. This can be involved in the test battery to assess spoken language processing to measure speed of decoding spoken language stimuli.

Limited studies are available on the development of auditory lexical decision task in children. Development of word recognition speed was investigated for children in the range of 3 to 6 years [7]. For children of 3 years of age word recognition speed was 0.832 msec which decreased to 0.465 msec for children of 6 years of age. Word recognition speed is noticed to decrease with age. In Indian context a study was conducted to study the maturation of lexical processing in Kannada speaking typically developing children in the age range of 4 to 10 years and compared it with the adults [8]. Auditory access conditions were investigated using like word association, category naming to single word presented, category naming to group of word presented, listing members belonging to a category were included to investigate lexical processing. Line drawing pictures of ten semantic categories with five items in each category were chosen as stimuli and kept constant across the tasks and the age group. In this study, accuracy and latency of responses were calculated manually. The results revealed that accuracy and latency performance showed effect of age. As age increased, accuracy increased and latency decreased. As latency was calculated manually using stop watch, results of this study are not reliable. A similar study was conducted to study lexical processing for Malayalam speaking children in the age range of 5 to 10 years [9]. Data obtained from children were compared with adults in the age range of 18 to 19 years. Children were grouped into six different groups i.e. 5 to 6, 6 to 7, 7 to 8, 8 to 9, 9 to 10 and 10 to 11 years. Auditory lexical access was studied using DMDX software for calculation of latency responses. Descriptive statistic of the study showed that as age increases mean latency of the auditory access condition decreases. It was observed that the reaction time of children in the age group of 5 to 6 years were 2331 msec which decreased to 972 msec for children in the age range of 10 to 11 years. For adults, reaction time was noted to be 862 msec. A significant age effect was noticed for reaction time of lexical access. Variability of the latency decreased with age. Rapid maturational changes were observed for accuracy in the age range of 5 to 7 years, further maturation of the scores was gradual. Children of 10 to 11 years almost reached adult like score on the auditory lexical access task. No significant gender effect was observed in this study. It was concluded that as age increases, accuracy of lexical access also increases and reaction time decreases.

Lexical processing test in Marathi (LxPT-M) was developed to evaluate the lexical decoding skills in individuals. It includes ten real words and ten nonwords. Real words were selected from the cohort prepared for the construction of AMST-M [10]. It was ensured that words chosen were different from those used in AMST-M. Ten nonwords were formed by considering phonetic rules of the Marathi language. A linguist, knowing the rules of Marathi, checked the nonwords and confirmed that they follow the rules of Marathi words. The twenty words and nonwords were audio recorded in a 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 words as well as nonwords were spoken by a female who is a native Marathi speaker. Each word/non-word was recorded separately. The recorded signal was edited using Audacity-win-2.1.2 software to ensure that the sample was free from noise. Also, the intensity of the recorded audio signal was normalized. All ten words and ten nonwords were rated as intelligible by ten Marathi speaking adults and ten Marathi speaking children. All words and nonwords for LxPT-M were coded by a software engineer and were to be presented through the DMDX-5 software. Interstimulus interval between two stimuli was 5000 msec. Developed test was administered on typically developing Marathi speaking children in the age range of 5 to 8 years to develop normative data. Result of the study showed that with increase in age, the scores of correct identifications of words and nonwords increased while the reaction time for correct identification of words and nonwords decreased.

It is observed from the results of various western studies that as age increases, reaction time taken for lexical access is reduced [11,12]. This showed that lexical decoding speed improves with age. Studies on the lexical decision task showed that it can be used in the assessment of lexical processing. Auditory lexical decision task which measures reaction time can be used to assess lexical decoding speed.

Lexical processing was investigated in various communication disorders. A study conducted on children with Specific Language Impairment (SLI) reported deficit in processing capacities resulted in poor performances on identification of speech perception task and longer processing speed task [13]. Children with CAPD are also reported to show deficits with lexical processing of words and nonwords with more deficits seen on nonwords [14]. On examining language in children with hearing impairment (HI), a more critical area of focus is on lexical representation and the processing of underlying word production and comprehension [15]. This is a critical challenge for hearing impaired children. It is hence important to monitor lexical development in children post fitting of amplification devices.

DMDX-5 software is an effective tool in analysing the lexical decoding speed. There is need to develop norms for language processing speed for words and nonwords for young children. This will help in detecting lexical processing deficits among young children in early age. There is a dearth of studies in Indian context regarding lexical processing in children with hearing impairment. Recent advancement in hearing aid industries, early identification and intervention of hearing impairment and increased availability of aural rehabilitation are factors that seem to have an impact on lexical processing development. Hence, there is strong need to explore lexical processing in children with hearing impairment.

Method

The aim of the present study was to investigate the development of lexical processing in Marathi speaking typically developing children in the age range of 3 to 5 year; and to study if lexical processing is affected in children with hearing impairment. Lexical Processing test in Marathi (LxPT-M) [10] was administered on typically developing children and children with Hearing Impairment to investigate the objectives of the study. Children were randomly selected from preschools and primary schools in Maharashtra, India, who served as participants.

Participants: A total of thirty participants were included in the present study. Group A included 20 typically developing children and Group B included ten children with hearing impairment using cochlear implant (bimodal condition). Children in Group A were language age matched based on Receptive Expressive Emergent Language Scale (REELS) [16] with Group B. Further, both groups included two sub-groups based on the combined language age. Group I and II included children with combined language age 3 to 4 and 4 to 5 years respectively. Each sub-group consisted of five children with hearing impairment and ten typically developing children. All participants in Group A were typically developing Marathi speaking children within the language age ranging from 36 to 60 months. It was ensured that they passed the hearing screening at 25 dB HL for 4 frequencies (500 Hz, 1 kHz, 2 kHz and 4 kHz). Participants who showed symptoms on the Screening Checklist for Auditory Processing (SCAP) [17] were excluded. Children who were identified to have neurological, psychological/emotional disturbances or attention deficit disorders on the WHO ten disability questionnaire [18] as well as those who scored below average intelligence on Raven's Coloured Progressive Matrices (CPM) [19] were excluded from the study. All participants in Group B were Marathi speaking children with pre-lingual deafness. Children with any associated intellectual or neurological problems were excluded. All participants were diagnosed with severe to profound hearing impairment using cochlear implant (bimodal condition). The participants were within the language age ranging from 36 to 60 months.

Material and equipment: A laptop (DELL, INSPIRON N5010) was used with speakers (Sony) along with DMDX-5 software installed on the laptop which was used for analysing the responses. Other test material used included the LxPT-M [10], SCAP [17], WHO ten disability questionnaire [18] and Raven's Coloured Progressive Matrices (CPM) [19].

Procedure: Informed written consent was taken from the parents of the participants. All the testing was done in a quiet room, which was free from distractions. Lexical processing test in Marathi (LxPT-M) included 10 real words and 10 nonwords. The recorded test material was presented at a calibrated level of 60 dBSPL using DELL INSPIRON N5010 laptop with speakers (Sony). LxPT-

M was carried out binaurally. The participant was instructed to listen to each stimulus and press the right ctrl button when they heard a word from the Marathi lexicon and press the left ctrl button when they felt the word did not belong to the Marathi lexicon (non-word). The responses were analysed using the DMDX-5 software. Correct or incorrect responses along with the reaction time (time duration between stimuli presented and response to stimuli by pressing the button) were calculated for all stimuli. Correct response was scored as 1 and incorrect response was scored as 0. Reaction time was calculated for all the correct responses and it ranged from 0 to 5000 msec. Practice trials were given prior to administration of the test to ensure that the participant understood the instructions. Verbal reinforcement was given after completion of the test.

Statistical analysis: Statistical analysis of the data was carried out using statistical software. Mean, standard deviation, median and range for the data obtained from participants of Group A and Group B were calculated. Initially Shapiro Wilk's test of Normality was administered. Non-parametric tests were carried out to investigate the aims of the study.

Results

The data obtained were tabulated and subjected to statistical analysis. Mann-Whitney U test was carried out to compare the scores and reaction time of words and nonwords of LxPT-M across genders and age in Marathi speaking typically developing children. Similarly, comparison of scores and reaction time of words and nonwords were done across children with and without Hearing Impairment.

Identification score for words and nonwords, reaction time for identification of words and nonwords were compared across males and females in typically developing children. Result showed no significant difference among genders for typically developing children in the age range of 3 to 4 years and 4 to 5 years (Table 1). Further data was combined to investigate age effect. Mean, SD, median and range obtained on LxPT-M for language aged matched typically developing children and children with HI are tabulated in Table 2. It can be noticed from table 1 that children in the language age of 4 to 5 years did not show much difference in identification score for words/nonwords and reaction time for words/nonwords. Mann-Whitney U test also showed no significant age difference for typically developing children (Table 1).

Children with HI with those of language aged matched typically developing children were compared on the performance of the LxPT-M. Table 2 shows children with HI showed lower mean score for identification of words and nonwords, and higher reaction time for identification of words and nonwords. Result of Mann-Whitney U test (Table 2) showed significantly poor performance for reaction time for correct identification of words and nonwords of children with HI when compared with language age matched typically developing children in the range of 3 to 5 years. Score for correct identification of words in the age range of 4 to 5 years showed poor performance among children with HI.

Discussion

Comparison of lexical processing based on LxPT-M [10] among Marathi speaking typically developing children in the present study showed that there is no gender difference among Marathi speaking children in the age range of 3 to 5 years. Similar findings were for Marathi speaking children in the age range of 5 to 8 years for all parameters except for reaction time for identification of nonwords [14]. Similar findings were reported for lexical processing studies of Kannada and Malayalam speaking typically children [8,9]. Result of the present study also revealed that typically developing children showed no developmental changes for lexical processing of words and nonwords in the age range of 3 to 5 years. Indian studies done showed maturational effect for lexical processing [8,9,14]. Difference in the result of the present study may be due to younger age. Score for correct identification of words and reaction time for correct identification of words were better in present study than for nonwords. This indicates that lexical processing for words were accurate and faster than the lexical processing for the nonwords. Similar findings were observed in the study done by the Sone [14].

Comparison of performance of lexical processing on LxPT-M among children with HI and to those of language matched typically developing children in the present study showed that children with HI showed significantly poor performance on lexical processing speed for both age groups. This indicates that children with HI take longer time for processing of words and nonwords. Higher number of children with HI showed deficits on reaction time for correct identification of words and nonwords and scores for correct identification of words/nonwords also support that lexical speed is slower in children with HI. There is however a limitation in the number of studies available to support findings of lexical processing abilities while comparing children with normal hearing and those with hearing impairment. Difficulties are found in auditory and phonological processing which in turn affects semantic processing in speech comprehension for hearing impaired children. In a spoken language environment, impaired hearing may limit processing speed. Lexical processing speed is affected among children with CAPD [20]. Performance of children at risk for CAPD take longer time than typically developing children [14]. This highlights importance of measurement of the reaction time in children with communication disorders. Literature on language impairment in the children with HI using CI shows that language impairment is observed when compared with typically developing children [21]. In the present study, when the language processing is compared with typically developing children those matched with language age showed almost equal performance on the accuracy for the lexical processing but lexical processing speed showed poor performance. This study highlights children with HI showed that language processing takes longer time.

Conclusion

Present study concludes that LxPT-M test can be administered at the earliest by the age of 3 years. The data obtained in the present study serve as pilot norms. Children with hearing impairment showed poor performance on the lexical processing of words and

nonwords. Children with HI take longer time for lexical processing of words and nonwords even if score for correct identification of words and nonwords is less affected. This study also highlights that the reaction time measurement is an important parameter for assessment of lexical processing in communication disorders. Further studies are required on the large number of clinical populations.

Tables

Table 1: Gender effect on the performance of LxPT-M

Stats	Gender effect								Age effect			
	3 to 4 years				4 to 5 years							
	WS	WR	NWS	NWR	WS	WR	NWS	NWR	WS	WR	NWS	NWR
U	15.5	15	23	14	13	21	14	6	67	58	46.5	67
Z	4.655	4.787	4.67	4.787	4.564	4.787	4.488	4.787	15.827	16.125	15.795	16.125
P	0.548	0.690	0.421	0.841	1.000	0.222	0.841	0.222	0.879	0.693	0.257	0.927

Note: WS= Identification score for words; WR=Reaction time for identification of words; NWS= Identification score for nonwords; NWR= Reaction time for identification of nonwords

Table 2:: Mean, SD, Median, and Range values for identification scores (words and nonwords) and reaction time in msec (for identification of words and nonwords) on LxPT-M across age.

Groups	Scores	I				II			
		Mean#	SD	Median#	Range	Mean#	SD	Median#	Range
A	WS	7.8	1.14	8	6-9	8.3	1.5	8.5	6-10
	WR	1588.5	406.61	1512.0	1012-2377	1481.0	324.0	1444.5	1026-1943
	NWS	5.8	1.93	6	2-9	6.9	1.52	7	4-9
	NWR	1782.3	549.2	1898.3	656-2696	1633.0	536.60	1546.0	981-2971
B	WS	5.67	0.58	6	5-6	7.6	1.52	8	5-9
	WR	2583.8	151.89	2612.8	2419.56-2719.18	3317.0	262.0	3175.7	3113.26-3745.67
	NWS	5.67	1.53	6	4-7	6.6	1.52	7	4-8
	NWR	3127.7	481.3	3173.8	2624.96-3584.43	3543.0	220.3	3470.8	3369.61-3927.58
Stats		WS	WR	NWS	NWR	WS	WR	NWS	NWR
	U	26.5	0	16	0	29	0	22.5	1
	Z	7.661	8.165	7.973	8.175	5.809	5.916	5.785	5.916
	P	0.859	0.001	0.31	0.001	0.014	0.007	0.217	0.014

Note: WS= Identification score for words; WR=Reaction time for identification of words; NWS= Identification score for nonwords; NWR= Reaction time for identification of nonwords; #Maximum achievable scores/reaction time: WS=10; NWS=10; WR=5000 msec; NWR=5000 msec

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