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Original Research Article

Association between Auditory Memory and Performance on Dichotic Digit Test

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ABSTRACT

Background: Present study was designed to investigate the effect of auditory memory on the performance of SDT and DDT for Marathi speaking typically developing children and children at risk for CAPD in the age range of 6 to 8 years.
Method: A total 60 typically developing children and nine children with risk for central auditory processing disorder were compared on performance of Single digit dichotic test (SDT) and Double Dichotic Digit Test (DDT) in Marathi. Single correct scores for right ear (RS); left ear (LS); double correct scores (DS); and ear difference (ED) were calculated separately.
Results: All participants showed better performance on SDT than those of DDT, for all the parameters. Children at risk for CAPD performed significantly poor on single correct score of right ear and ear difference of DDT. Result of Spearman's correlation showed significant moderate correlation between memory span and single correct score of left ear, double correct score of DDT among typically developing children. Performance on single correct score of left ear and double correct score of the DDT of participants of children with memory span four or more than four was significantly better than those of children with memory span less than four.
Conclusion: Present study suggests that for children in the age range of 6 to 8 years DDT is better tool than SDT in detection binaural integration deficits. Evidences obtained from this study support the notion that auditory memory affects the performance of the dichotic listening skills.

Key Words: Dichotic listening, Single and double pair dichotic digit test, Binaural integration, CAPD, Memory span

INTRODUCTION

Dichotic listening plays vital role in the spoken language processing. Dichotic listening was first used by Brodbent [1] to explore the attention load experience by air traffic controllers. Later, Kimura [2] developed dichotic listening test to study hemispheric function among normal and brain lesion individuals. Right ear advantage (REA) is believed to reflect dominance of the left hemisphere for speech and language perception which result in to higher score for the material presented to right ear than left ear. [3] Dichotic listening was not only used to test brain laterality and attention but also has been used in various research related to language processing; [4] emotion; [5] hypnosis and altered states of consciousness; [6] individuals Parkinson's Disease, [7] dyslexia; [8,9] auditory processing. [10]

Kimura [2] used digits triplets for dichotic digit test while Musiek [10] recommended dichotic digit test using digit pairs to assess central auditory processing. The Task Force on Central Auditory

Processing Consensus Development formed by American Speech and Hearing Association highlighted the importance of the Dichotic digit test in the assessment of the central auditory processing disorders. [11] American Academy of Audiology recommends dichotic digit test for assessment of possible Central auditory processing disorders (CAPD) due to their availability, clinical feasibility, also due to good sensitivity and reliability. [12] Dichotic digit test has been shown to be sensitive to brainstem and cortical lesion [10] as well as lesion of corpus callosum. [13]

Dichotic digit test requires the participant to repeat the digits heard in both the ears. Thus, a child should have a memory span of at least 4 to get a good score on dichotic digit test developed by Musiek. [10] Evidence from literature indicates that some of the children with CAPD perform poorly on the auditory short term memory task. A study done by Muthuselvi and Yathiraj [14] showed that auditory memory was noted to be one of the prominent auditory processes that were affected. Yathiraj and Maggu [15,16] reported that 32.2% of children at risk of CAPD have auditory memory deficits. Yathiraj and Vanaja [17] investigated 100 children who were at risk for CAPD and observed that 36% failed auditory memory test with a cut of criteria of mean minus 1 SD while 12% failed the test when the cut off criteria was mean minus 2 SD.

A review of literature also indicates an association between performance on auditory memory and dichotic listening tests. Wilson et al. [18] studied associations among three screening tests Children's Auditory Performance Scale, Screening Instrument for Targeting Educational Risk, Test of Auditory Perceptual Skills Revised (TAPS-R) and four diagnostic tests Low-Pass Filtered Speech (LPFS), Competing Sentences (CS), Two-Pair Dichotic Digits (DD), and Frequency Patterns with Linguistic Report (FP). Screening and diagnostic tests were administered on 104 children in the age range of 6 to 15 years. Pearson's product-moment correlation coefficient analysis showed weak to moderate correlations predominantly between the short-term and working memory test results of the TAPS-R and the DD and FP test results of the CAPD test battery. Similarly, forward not reserve span have been to be strongly associated with dichotic digit test for children with CAPD. [19] A high correlation was noticed between Digit Span tests (forward and backward) and the Dichotic digit test included in audiometric tests used for diagnosing APD. [20]

Penner, Schläfli, Opwis, and Hugdahl [21] administered dichotic-listening task in three working-memory load conditions; each consisting of trials of 3, 4, and 5 dichotically presented letter pairs to 30 native German speaking adults. Results showed an enhanced right ear advantage as working-memory load increased. This right-ear effect increased significantly from 3 to 4 stimulus pairs up to 5th pair. Similarly, an investigation on Malaya speaking children showed lesser memory load improves results the dichotic listening scores and reduces the REA. [22]

A few researchers have explored the usefulness of single digit dichotic test. Mukari, Keith, Tharpe and Jonson, [22] studied developmental trends in performance of children in the age range of 6 to 11 years on dichotic digit test using single and double digit pairs in Malaya language. They observed that as single digit dichotic test was less loaded with memory, it showed ceiling effect for right and left ear scores resulting in minimal REA. Double dichotic digit test showed ceiling effect only at age of 11 years and showed significant REA for all age groups. They concluded that double digit dichotic test is more useful test than the single digit. Other studies [23,24] also showed that when ceiling effect is noticed sensitivity of dichotic digit test reduced to identify children with processing difficulties.

It can be construed from these studies that though the performance on dichotic digit test using digit pairs is influenced by auditory memory, they are more sensitive than single digit dichotic test in identifying CAPD in children who do not have memory problems. However, an investigation on development of auditory processes in children aged 6 to 10 years showed that the double correct scores are highly variable in 6 year old children. [25] This suggests that there is a need to investigate effect of auditory memory on dichotic listening in young children. Study investigating performance of the SDT and DDT among typically developing children and children at risk for CAPD will help clinically in selection of test tool to investigate binaural integration. Correlation study between the memory and binaural integration will through more light on the association of different processes involved in the spoken language processing. Hence the present study was carried out to investigate the effect of auditory memory on the performance of SDT and DDT for Marathi speaking children in the age range of 6 to 8 years.

MATERIALS AND METHODS

The present study was a prospective cross-sectional study conducted in the state of Maharashtra, India. The study was approved by the Ethical Committee of Bharati Vidyapeeth (Deemed to be University).

Participants: Two groups of participants were included in the study. Group I consisted of 60 typically developing children in the age range of 6 to 8 years and Group II included 9 children in the age range of 6 to 8 years who were at risk for central auditory processing disorder. All the children were native speakers of Marathi, an Indoaryan language spoken in the state of Maharashtra, India. The hearing sensitivity was within normal limits for all the children and there was no. history of neurological, psychological, emotional disturbances or attention deficits disorders. All the children had average intelligence and were right handed. Children in Group I obtained a score of more than 6 on screening checklist for auditory processing (SCAP) while children of Group II obtained a score of more than 6 on SCAP.

Material and equipment: A laptop computer (DELL, INSPIRON N5010) with insert earphone (Sony) was used for carrying out the tests. Screening checklist for Auditory Processing for children [26] was used for screening children who are at risk for CAPD. Single digit dichotic test (SDT) in Marathi [27] and Dichotic Digit Test (DDT) in Marathi. [28] SDT consists of the 25 single pairs of digits, whereas DDT includes 25 double pairs of digits which are presented dichotically.

Procedure: Informed written consent was taken from all the parents for participation of their children in present study. A verbal ascent was taken from each child for their participation in the study. Teachers were requested to administer the Marathi version of SCAP for each participant. Using DELL INSPIRON laptop N5010, hearing screening was carried out using pure tones at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz at an intensity equivalent to 25 dB HL in a quiet room. Pure tones were generated using the Audacity-win-2.1.2 software. Intensity was measured and adjusted using a sound level meter.

SDT and DDT were administered in a quiet room. DELL INSPIRON-N5010 laptop was used to present the SDT and DDT. To avoid the practice effect, SDT was administered first for 50 % of the children while DDT was administered first for the remaining children. Initially practice trials were given to familiarize the participants. Then the test materials were presented and the participants were instructed to repeat the digits heard in both ears.

Scoring: Responses were recorded in the written form and scored by the administrator. Single correct scores for right ear (RS) as well as left ear (LS); and double correct scores (DS) were calculated separately. For SDT, each correct response was given a score of ‘1’ and incorrect response ‘0’ while calculating single correct scores. For double correct score, a score of '1' was awarded only if both the digits presented dichotically were correctly identified and score of '0' was given if the response was incorrect for any two digits presented dichotically. For DDT, a score of '0.5' was given for each digit repeated correctly while calculating single correct scores whereas for double correct score, a score of '1' was awarded only if the all four digits presented were correctly identified and a score of '0' was given if the response was incorrect for any four digits presented dichotically. Additionally ear difference (ED) was calculated for both SDT and DDT by finding the difference in right ear and left ear score.

Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Science 22 (SPSS). Shapiro Wilk's test was done to check normality test. Mann-Whitney U test was done to compare the median of both Groups. Values below 0.05 level of significance was considered statistically significant. Association between SDT and DDT, memory span and performance of dichotic tests were done by Spearman's Correlation.

RESULTS

Descriptive statistics, mean standard deviation, median and range for all scores of SDT and DDT for typically developing children and those at risk for CAPD are tabulated in Table 1. It can be observed from the table that the performance on SDT was better than those of DDT, for all the parameters. Shapiro Wilk's test showed that the data were not normally distributed. Hence non parametric tests were performed to investigate the objectives of the study. Association between SDT and DDT was investigated using Spearman Correlation. Mann-Whitney U test was used to compare the performance of children who were at risk for CAPD with those of typically developing children. Relationship between Memory span and dichotic digit test scores were investigated by Spearman Correlation.

Table 1: Mean, SD, Median, and Range for SDT and DDT (RS, LS, ED, DS) of typically developing children across typically developing children and children at risk for CAPD

Test	Scores	Group I				Group II			
		Mean	SD	Median	Range	Mean	SD	Median	Range
SDT	RS	21.84	2.20	22	16-25	21.33	2.50	22	16-24
	LS	20.67	3.67	21	8-25	20.67	3.04	22	16-25
	ED	1.16	3.36	1	-5-10	0.67	2	0	-3-4
	DS	18.37	4.20	19	7-24	17.88	3.76	19	11-22
DDT	RS	17.45	2.50	18	11.5-22.5	13.17	3.04	12	9-18
	LS	11.65	3.68	11.5	3-19.5	12	2.45	12	9.5-15.5
	ED	5.80	4.23	5.5	-.7.5-18	1.17	3.47	1	-4-8.5
	DS	1.29	2.07	0	0-9	0.56	0.88	0	0-2

Note- RS: Single correct score for right ear; LS: Single correct score for left ear; ED: Ear difference score; DS: Double correct score

Association between score of SDT and DDT

Spearman's Correlation was done to investigate relation between scores of SDT and DDT for typically developing children. Spearman's Correlation Coefficient revealed that there was significant low correlation between SDT and DDT for single correct score of left ear ($r_s[60]=0.282$, $p<0.05$) and a significant moderate correlation was observed for double correct score ($r_s[60]=0.347$, $p<0.05$). No significant correlation was observed for single correct score of right ear and ear difference scores.

Comparison of typically developing children and children at risk for CAPD on the performance of SDT and DDT

The data obtained from children at risk for CAPD were compared with the data obtained from typically developing children. Results of Mann-Whitney U test showed a significant difference between the two groups for single correct score of right ear and ear difference of DDT (refer Table 2). No significant difference was observed between the two groups for any of the scores of SDT.

Table 2: Comparison of typically developing children and children at risk for CAPD on the performance of SDT and DDT

	SDT				DDT			
	RS	LS	ED	DS	RS	LS	ED	DS
Mann Whitney U	254	255.5	250	255	96.5	309.5	81	244
z value	54.64	54.91	54.82	55	55.12	55.15	55.18	47.65
p value	0.833	0.855	0.777	0.849	0.002	0.425	0.001	0.652

Note- RS: Single correct score for right ear; LS: Single correct score for left ear; ED: Ear difference score; DS: Double correct score

Association between Memory span and dichotic digit test scores

Relationship between the memory span and dichotic digit test (SDT and DDT) was investigated using the Spearman's correlation. Spearman's Correlation was calculated separately for typically developing children and children at risk for CAPD. It can be observed from Table 3 that there was a significant moderate correlation between memory span and single correct score of left ear, double correct score of DDT among typically developing children. No significant correlation was noticed for any of the scores of SDT and DDT among children at risk for CAPD.

Table 3: Correlation between Memory span and dichotic digit test scores for typically developing children and children at risk for CAPD

	Typically developing children				Children at risk for CAPD			
Test	SDT		DDT		SDT		DDT	
Scores	Spearman's Correlation Coefficient	p-Value	Spearman's Correlation Coefficient	p-Value	Spearman's Correlation Coefficient	p- Value	Spearman's Correlation Coefficient	p- Value
RS	0.091	0.532	0.153	0.295	0.010	0.981	0.009	0.981
LS	0.113	0.439	0.393	0.005	0.400	0.286	0.362	0.339
ED	0.119	0.417	0.293	0.041	0.430	0.248	0.413	0.269
DS	0.234	0.106	0.327	0.022	0.432	0.245	0.145	0.710

Note- RS: Single correct score for right ear; LS: Single correct score for left ear; ED: Ear difference score; DS: Double correct score

Further analysis was carried out on typically developing children by dividing them into two subgroups. Subgroup M1 consisted of 31 children who had an auditory memory span of less than four while subgroup M2 included 29 children with memory span of four and more than four. Mean, standard deviation, median and range values for subgroup M1 and M2 tabulated in Table 4.

Table 4: Mean, SD, Median, and Range for SDT and DDT of typically developing children across two memory subgroup M1 and M2.

Test	Scores	Subgroup M1				Subgroup M2			
		Mean	SD	Median	Range	Mean	SD	Median	Range
SDT	RS	21.61	2.26	22	16-25	22	2.19	23	17-25
	LS	20.05	3.75	21	13-24	21.10	3.62	21	8-25
	ED	1.55	3.41	1	-5-9	0.90	3.36	0	-5-10
	DS	17.05	4.65	18	8-24	19.28	3.66	20	7-24
DDT	RS	16.75	2.89	17	11.5-22.5	17.93	2.11	18	14-21
	LS	10.08	3.48	9.75	3-19	12.74	3.47	13	3.5-19.5
	ED	6.68	5.19	6.75	-7.5-17.5	5.19	3.38	5	0-18
	DS	0.50	1.05	0	0-3	1.83	2.42	1	0-9

Note- RS: Single correct score for right ear; LS: Single correct score for left ear; ED: Ear difference score; DS: Double correct score

It can be observed from the table that the performance of participants of M2 was better than those of M1. Mann Whitney U test showed a significant difference between the two subgroups for single correct score of left ear and double correct score of the DDT (Table 5). No significant difference was noticed for any of the scores of SDT and for right ear scores on DDT.

Table 5: Comparison of performance of the two subgroup (M1 & M2) on dichotic digit test

	SDT				DDT			
z/*p* values	RS	LS	ED	DS	RS	LS	ED	DS
Mann Whitney U	236.500	226.000	230.000	193.000	188.500	141.500	190.000	164.000
z value	0.730	0.955	0.866	1.664	1.760	2.771	1.725	2.540
p value	.466	.340	.387	.096	.078	.006	.085	.011

Note- RS: Single correct score for right ear; LS: Single correct score for left ear; ED: Ear difference score; DS: Double correct score

DISCUSSION

The performance of dichotic listening task depends on the structural integrity of ascending and inter-hemispheric pathways of the auditory, cognitive and linguistic system. Hence this dichotic test is often a part of the auditory processing assessment batteries. [29-31] In the present study binaural integration were studied among typically developing children and children at risk for CAPD using SDT and DDT. The dichotic digit test recommended by Musiek [10] for assessing binaural integration involves dichotic presentation of digit pairs. There is dearth of studies comparing the effect of the single and double digit pair used in dichotic digit test among Marathi speaking typically developing children and children at risk for CAPD. Also relation between memory span and dichotic digit test scores is not explored.

Descriptive data for both the SDT and DDT showed that SDT was easier than DDT. Performance of SDT was better than DDT for all single correct scores and double correct scores. This was an expected finding as the memory load is less in SDT. These results support the earlier reports in the literature which show that linguistic or memory load on the stimuli used in the testing affects the scores of dichotic listening tests. [22,32]

It was observed in the present study that the difference in scores was greater for double correct scores than single correct scores. This could be due to memory load required to remember all the four digits during DDT. Similar results have been reported in the literature. [21,22] When memory span of all participants were checked, it was noticed that many children had auditory memory span of three or four words. It was observed that a few participants with memory span less than four could also repeat all the four digits during DDT. This could be due to due to inter-stimulus time in AMST and DDT is different. It is observed from the literature that as inter-stimulus time increased, memory load increase which results into poorer performance in children. [33] For DDT, inter-stimulus time is shorter than the AMST, this would have reduced memory load in DDT and hence helped in better performance on DDT. Also stimuli used in DDT were digits which are less linguistically loaded than the words of the AMST. It is seen that when digit used in the memory recall task over other stimuli type, digits showed superiority in the performance of recall. [34] This also could be possible reason for better performance on DDT.

Performance of the SDT and DDT among typically developing children and children at risk for CAPD showed that single correct score of right ear and ear difference of DDT showed significant difference in the performance among two Groups. SDT did not show any significant difference among two groups. This could be due to the ceiling effect observed for SDT due to less memory load. Study done by; [23] and Neijenhuis et al, [35] also reported that when ceiling effect is observed for the dichotic listening test it affects detection of children with listening deficits. These results suggest that SDT is not a good choice test for detection of binaural integration deficits.

A review of literature showed low to high correlation between auditory memory and dichotic listening tests. [18-20] In the present study, association between the auditory memory span and performance of the Dichotic digit test showed significant moderate correlation only for single correct score of left ear and double correct score of

DDT. No correlation was observed for the single correct score of right ear of DDT. Further, it was observed that when children were divided in two groups based on the memory span. Children who have memory span below four and memory span of four and above showed significant difference for LS and DS of DDT. This indicates that performance of the left ear reduces when there is a greater load on the auditory system and decreased left ear performance reduces the double correct scores. This could be due to dominance of left hemisphere for linguistic stimuli. [3] Left ear listening skills are probably more dependent on the short term memory as signal processed needs to be transferred to left hemisphere for comprehension. As double correct score is depending on the integration of information presented dichotically it requires the assistance from short term memory. Thus, when the auditory memory is poor, left ear scores and double correct scores get more affected than the right ear scores.

CONCLUSIONS

Over several decades dichotic listening (binaural integration) is widely tested by the various dichotic tests using different stimuli material. The results of the present study suggests that for children in the age range of 6 to 8 years DDT is better tool than SDT in detection binaural integration deficits. SDT is easier and scored higher than DDT, but does not help in detection of the binaural deficits. Evidences obtained from this study support the notion that auditory memory affects the performance of the dichotic listening skills. Thus it is recommended auditory memory should be evaluated before administering dichotic digit tests using digit pairs.

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