Development of Local Child Norms for the Dichotic Digits Test

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Submitted by Kris English, PhD, to honor an esteemed colleague in educational audiology, Gail Gegg Rosenberg. This article was first published in the 1998 issue of the *Florida Journal of Communication Disorders, 18,* 4-10. The current leadership of that professional organization has given permission to reprint it in the 2011 edition of the *Journal of Educational Audiology*.

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The Dichotic Digits Test (DDT; Musiek, 1983a) has been shown to be useful as an audiological screening procedure for detecting central auditory processing (CAP) disorders in children or as a component of the CAP battery. Published child norms for the DDT in mean (M) percent correct are not accompanied by standard deviations (SD) or other commonly used statistical information essential to determining the extent to which a child's performance may be different from that of age-alike peers. The purpose of this study was to obtain norms on the DDT at 12 month intervals for a pediatric population (N=200) ranging in age from 5-0 to 12-11 years of age. Over a 16- month period, 200 students referred for routine audiological evaluation were administered the DDT as part of the audiological test battery. Subjects exhibited normal peripheral hearing sensitivity and did not participate in any special services programs in the Sarasota County Florida School District. Data were analyzed to provide mean scores, standard deviations, and other statistical data. These norms allow audiologists evaluating young children to describe results consistent with current reporting procedures for the interdisciplinary evaluation of CAP disorders in children.

Introduction

A model explaining how the central auditory nervous system (CANS) manages dichotically presented stimuli was developed by Kimura (1961). Dichotic listening refers to the presentation of different auditory stimuli to both ears simultaneously. Broadbent (1954) is reputed to be the first to have utilized a dichotic digits paradigm to test both ears simultaneously. Kimura (1961) is credited with formally introducing dichotic speech tests into the arena of central auditory processing evaluation. This was accomplished by her adaptation of Broadbent's method for assessing hemispheric asymmetry and unilateral lesion effects. Kimura's method employed a triad of digits presented dichotically to evaluate central auditory functional processing ability (Bellis, 1996). The use of digits as stimuli continues to be a favored dichotic testing paradigm in the 1990s. Musiek (1983a) is noted for authoring the revision of Kimura's protocol, the Dichotic Digits Test, in which two digits are presented to each ear simultaneously. The Task Force on Central Auditory Processing Consensus Development acknowledged competing dichotic digits as one of the dichotic stimuli that can be used effectively to measure central auditory processing disorders (ASHA, 1996).

The Dichotic Digits Test (DDT; Musiek, 1983) has been acclaimed as a highly sensitive instrument that may be used as a screening tool for central auditory processing (CAP) disorders or a component of the CAP test battery (Bellis,1996; Mueller & Bright, 1994; Musiek, 1983a; Musiek, Gollegly, Kibbe, & Verkest-Lenz, 1991; Musiek, Gollegly, Lamb & Lamb,1990; Stecker,1992). Table 1 summarizes the features of the Dichotic Digits Test that render it an appealing dichotic test to be used in the audiological assessment of central auditory processing abilities in children.

Use of dichotic digits in the evaluation of central auditory processing abilities in children is recognized as a preferred practice with regard to maturational effects. Research has shown that the greater the linguistic load of the auditory stimuli, the more

Table 1. Summary of features of the *Dichotic Digits Test (DDT)* that render it appealing as a dichotic listening test to be used in the audiological assessment of central auditory processing (CAP) abilities in children.

The *Dichotic Digits Test (DDT)* is:

- highly sensitive as a screening test of central auditory processing (CAP) disorders
- easily administered in under five minutes
- able to be quickly scored
- a lightly linguistically loaded, closed-response set (digits 1-10, except 7)
- comprised of digits, which for some persons are easier to respond to than open-set word stimuli
- easily understood by children with directions that rarely need to be repeated
- relatively resistant to at least a mild conductive or sensorineural hearing loss
- not rigidly controlled with regard to the subject's response time
- adaptable to other response modes such as pointing or writing

prominent the maturational effects are likely to be (Bellis, 1996). Maturation effects are noted on most tests of auditory perception, but perhaps more so on dichotic tests (Musiek, Gollegly, Lamb, & Lamb, 1990). Very simply, the use of digits in a dichotic testing paradigm in the evaluation of children will very often show a different profile than that obtained for dichotic sentences. This occurs because the sentence stimuli are more linguistically loaded and place greater stress on the young child's ability to transfer information interhemisperically. Bellis (1996) rates the DDT as being somewhat near the middle of the continuum of least-to most-difficult dichotic tests because the digit stimuli are very closely aligned and only lightly linguistically loaded.

Published norms for children for the DDT are available only in mean percent correct scores. There are no accompanying standard deviations (SD) or other normative data. In the test's instruction guide, the author strongly recommends establishing local norms. There is a diagnostic and educational need to have available sufficient normative data for children that may be used to describe the degree of deviation from the norm. Test norms should be reported in terms that match the local regulations and current practices (Hutchison, 1996).

Thus, there are three very important reasons for establishing local normative data for the DDT so that results may be reported in a manner consistent with other individual assessment instruments used with children. First, when the DDT is used as part of a battery, it is difficult to describe an individual's performance with respect to findings of other audiological CAP tests. For example, it would allow a child's performance on the DDT to be compared with mean scores (and deviations from the mean) on tests such as the Screening Test for Auditory Processing Disorders (SCAN; Keith, 1986) and the Staggered Spondaic Word Test (SSW; Katz, 1986). Secondly, it becomes problematic when audiological CAP results are considered in comparison with psycho-educational and psycho-linguistic test results in the interdisciplinary assessment of students. Evaluation instruments in these domains typically provide statistical information such as SDs. Finally, establishment of local norms is strongly recommended by the test's author. The purpose of this study was to develop local norms for children ages 5.0 to 12.11 for the Dichotic Digits Test to increase the flexibility of this test with respect to current practices in reporting test performance.

Materials and Methods

Subjects

Subjects were 200 participants whose ages ranged from 5.0 to 12.11 years. Age and maturation have been shown to influence CAP test results. Previous investigators have suggested obtaining normative data with children at each year under approximately 12 to 14 years of age (Musiek, 1990; Musiek & Lamb,1994).The DDT's author currently provides only mean percent scores for the 7.0 – 11.11 age range. This study included younger students (5.0 – 6.11) as well as those in the 12.0 – 12.11 age range, due to the maturational concern and because many children below the age of 7 years are referred for an audiological CAP evaluation.

Mean ages for the cohort of 25 students in each 12-month interval are shown in Table 2. The subject group included 96 males (48%) and 104 females (56%). Racial background of the students was: 149 Caucasian (74.5%), 39 African-American (19.5%), 7 Hispanic (3.5 %), and 5 Asian (2.5%). Subjects in this study resided in a middle-sized Florida school district that has many resources available to its students both within the schools and the community. In addition, the school district's rate of free and reduced lunch is below the average for the State of Florida. The geographic area is primarily urban and suburban in composition

Table 2. Age in years and gender of subjects (N = 200).

Age Range	Mean Age	Males	Females
5.0-5.11	5.5	12	13
6.0-6.11	6.5	12	13
7.0-7.11	7.4	12	13
8.0-8.11	8.4	14	11
9.0-9.11	9.5	11	14
10.0-10.11	10.5	14	11
11.0-11.11	11.4	11	14
12.0-12.11	12.4	10	15
Total Group	**8.9**	**96**	**104**

Subjects were students referred for routine audiological evaluation. None of the students participated in any special services programs in the Sarasota County Florida School District at the time of the evaluation. All students had normal peripheral hearing with pure tone thresholds at 15 dB HL or better for octave frequencies 250 – 8000 Hz. Speech recognition scores were 92 percent or better for each ear using age appropriate open-set recorded word discrimination lists (e.g., PBKs, CID W-22s, NU-6) presented at a 30 dB sensation level (SL; re: spondee threshold). Immittance audiometry results were within normal limits for all subjects.

Dichotic Digits Test Procedure

The Dichotic Digits Test (Musiek, 1983a, 1983b) is composed of naturally spoken digits from one to 10, exclusive of the number seven. (However, the number seven is included in the single digit subtest.) The DDT test is composed of 20 digit pairs for a total of 40 test items per ear. The two-digit stimuli on one channel of the tape have been aligned with the two digits on the other channel to produce a dichotic listening task.

Example:	Left Ear	5, 4
	Right Ear	2, 1

The cassette tape was played on an Optimus dual-channel tape player with channel one directed to the left ear and channel two to the right ear, as per test protocol. The signal was fed through the speech circuitry of the Grason Stadler (GSI 10) two-channel clinical audiometer and passed on to TDH-39 earphones at 50 dB SL (re: spondee threshold). Testing was conducted in a double-walled I.A.C. sound treated room.

Each participant was given identical instructions adapted from those offered by Musiek (1983b). Adaptations were made in the narrative to accommodate the language level of the youngest participants. Following are the test instructions:

> *You will hear two numbers in each of your ears. Listen carefully in both ears and repeat all of the numbers you hear. Do not worry about repeating the numbers in any special order. If you are not sure about the numbers you heard, please guess. Now let's practice.*

Oral practice was provided prior to beginning presentation of the three tape recorder practice items. Participants were provided ample time to respond, and in some cases this did require a pause, which is allowable according to published test protocol. There is no required inter-stimulus interval and Musiek (1983a) indicates that the original norms were established with the subjects being given as much time as they wished prior to responding. Subjects' responses were recorded on a DDT worksheet routinely used in this clinical setting when administering this specific dichotic test (see Appendix). Subject responses were scored according to protocol provided by the test author, with the total number of correct responses being multiplied by 2.5 to derive a percentage score rounded to the nearest digit.

Results and Discussion

For the purpose of this study, statistics were applied to only the two- digit subtest of the DDT. Table 3 portrays a summary of local norms computed for the left and right ears that include mean scores in percent, standard deviation (SD), range of scores, and the standard error of measurement (SEM) for the eight age range groups. As is typical for this test and some other dichotic tests, the left ear scores are lower than scores for the right ear for each age group. There was less variability in the 12.0 – 12.11 year old group, as is shown by the lowest SDs. For both ears, with the exception of three instances, the SDs declined with an increase in age and this characteristic would appear to be characteristic of the maturation of the central auditory nervous system (CANS).

Table 3. Mean scores, standard deviations (SD), range of scores, and standard error of measurement (SEM) for subjects (CA: 5.0-12.11 years) for left and right ears on the Dichotic Digits Test.

	Left Ear				Right Ear			
Age	Mean	SD	Range	SEM	Mean	SD	Range	SEM
5.0-5.11	52.5%	7.1	42-62	1.4	69.9%	9.8	55-90	2.0
6.0-6.11	58.7%	9.9	48-75	2.0	71.5%	9.9	58-90	2.0
7.0-7.11	61.3%	8.3	50-80	1.7	73.9%	8.5	62-95	1.7
8.0-8.11	70.6%	8.2	60-88	1.6	79.9%	8.2	70-95	1.6
9.0-9.11	75.0%	7.0	62-90	1.4	81.7%	8.0	70-98	1.6
10.0-10.11	78.4%	6.8	68-92	1.4	86.3%	6.8	75-98	1.4
11.0-11.11	88.1%	7.1	75-98	1.4	92.6%	4.3	80-100	0.9
12.0-12.11	90.7%	5.7	75-98	1.1	96.2%	4.1	82-100	0.8

In Table 4, differences between Musiek's norms and normative data derived from the current Sarasota study are shown. In all instances, the current study shows higher mean scores. The larger differences at the 7.0 – 8.11 age levels may suggest a different maturational rate than that which characterized the subjects in the original normative study. For the left ear, differences between the two sets of norms are less than .50 for the 9.0 – 11.11 age level.

Table 4. Difference between published norms (mean percent) for the Dichotic Digits Test (Musiek, 1983a) and the current study.

	Left Ear			Right Ear		
Age	Musiek Norms	Sarasota Norms	Difference	Musiek Norms	Sarasota Norms	Difference
5.0-5.11		52.5%			69.9%	
6.0-6.11		58.7%			71.5%	
7.0-7.11	55.0%	61.3%	6.3	70.0%	73.9%	3.9
8.0-8.11	65.0%	70.6%	5.6	75.0%	79.9%	4.9
9.0-9.11	75.0%	75.0%	0.1	80.0%	81.7%	1.7
10.0-10.11	78.0%	78.4%	0.4	85.0%	86.3%	1.3
11.0-11.11	88.0%	88.1%	0.1	90.0%	92.6%	2.6
12.0-12.11		90.7%			96.2%	

A summary of deviation from the mean is provided in Table 5. This information is also included on the DDT Worksheet used in this study. Because deviation from the mean is an important element in the interpretation of frequently used psycho-educational and psycho-linguistic tests, this information should be useful to audiologists in quickly determining a child's performance in several arenas. It will all the audiologist to compare results on the DDT with other tests in the audiological CAP battery, as well as the child's performance on psycho-educational and psycho-linguistic tests which may be considered in determining the child's eligibility for special education services.

An additional analysis of data that may be of interest is the summary of mean ear difference scores for each of the eight age groups (see Table 6.) These data allow the audiologist to determine if the ear difference is normal or abnormal. For instance, if the right ear score is very strong and the left score is weak, but within the normal range, the ear difference may actually exceed the mean. In such cases, this finding could provide important information to support or refute an ear difference identified on another test in the CAP battery.

The normative data obtained in this study will facilitate greater confidence in reporting audiological CAP results to parents and other professionals. It will now be possible to compare a student's performance on the DDT with his/her results on other CAP tests that provide SDs (e.g. Screening Test for Auditory Processing Disorders [SCAN; Keith, 1986], Staggered Spondaic Word Test [SSW; Katz,1986], Willeford battery of CAP tests [Willeford, 1977]).

Further analysis of data collected during this study may be conducted to assist in providing a more comprehensive profile of students' CAP abilities and functional levels. More specifically, application of statistical analysis in the following areas may provide useful and critical information for audiologists involved in CAP evaluation of children:

- Ear effect scores (double errors for the same ear)
- Order effect scores (first response ear)
- Error pattern analysis (e.g., position of error or deleted digits, response pattern, reversals).

DDT norms obtained for this subject sample should be very appropriate for students residing in similar geographic areas. However, audiologists should use caution when applying these norms in other regions of the state or nation if the demographics are notably different from the sample used in this investigation.

Table 6. Summary of mean ear difference scores and standard deviations (SD) for eight age groups of children.

Age Range	Mean Ear Difference Score	SD
5.0-5.11	7.4	9.4
6.0-6.11	12.8	4.1
7.0-7.11	12.6	5.9
8.0-8.11	9.4	3.1
9.0-9.11	6.6	4.5
10.0-10.11	7.9	4.6
11.0-11.11	4.5	6.9
12.0-12.11	5.6	3.9

Summary

Normative data were obtained for a pediatric population (5.0 – 12.11 years, N=200) using the Dichotic Digits Test. In all instances, the mean percent score was slightly (.50) to moderately (6.28) higher than norms available from the test's developer. The availability of more sufficient normative data will allow audiologists to interpret a child's DDT results more confidently. Further statistical analysis of data complied during this study would expand the flexibility of this dichotic test with regard to ease of interpretation. The DDT is a valuable component in the audiologist's CAP test battery and the availability of a more complete array of normative data should enhance its use with the pediatric population.

Table 5. Summary of deviation from the mean for children (CA: 5.0-12.11 years) for left and right ears on the Dichotic Digits Test.

	Left Ear				Right Ear			
Age	Mean	SD	-1 SD	-2 SD	Mean	SD	-1 SD	-2 SD
5.0-5.11	52.5%	7.1	45.4%	38.3%	69.9%	9.8	60.1%	50.3%
6.0-6.11	58.7%	9.9	48.8%	38.9%	71.5%	9.9	61.6%	51.7%
7.0-7.11	61.3%	8.3	53.0%	44.7%	73.9%	8.5	65.4%	56.9%
8.0-8.11	70.6%	8.2	62.4%	54.2%	79.9%	8.2	71.7%	63.5%
9.0-9.11	75.0%	7.0	68.0%	61.0%	81.7%	8.0	73.7%	65.7%
10.0-10.11	78.4%	6.8	71.6%	64.8%	86.3%	6.8	79.5%	72.7%
11.0-11.11	88.1%	7.1	81.0%	73.9%	92.6%	4.3	83.3%	84.0%
12.0-12.11	90.7%	5.7	85.0%	79.3%	96.2%	4.1	92.1%	88.0%

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