Research Article

Evaluation of Difference in Performance of Young Adults in Dichotic Digit Test in Tamil and Dichotic Consonant Vowel Test

Ramya Sudersonam , Ramya Vaidyanath*

Faculty of Audiology and Speech Language Pathology, Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), Chennai, India

Use your device to scan and read the article online

Citation: Sudersonam R, Vaidyanath R. Evaluation of Difference in Performance of Young Adults in Dichotic Digit Test in Tamil and Dichotic Consonant Vowel Test. Aud Vestib Res. 2023;32(2):137-44.

https://doi.org/10.18502/avr.v32i2.12184

Highlights

- Tamil speakers' performance in dichotic consonant vowels and digits were compared
- Overall, the performance was noted to be better in dichotic digits
- Digits are recommended for evaluating native Tamil speaker's dichotic listening

Article info:
Received: 14 Oct 2022
Revised: 19 Nov 2022
Accepted: 31 Dec 2022

*** Corresponding Author:**
Faculty of Audiology and Speech Language Pathology, Sri Ramachandra Institute of Higher Education and Research (Deemed to be University), Chennai, India.
ramyavaidyanath@sriramachandra.edu.in

ABSTRACT

Background and Aim: Dichotic listening has been defined as the simultaneous stimulation of both ears and has been used to evaluate a listener's binaural integration/separation ability. Dichotic tests are available in various languages and use varied stimuli. The study aimed to evaluate the differential performance of Tamil-speaking young adults in two tests of dichotic perception namely Dichotic Consonant Vowel (DCV) test and Dichotic Digit Test in Tamil (DDT-T).

Methods: Sixty adults with normal hearing aged 18 to 35 years were the participants of the study. All the young adults were native speakers of the Tamil language without significant auditory history. DCV and DDT-T were administered in randomized order at 50 dB SL (re: SRT) in free recall condition. The participants were instructed to respond orally and the responses were noted.

Results: Better performance was observed in dichotic digit compared to DCV test for all participants. This was attributed to the higher number of cues available in DDT-T. Further, error analyses of participants' responses revealed that voicing errors were higher with the highest errors in the identification of unvoiced consonant /ta/ in both ears. The reason for this could be the lack of contextual cues in DCV test for Tamil-speaking individuals to interpret the voicing feature of a consonant.

Conclusion: It can be concluded that DDT-T was more useful in assessing binaural integration ability of native Tamil speakers compared to DCV. It is recommended to be used in the behavioral test battery for evaluating auditory processing disorder in native Tamil speakers.

Keywords: Dichotic digit; dichotic consonant vowel; free recall

Introduction

Dichotic listening was defined by Stevens and Davis [1] as stimulating both ears at the same time with different stimulus. Musiek and Chermak [2] stated that based on the mode of administration, dichotic tests can be used to evaluate either the binaural integration or binaural separation ability of an individual. American Speech-Language-Hearing Association [3] and American Academy of Audiology [4] have recommended the addition of dichotic listening tests as one of the behavioral tests for assessing Auditory Processing Disorder (APD). One of the initial tests to assess dichotic listening ability, staggered spondaic word test was developed by Katz [5]. Over the years dichotic listening tests have been developed using a variety of stimuli including Consonant Vowel (CV) pairs [6], words [7], digits [8], Consonant Vowel Consonant (CVC) rhyme words [9], sentences [10] and competing sentences [11].

Dichotic listening tests have also been developed in various Indian languages. They include Dichotic Consonant Vowel (DCV) test [12], dichotic rhyme test in Telugu [13], dichotic rhyme test in Kannada [14], dichotic rhyme test in Malayalam [15], dichotic rhyme test in Tamil [16], dichotic rhyme test in Bangla [17], dichotic word (CVC) test in Kannada [18], dichotic word (CVC) in Hindi [19], dichotic word test in Tamil [20] and dichotic digit test in Tamil [21].

Although, dichotic listening has been assessed using various stimuli Speaks et al. [22] reported that dichotic digits were less affected by peripheral hearing loss compared to the performance using other dichotic stimuli such as dichotic vowel words, dichotic consonant words and dichotic CV syllables. Currently, dichotic digit test is available in various languages such as English [8], Cantonese [23] and Malay language [24]. It is also available in various Indian languages including Hindi, Kannada, Telugu (N Shivashankar, personal communication, March 12, 2018) and Tulu [25]. More recently Dichotic Digit Test in Tamil (DDT-T) was developed by Sudersonam and Vaidyanath [21].

In India, the widely used [26-28] test to assess binaural integration abilities as part of the APD test battery is the DCV test recorded by Yathiraj [12]. The test comprises of 30 pairs of stop consonant vowel syllables (/pa/, /ta/, /ka/, /ba/, /da/ and /ga/) with 0 ms lag. This test has been used in assessment of binaural integration abilities in the Tamil speaking population as well. However, in Tamil language perception of stop consonant are governed by specific features or rules with orthographic absence of difference between voiced and unvoiced consonants being one such [29]. According to Bhuvaneshwari and Padakannaya [29] both voiced and unvoiced consonants of Tamil are produced with identical point of articulation in words and are identified as voiced or unvoiced based on the context. Hence, in DCV test when stop consonants are presented in isolation, where one CV is presented to each ear simultaneously, it is expected that native Tamil speakers might have difficulties in differentiating voiced from the unvoiced consonants.

The aim of the current study was to evaluate the performance of Tamil speaking young adults with normal hearing on two dichotic test including DCV test and Dichotic Digit Test (DDT) in Tamil as well as to compare the performance on the two. This was done to ascertain the advantage of DDT over other stimuli as mentioned by Speaks et al. [22]. Also, Mukari et al. [24] stated that speech perception has been found to be better when tested in native language.

Methods

Sixty young native speakers of Tamil (30 males) aged between 18 to 35 years (mean age=21.5 years) were chosen as participants for the study. The participants hearing sensitivity was within normal limits indicated by bilateral pure-tone hearing thresholds≤15 dB HL at the octave frequencies from 250 to 8000 Hz for air conduction and 250 to 4000 Hz for bone conduction. A detailed case history was collected to ensure that the participants had no complaints of otological, neurological, cognitive or any speech and language difficulties that could influence the results. The Edinburgh inventory [30] was administered to evaluate the handedness of the participants and all were found to be right-handed. All participants provided written informed consent prior to the initiation of testing.

The DCV test, recorded by Yathiraj [12] used in this study, consisted of 30 pairs of stop consonant vowels (/pa/, /ta/, /ka/, /ba/, /da/ and /ga/). The list with 0 ms lag was used in the study. The DDT-T [21] consisted of six equivalent lists with 30 stimulus sets containing four digits with a pair of digits presented to each ear simultaneously. The test stimuli consisted of only Tamil monosyllabic digits |onnɨ| (1), |rendɨ| (2), |mu:nnɨ| (3) , |na:llɨ| (4), |ʌndʒɨ| (5) and |patɨ| (10). Other digits were excluded as these were either bisyllabic or trisyllabic in nature. The digits presented to the two ears had simultaneous onset. Each pair of digits presented in an ear had an inter-stimulus interval of 500 ms. The inter-stimulus interval between each stimulus set was 5s and was calculated from the offset of the digit with longest duration. List 1 of DDT-T was used for testing all the participants in the current study.

Procedure

The testing was carried out in a sound treated double room setup with ambient noise level within the permissible limits as recommended by ANSI S3.1 [31]. A calibrated dual channel diagnostic audiometer (Piano-Inventis) with TDH-39 headphones, B-71 bone vibrator and the facility for auxiliary input for routing signals was used for the testing. The calibration of the audiometer was done as per the specifications of ANSI S3.6 [32]. To ensure that the participants had normal hearing sensitivity, pure-tone audiometry was carried out at octave frequencies from 250 to 8000 Hz for air conduction and 250 to 4000 Hz for bone conduction. A modified Hughson-Westlake procedure [33] was used to obtain the pure-tone hearing thresholds. Individuals with hearing thresholds≤15 dB HL and air bone gap<10 dB HL were selected as participants for the study. Immittance audiometry was carried out to ensure the participants had normal middle ear function.

Speech Recognition Threshold (SRT) was obtained in all the participants using spondee word list in Tamil developed by Samuel [34]. The DCV test and DDT-T were administered on all 60 participants who met the inclusion criteria. The order of presentation of DCV and DDT-T was randomized to avoid any test-order effect. A calibration tone of 1000 Hz provided as part of the test materials was presented at the beginning of each test. The intensity was adjusted such that the participants heard the tone in the center with the intensity being equal in both the ears. The VU meter deflection was also monitored at 0 dB during the presentation of the calibration tone.

Both the dichotic tests (DDT-T and DCV) were administered as per the recommendations of the original tests at 50 dB SL (re: SRT). The two tests were carried out in free recall condition. The participants were instructed to repeat the digits and CVs heard in the two ears regardless of the order. The participants were provided with practice trials before the beginning of the testing to ensure that instructions were understood. The responses were noted down in a response sheet and were scored as Single Correct Right (SCR), Single Correct Left (SCL) and Double Correct (DC) scores. For the DDT-T, each digit correctly repeated was given a score of 0.5 and an incorrect response was given a score of 0. While, on the DCV each CV correctly repeated was given a score of 1 and an incorrect response was given a score of 0. A double correct score of 1 was provided when the stimulus from both the right and left ears were repeated correctly. Additionally, the data obtained on the DCV was analyzed for errors in identification of each consonant. The place, manner and voicing error as well as the total number of errors made when both the CVs of the pair were voiced or unvoiced versus when one was voiced and the other unvoiced were also calculated.

Statistical analysis

The data obtained from 60 participants was subjected to descriptive and inferential statistics. Shapiro-Wilk test was used to test if the obtained data was normally distributed. As the data was found to be not normally distributed ($p>0.05$), non-parametric statistics were used for analysis. Wilcoxon signed-rank test was used to compare the SCR, SCL and the DC scores obtained on the two tests as well as to compare the type of errors across the two ears and within an ear on the DCV test.

Results

The mean, median and standard deviation of single correct right, single correct left and double correct scores of the DCV test and DDT-T are provided in Table 1. It can be observed from the Table 1 that all three scores (SCR, SCL and DC) of DDT-T were higher compared to that of DCV. To evaluate if the differences were significant further analysis were carried out.

Prior to the analysis, Shapiro-Wilk test was performed to evaluate if the scores were normally distributed. From the results of normality test it was observed that the SCL ($W=0.96$, $p>0.05$) and DC ($W=0.96$, $p=0.05$) scores of DCV test followed a normal distribution ($p>0.05$). However, SCR of DCV ($W=0.95$, $p<0.05$) and all the three scores [SCR ($W=0.84$, $p<0.001$), SCL ($W=0.88$, $p<0.001$) and DC ($W=0.90$, $p<0.001$)] of DDT-T did not ($p<0.05$). Hence, non-parametric tests were used for further analysis of the data.

The scores of each ear (SCR and SCL) and the DC on the two tests (DDT-T and DCV) was compared using Wilcoxon signed-rank test. The results revealed a highly significant difference between the scores of the two tests [DDT-T SCR – DCV SCR ($Z=6.72$, $p<0.001$); DDT-T SCL – DCV SCL ($Z=6.73$, $p<0.001$); and DDT-T DC – DCV DC ($Z=6.74$, $p<0.001$)].

In addition to comparing the single correct and double correct scores of the two tests the Right Ear Advantage

Table 1. Mean, median and standard deviation (SD) of single correct right ear scores, single correct left ear scores and double correct scores of dichotic consonant vowel test and dichotic digit test in Tamil

	DCV-SCR	DCV-SCL	DCV-DC	DCV-REA	DDT-T SCR	DDT-T SCL	DDT-T DC	DDT-T REA
Mean	23.02	20.20	16.25	2.82	29.35	28.57	26.08	0.78
Median	23.50	20.00	17.00	3.00	29.50	28.75	26.00	1.00
SD	4.09	3.55	4.69	3.49	0.70	1.14	2.84	1.12

DCV; dichotic consonant vowel test, SCR; single correct right, SCL; single correct left, DC: double correct, REA; right ear advantage, DDT-T; dichotic digit test in Tamil; Maximum score for DCV and DDT-T=30

(REA) obtained was also compared using Wilcoxon signed rank test. Comparing the difference between the right ear and left ear scores (REA) of the two tests revealed a highly significant difference ($Z=-4.03$, $p<0.001$). The mean REA was higher in DCV when compared that observed in DDT-T.

The stimulus of the DCV test had six voiced consonant pairs (eg. /da/, /ba/), six unvoiced consonant pairs (eg. /pa/, /ka/) and eighteen pairs that had one voiced and one unvoiced consonant (eg. /ka/, /da/). The number of errors made by the participants in voiced consonant pairs, unvoiced consonant pairs and voiced and unvoiced consonants pair were compared (Figure 1).

It can be observed from the Figure 1 that the percentages of errors were greatest in the consonant pair with both unvoiced CVs followed by the pairs with both voiced consonants. The errors were found to be least when the pair consisted of one voiced and unvoiced consonants.

The responses of the participants from DCV test were further analyzed for errors in place of articulation, manner of articulation and in voicing. Additionally, the number of errors for identification of each of the six consonants were also calculated. This analysis was carried out for each ear separately and the mean errors for each type and ear is represented in Figure 2.

Wilcoxon signed-rank test was carried out to compare each type of errors across the two ears. Comparing across the two ears, the left ear place errors were found to be significantly higher compared to the right ear place errors ($Z=2.88$, $p<0.001$) and a similar trend was also observed for the voicing ($Z=2.75$, $p<0.01$) as well as the combined place and voicing errors ($Z=2.54$, $p<0.01$).

The type of error within each of the two ears was also compared using Wilcoxon signed rank test. The voicing errors were found to be the maximum followed place errors and combined place and voicing errors in both ears. A significant difference was seen when comparing the

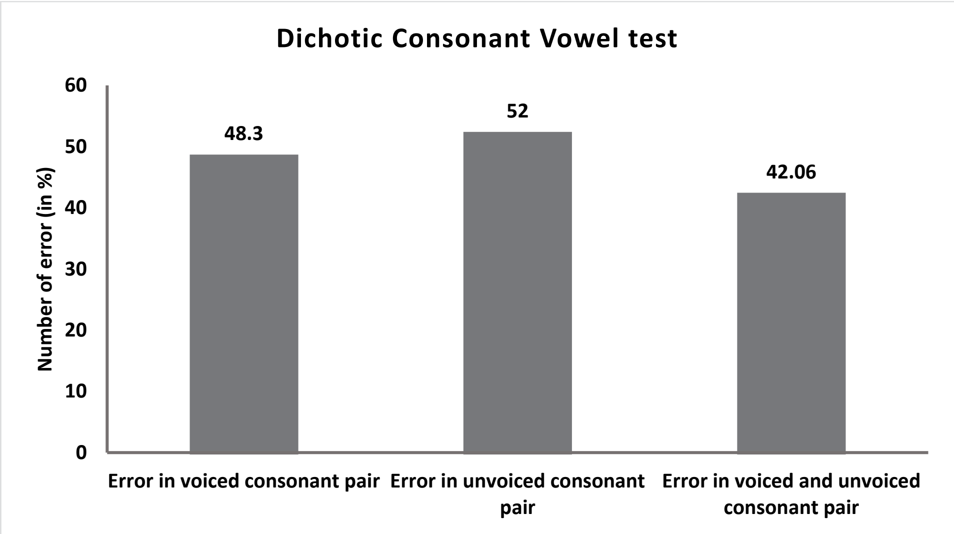

Figure 1. The percentage of errors made by participants in voiced consonant pairs, unvoiced consonant pairs and pairs that had one voiced and one unvoiced consonant of the dichotic consonant vowel test

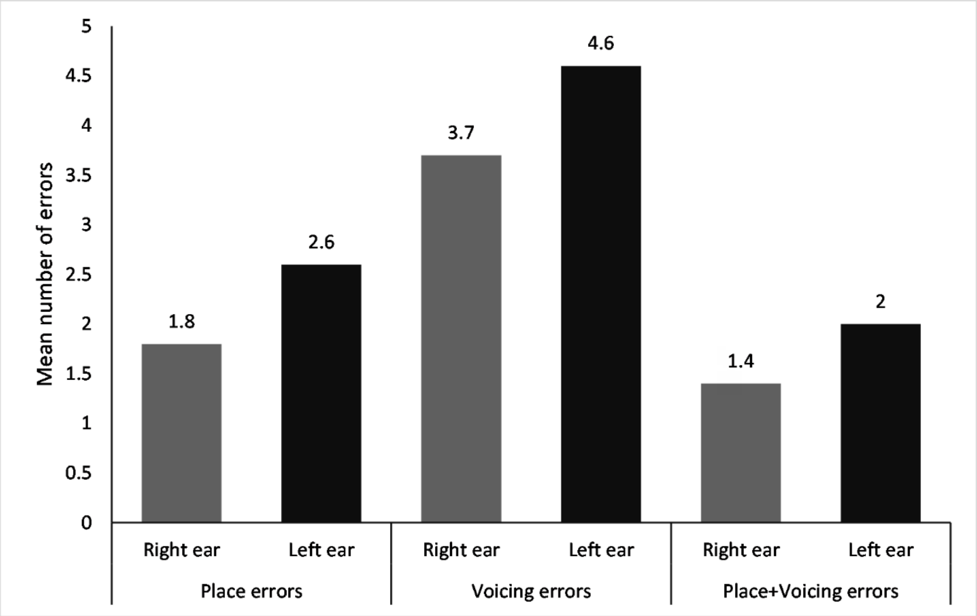

Figure 2. The mean number of errors made by participants in place, voicing and place + voicing in the right and left ear of the dichotic consonant vowel test

right ear place error with right ear voicing error (Z=4.57, p<0.001), right ear combined place and voicing error with right ear voicing error (Z=5.45, p<0.001), left ear place error with left ear voicing error (Z=3.96, p<0.001), left ear combined place and voicing error with left ear place error (Z=2.22, p<0.05) and left ear combined place and voicing error with left ear voicing error (Z=5.14, p<0.001). However, no difference was not seen when combined place and voicing error in right ear was compared to right ear place error (Z=1.59, p>0.05).

The highest number of error was observed in the identification of voiceless consonant /ta/ in the two ears. This was followed by errors in identification of /ba/, /da/, /ga/, /pa/ and /ka/ in right ear and /pa/, /ka/, /da/, /ba/ and /ga/ in left ear.

Discussion

The results revealed young adults performed better on DDT-T compared to that in DCV. The superior performance of the participants in DDT-T compared to DCV was attributed to the higher number of perceptual cues available in the perception of digits compared to the CVs. This is identical to the earlier findings of Speaks et al. [22]. They compared the performance on dichotic digit tests with that of dichotic vowel words, consonant words and CV nonsense syllables in individuals with sensorineural hearing loss and found the performance on dichotic digits to be better compared to other stimuli.

Better scores observed in DDT-T in comparison to DCV is also similar to the findings reported by Yathiraj and Priyadarsini [35] in children. They administered DDT in Kannada and DCV on 24 children in the age range of seven to twelve years and found that the scores of DDT were better compared to DCV. These authors attributed higher scores in DDT to the higher level of redundant cues in DDT compared to DCV test.

In addition, the REA that was noted to be higher in DCV when compared to the DDT-T is also similar to the findings of Speaks et al. [22]. They reported that as the test difficulty increased REA increased. They noted higher REA while using CV syllables when compared to vowel words and consonant words.

Further, the performance of the participants on DCV test in the current study was compared with the normative data for adults developed by Prachi [36]. It was observed that some of the participants (n=18) out of the 60 obtained scores poorer (below 1 SD) than those reported in the norms even when none of these participants reported of any auditory difficulties. This poorer performance on the DCV might have been due to the influence of the native language (Tamil) of these listeners. There are high chances of these results being wrongly interpreted as an individual having binaural integration deficit based on the performance in the test.

In the current study, higher number of voicing errors were observed in DCV test and this finds support from the observation of Bhuvaneshwari and Padakannaya [29]. They reported that voicing features of a consonant in Tamil was perceived based on the context as voiced or unvoiced. Hence, when the CVs are presented in isolation as in the DCV test, they lacked the contextual cues required by the Tamil speaking listeners to correctly identify the consonants as voiced or unvoiced. Further, in the error analysis it was observed that the highest number of errors was made in the unvoiced consonant /ta/.

Additionally, the findings of the study also highlight the need for using test materials in the native language of the listeners. Even though the CVs were recorded in the Indian accent, the voicing contrast used in the CVs is not native to Tamil language. The exposure of the participants to other languages may not help them overcome the influence of their native language. The lack of influence of second language on the perception of dichotic stimuli was also reported by Keith et al. [37]. They administered staggered spondaic word test and DCV test on native English speakers as well as Hindi and Arabic speakers who learnt English as their second language. They found that the performance of the Arabic speakers was significantly poorer compared to the other two groups. These authors opined that lack of /p/ in the Arabic phonology as one of the main factors for the poor performance. They also cautioned about the use of tests with meaningful or nonsense speech stimuli in non-native speakers of the language and comparison with norms of native speakers. This could lead to wrongly diagnosing an individual with normal processing abilities as having an abnormality.

The highest error during the identification of unvoiced consonant /ta/ also supports the findings of Berlin et al. [38] who reported that /ta/ and /da/ consonants were least correctly identified during dichotic CV test. They reported that voiced consonants when competing with unvoiced consonant did poorly during simultaneous presentation. However, the voiced consonant become intelligible as the time separation increased. According to Berlin et al. the unvoiced consonants seemed to arrive later due to the longer burst duration compared to the voiced consonants even though both were presented simultaneously.

Conclusion

It can be concluded from the present study that dichotic digit test in Tamil (DDT-T) can be used to assess binaural integration ability in native Tamil speaking individuals. This is evident from the higher scores in DDT-T compared to dichotic consonant vowel (DCV) in listeners with no known auditory difficulties. Also, higher number of voicing errors was noted in the DCV test. This could be because of the difficulty the native Tamil speakers experienced in perception of voicing contrast when voiced and unvoiced consonants were presented in isolation in DCV test. Hence, based on the findings of the study it is recommended to use DDT-T in the test battery for evaluation of auditory processing disorder in native Tamil speakers.

Ethical Considerations

Compliance with ethical guidelines

The methodology of the study was approved by the institutional ethical committee prior to initiation of the study (Ref: CSP/18/APR/68/124). Written informed consent was obtained from all the participants of the study.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

RS: Study design, acquisition of data, drafting the manuscript, statistical analysis; RV: Study design, supervision, interpretation of the results, and critical revision of the manuscript, statistical analysis.

Conflict of interest

The authors disclose no potential conflict of interest.

Acknowledgements

The authors would like to acknowledge the Faculty of Audiology and Speech Language Pathology at the Sri Ramachandra Institute of Higher Education and Research for providing the facility to carrying out the study. All the participants of the study are also acknowledged.

References

[1] Stevens SS, Davis H. Hearing, Its Psychology and Physiology. vol v. 10. J. 1st ed. Wiley & Sons, Incorporated, United Kingdom. 1938.

[2] Musiek FE, Chermak GD, editors. Handbook of Central Auditory Processing Disorder Auditory Neuroscience and Diagnosis; Vol. I. 2nd ed. San Diego: Plural Publishing, Inc.; 2013.

[3] American Speech-Language-Hearing Association. (central) auditory processing disorders [Technical Report]. 2005. Available from www.asha.org/policy.

[4] American Academy of Audiology. American Academy of Audiology Clinical Practice Guidelines: Diagnosis, Treatment and Management of children and adults with Central Auditory Processing Disorder. American Academy of Audiology; 2010 [https://www.audiology.org/wp-content/uploads/2021/05/CAPD-Guidelines-8-2010-1.pdf_539952af956c79.73897613-1.pdf].

[5] Katz J. The SSW test: an interim report. J Speech Hear Disord. 1968;33(2):132-46. [DOI:10.1044/jshd.3302.132]

[6] Studdert-Kennedy M, Shankweiler D. Hemispheric specialization for speech perception. J Acoust Soc Am. 1970;48(2):579-94. [DOI:10.1121/1.1912174]

[7] Roberts MA, Persinger MA, Grote C, Evertowski LM, Springer JA, Tuten T, et al. The Dichotic Word Listening Test: preliminary observations in American and Canadian samples. Appl Neuropsychol. 1994;1(1-2):45-56. [DOI:10.1080/09084282.1994.9645330]

[8] Musiek FE. Assessment of central auditory dysfunction: the dichotic digit test revisited. Ear Hear. 1983;4(2):79-83. [DOI:10.1097/00003446-198303000-00002]

[9] Wexler BE, Halwes T. Increasing the power of dichotic methods: the fused rhymed words test. Neuropsychologia. 1983;21(1):59-66. [DOI:10.1016/0028-3932(83)90100-8]

[10] Fifer RC, Jerger JF, Berlin CI, Tobey EA, Campbell JC. Development of a dichotic sentence identification test for hearing-impaired adults. Ear Hear. 1983;4(6):300-5. [DOI:10.1097/00003446-198311000-00007]

[11] Willeford JA. Assessing central auditory behavior in children: A test battery approach. In: Keith R, editor. Central Auditory Dysfunction. New York, NY: Grune and Stratton; 1977. p. 43-72.

[12] Yathiraj A. The Dichotic CV test. Developed at All India Institute of Speech and Hearing, Mysuru. 1999.

[13] Kishore T, Rajalakshmi K. Dichotic Rhyme Test in Telugu: A Normative Data on Adults. Student research at AIISH, Mysore (articles based on dissertation done at AIISH) Volume VI 2008. P. 120-30. [http://203.129.241.86:8080/xmlui/handle/123456789/884]

[14] Sangamesh C, Rajalakshmi K. Dichotic Rhyme Test in Kannada: A Normative Data on Adults. Student research at AIISH, Mysore (articles based on dissertation done at AIISH) Volume VI 2008. p. 203-16 [http://203.129.241.86:8080/xmlui/handle/123456789/891].

[15] Giridhar GK, Rajalakshmi K. Dichotic Rhyme Test in Malayalam: A Normative Data on Adults. Mysuru 2010 [http://203.129.241.86:8080/xmlui/handle/123456789/1010].

[16] Bharathidasan S, Rajalakshmi K. Dichotic Rhyme Test in Tamil: A Normative Data on Adults. Mysuru 2013 [http://203.129.241.86:8080/xmlui/handle/123456789/1199].

[17] Arefin S, Chatterjee I, Shahi AC, Chatterjee S, Ghosh P. Development and Standardization of Dichotic Rhyme Test in Bangla. Asia Pacific Journal of Research. 2016;1(38):87-96.

[18] Singh G, Devi N. Dichotic Word (CVCV) Test in Native Kannada Speaking Children. Student research at AIISH, Mysore (articles based on dissertation done at AIISH) Volume VII 2009. p. 35-53. [http://203.129.241.86:8080/xmlui/handle/123456789/929].

[19] Kumar M, Jain C. Dichotic word (CVC) test for native Hindi speaking. Mysuru 2011 [http://203.129.241.86:8080/xmlui/handle/123456789/1048].

[20] Selvaraj A, Rajeswaran R, Jayachandran D. Development of Dichotic Word Test in Tamil Speaking Children. Language in India. 2018;18(2):13-32.

[21] Sudersonam R, Vaidyanath R. Development of dichotic digit test in Tamil. Chennai: Sri Ramachandra Institute of Higher Education and Research; 2019. Unpublished dissertation.

[22] Speaks C, Niccum N, Van Tasell D. Effects of stimulus material on the dichotic listening performance of patients with sensorineural hearing loss. J Speech Hear Res. 1985;28(1):16-25. [DOI:10.1044/jshr.2801.16]

[23] Fuente A, McPherson B, Chiang LP, Tang CH. Cantonese Dichotic Digit Test: Test Creation and Normative Values for Children and Adults. Asia Pacific Journal of Speech, Language and Hearing. 2007;10(2):105-22. [DOI:10.1179/136132807805297602]

[24] Mukari SZ, Keith RW, Tharpe AM, Johnson CD. Development and standardization of single and double dichotic digit tests in the Malay language. Int J Audiol. 2006;45(6):344-52. [DOI:10.1080/14992020600582174]

[25] Bhargavi PG, Kanaka G. Development of dichotic digit test in Tulu. Indian J Otol. 2019;25(2):71-5. [DOI:10.4103/indianjotol.INDIANJOTOL_119_18]

[26] Yathiraj A. Development of a Screening Test for APD. AIISH, Mysuru: 2012 [http://203.129.241.86:8080/xmlui/handle/123456789/4079]

[27] Yathiraj A, Vanaja CS. Criteria to Classify Children as Having Auditory Processing Disorders. Am J Audiol. 2018;27(2):173-83. [DOI:10.1044/2018_AJA-17-0091]

[28] Kumar P, Mohan BM, Pavithra K, Naveen CP. Exploring (central) auditory processing deficits in individuals with Broca's aphasia: Based on case study. Indian J Otol. 2016;22(2):135-8. [DOI:10.4103/0971-7749.182282]

[29] Bhuvaneshwari B, Padakannaya P. Reading in Tamil: a more alphabetic and less syllabic akshara-based orthography. In: Winskel H, Padakannaya P, editors. South and Southeast Asian Psycholinguistics. 1st ed. Cambridge: Cambridge University Press; 2014. p. 192-201. [DOI:10.1017/CBO9781139084642.022]

[30] Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia. 1971;9(1):97-113. [DOI:10.1016/0028-3932(71)90067-4]

[31] American National Standards Institute. Maximum permissible ambient noise for audiometric test rooms (ANSI S3.1-1999). New York: American National Standards Institute; 1999.

[32] American National Standards Institute. Specification for audiometers (ANSI S3.6-2004). New York, NY: Author. 2004.

[33] Cahart R, Jerger J. Preferred method for clinical determination of pure tone thresholds. J Speech Hear Disord. 1959;24:330-45. [DOI:10.1044/jshd.2404.330]

[34] Samuel JD. Development and Standardization of Phonetically Balanced Test Materials In Tamil Language. Mysore: All India Institute of Speech and Hearing; 1976. [http://203.129.241.86:8080/xmlui/handle/123456789/303].

[35] Yathiraj A, Priyadarsini K. Effect of Training on Dichotic CV and Dichotic Digit Scores. J Indian Speech Hear Assoc. 2009;23:74-80.

[36] Prachi PP. Dichotic CV Test-Revised Normative Data For Adults. Mysore: All India Institute of Speech and Hearing; 2000 [http://203.129.241.86:8080/xmlui/handle/123456789/4403].

[37] Keith RW, Katbamna B, Tawfik S, Smolak LH. The effect of linguistic background on staggered spondaic word and dichotic consonant vowel scores. Br J Audiol. 1987;21(1):21-6. [DOI:10.3109/03005368709077770]

[38] Berlin CI, Lowe-Bell SS, Cullen Jr JK, Thompson CL. Dichotic speech perception: an interpretation of right-ear advantage and temporal offset effects. J Acoust Soc Am. 1973;53(3):699-709. [DOI:10.1121/1.1913381]