Reliability of Dichotic Listening Using Two Stimulus Formats with Normal and Learning-Disabled Children

(auditory processing, hemispheric specialization, lateralization)

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This study was designed to establish test-retest reliability of the consonant vowel and digit formats of the dichotic listening test with normal and learning-disabled children between the ages of 7 and 10 years. Between-group differences on ear advantage and total accuracy scores were also examined. The results indicated that both groups showed a right ear advantage and that there were no significant differences in ear advantage between the two groups on either format. However, on the digit format, the learning-disabled group performed significantly lower than the normal group on both the percentage of total accuracy and the left ear raw score. There were no significant differences between the two groups on percentage of total accuracy or raw ear scores on the consonant vowel format. The normal group tended to obtain higher reliability coefficients than the learning-disabled group. Both groups tended to obtain higher reliability on the consonant vowel format than on the digit format. Wide variability in reliability results was found when using different laterality formulas to determine ear advantage.

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Many learning-disabled children are hypothesized to have problems in hemispheric specialization (1). The dichotic listening test, one of several techniques developed to study hemispheric specialization, was developed by Broadbent (2) and adapted by Kimura (3, 4) for use as a tool to determine hemispheric specialization for language functions. Linguistic stimuli, words or other speech sounds, are used most frequently with the dichotic listening technique, and generally have resulted in a right ear advantage (REA). Nonlinguistic stimuli, such as environmental noises and music, tend to yield a left ear advantage (LEA). It has been suggested that a REA reflects specialization of linguistic functions in the left hemisphere, and a LEA reflects specialization of nonlinguistic functions in the right hemisphere (3, 4).

Two major theories have been developed to explain the ear advantages found with the dichotic listening technique. Kimura (3) proposed a structural paradigm based on the anatomy of the auditory system. She suggested that information traveling over contralateral pathways from the ears to the hemispheres is more easily processed than information from the ipsilateral pathways. Also, information traveling first to the hemisphere not specialized for that information must be transferred to the opposite hemisphere via the corpus callosum before it can be processed. Kinsbourne (5) proposed a functional attentional theory to explain the ear advantage results. He theorized that...
activation of cognitive activity which is lateralized to one hemisphere guides attention to the contralateral side of space. Therefore, when listening to linguistic material, the subject's attention is directed to the right side of space, and the converse is true for nonlinguistic stimuli.

With the advent of a relatively uncomplicated, noninvasive procedure to examine hemispheric specialization of language functions, researchers began to try to answer many questions concerning the development and extent of specialization for language functions. Studies have been done to investigate the effects of age, sex, handedness, brain lesions, corpus callosum sectioning, learning disability, and other variables on dichotic listening.

In 1977, Ayres (6) reported an extensive review of the literature on dichotic listening research that indicated that a variety of results had been found when studying each of the above variables. Since then, results of further studies on each variable have continued to yield somewhat disparate results even though the studies appear to have a similar experimental design. For instance, some studies show that the REA increases with age, while others show it remains the same (7). Some studies show left-handed people have a strong and consistent REA (8, 9), whereas other studies show them to have a LEA or no ear advantage (10, 11). Some studies show learning-disabled children have a lesser degree of REA (12), a LEA (13), or no significant ear advantage (14), whereas other studies show learning-disabled children to have REA scores comparable to those of normal children (15-17). Some studies show that the total accuracy score, the total number or percentage of correct stimuli, is lower for the learning-disabled child (6, 17, 18), whereas others show the two groups to be comparable (13, 19, 20). Some studies show significant differences on ear advantage and total accuracy scores between different subgroups of learning-disabled children (20-22).

A possible explanation for the variety of results in dichotic listening research is the extensive number of administration and stimuli parameters that often vary among studies (23). One parameter is the test format that has most commonly been consonant vowels (CV), digits or words. It has been suggested that the CV and digit formats of the dichotic listening test may measure different characteristics of auditory and phonetic processing (7). A second parameter is the response mode, such as one-choice preferred, two-choice forced, and free recall. In a CV dichotic listening study with adults, use of the one-choice preferred and the two-choice forced response modes yielded similar results (24); however, comparisons between these and the free recall response mode have not been made.

Other administration and stimuli parameters include: formulas and definitions used to determine measurements of laterality (25); methods of indicating the response, which may be verbal, written, or gestural (25); order of report, which is channel by channel (reporting one ear and then the other), temporal sequencing (reporting each pair of stimuli in sequential order), free recall (reporting randomly) (26); rate of presentation of stimuli (23); intensity level of the stimuli as measured in decibels (dB) (27); signal-to-noise ratio (28); temporal order (the time of onset and offset of the stimuli) (29); length of the stimulus, which can be either duration of the stimuli or the number of stimuli in a series, or both (23); and calibration of equipment (30).

Studies have shown that varying just one of the test parameters can significantly affect the dichotic listening results (29). If variability exists in not just one, but perhaps several, of the parameters, the possibility for disparate results, even between studies of similar design, is great.

Careful control of all test parameters will help simplify comparisons of dichotic listening research results. However, comparability of research results will not occur unless the different dichotic listening test formats are reliable measures. Reliability has been established for all three types of test formats with normal adults. The test-retest reliability coefficients range from .66 to .90 and the retention of initial ear preference ranges from 70 percent to 90 percent (31-34). A study using words reported the highest reliability (32) and a study using CVs reported the lowest reliability (34). The highest retention of initial ear preference occurred for words (33) and the lowest for digits (32). However, it is difficult to compare the results of these two studies because ear advantage was defined differently in each study.

There have been fewer test-retest reliability studies conducted with normal children than with adults. The published studies involve children from 5 years of age to approximately 11 years of age, and include the word and digit formats, but not the CV format of the dichotic listening test. One study (in German) found the test-retest reliability for the word format to be .79 for the right ear and .46 for the left ear (35). Another study, which did not report test-retest reliability coefficients,
reported that 90 percent of the subjects retained initial ear preference across test sessions (33). A Dutch study found the test-retest reliability of the digit format to be .76 for boys and .69 for girls, with 78 percent of the subjects retaining initial ear preference (36). Though these results appear comparable to the reliability results from studies with adults, the use of non-English test subjects and stimuli in two of the studies requires that comparisons between adults and children remain tentative until further reliability studies with English speaking children are conducted.

A major difficulty in comparing test-retest reliability studies, in addition to the problems caused by the use of different test formats and stimuli in different languages, is the wide variety of formulas that have been used to compute the REA. There were five different formulas used in the reliability studies with adults and children (24, 31-33, 37). Although the different formulas have been considered to yield similar information about ear laterality (27), definite differences in lateralization results have been found when comparing two of the formulas on the same data (25).

Reliability studies that explore test-retest reliability of the dichotic listening test with learning-disabled children have not been published. It is particularly important to identify the stability of the dichotic listening test with learning-disabled children because researchers have begun to use the test as a diagnostic tool for assessing lateralization of language for individual children (38), and as a measurement of change in lateralization of language functions after a period of sensory integration therapy (39). The dichotic listening test must be established as a reliable and valid measure before researchers can use it with confidence.

This study is designated to address the following questions on the dichotic listening test:

1. Does the degree and direction of ear preference differ significantly between learning-disabled and normal groups on the digit and CV formats?
2. Does the percentage of total accuracy scores differ significantly between the learning-disabled and normal groups on the digit and CV formats?
3. What is the test-retest reliability of the dichotic listening test as computed by different formulas for normal and learning-disabled groups?
4. What is the test-retest reliability of the CV and digit formats REA scores as computed by different formulas for normal and learning-disabled groups?

Method

Subjects. Of a total of 60 children tested, 30 were learning-disabled and 30 were normal achievers. There were 7 girls and 23 boys in each group. The subjects ranged from 7.0 years to 10.10 years of age. The mean ages of the learning-disabled and normal groups were 8.10 years and 9.0 years, respectively. Each group included six 7-year-olds, nine 8-year-olds, six 9-year-olds, and nine 10-year-olds. All subjects had a full scale IQ above 85. The mean full scale IQ was 101 for each group. Fifty-six children were right-handed and four were left-handed, with two left-handed children in each group. The learning-disabled children were from a private and a public school. All normally achieving children were from public schools. Both groups comprised children from lower middle to upper middle income families. All learning-disabled children had sensory integrative dysfunction and had received from 1 to 3 years of sensory integration therapy by a registered occupational therapist at the time of testing.

Stimulus Materials. The CV tape consisted of a randomized list of 60 pairs of 6, naturally produced, English stop-consonant-vowels/pa,ta,ka,ba,da,ga/ presented at a rate of 270 msec with an inter-trial stimulus interval of 6 seconds. The digit tape consisted of a randomized list of 20 series of 3 pairs of digits (a total of 120 digits), naturally produced one-syllable digits 1 to 9, presented at an approximate rate of 1.5 seconds per trial with an inter-trial stimulus interval of 15 seconds. Both tapes were from the Kresge Hearing Research Laboratory of the South and were produced by using a computer-based routine that ensured simultaneous onset of each pair of stimuli.

The test tapes were played on a Sony TC-280 reel-to-reel stereo tape recorder. Stimuli were presented at 71dB sound pressure level, which was obtained by adjusting the output of a 1,000 Hz calibration tone to zero on the VU meter of a Grason-Stadler Model 162 two-channel speech audiometer. The tapes were recalibrated on the VU meter before and after each experimental session. The audiometer was calibrated with the aid of a Brüel and
Kjaer type 2203/1613 sound level meter. The subjects listened to the tape through a matched set of 10 ohm TDH-39 headphones with MX41/AR ear cushions. The tape was monitored by the examiner with a set of KLM 600 ohm headphones. Signal-to-noise ratio was greater than 40 db.

Procedure. Children were tested individually in a small, quiet room in approximately 25-minute sessions. Handedness was determined by asking each child to write his or her name on the answer sheel. Immediately before the dichotic testing, each subject was given a pure tone hearing screening in each ear at 15 dB HL for 1,000, 2,000, and 4,000 Hz, and at 20 dB HL for 500 Hz. All subjects who passed the hearing screening were given the CV and digit dichotic listening test with order of administration counterbalanced between subjects. During each format of the test, headphones were reversed after the first half of the stimuli were presented in order to control for any differences between channels or sides of headphones. Each test was preceded by a pre-trial period of testing.

The CV format: The original design was to give the CV format twice, once with a one-choice preferred response mode and once with a two-choice forced response mode in order to examine the effects of the two response modes. However, in the pilot study with normal and learning-disabled children, most children who were asked to use the two-choice forced response mode with the CV format would give only one response for each trial despite strong encouragement to guess. Therefore, it was decided to give the CV format only once with a one-choice preferred response mode elicited by asking the subject to report the sound heard “best” or “loud-
est.” This is the procedure used by Ayres (6).

Before the actual CV test trials were given, the subject received a pre-trial period of 12 monaural presentations of the six syllables with syllables repeated until the subject identified each of the six syllables at least once. Subjects were told that they would hear sounds that were the same as those printed on a card in front of them. This was followed by four CV dichotic pre-trials. The card was removed and 60 CV test trials were then administered.

The digit format: Before the digit format of the dichotic listening test, each subject was given five dichotic pre-trials. These consisted of one trial with one pair of digits, two trials with two pairs of digits, and two trials with three pairs of digits. If subjects did not identify both digits in the first pre-trial, the trial was repeated until both were identified. This pre-trial was followed by 20 test trials. Each subject was instructed to report all of the numbers heard, a free recall response mode. On both the CV and the digit format, the subjects verbalized what was heard and the examiner recorded the response. Correct responses were computed for each ear and for the entire digit test.

Retest. One week following the initial testing, 30 subjects were re-tested at the same time of day using procedures identical to those used during the initial testing session. The subjects were 15 learning-disabled and 15 normal children. There were 4 girls and 11 boys and 14 right handers and one left hander in each group.

Results
Right Ear Advantage, Total Accuracy and Single Ear Scores. A two-way analysis of variance with one repeated measure was performed to examine the effects of Group (learning disabled/normal), Format (CV/digit), and their interactions. Two analyses of variance were executed, one for each of the following dependent variables: (a) right ear advantage (REA), as determined by the R/L ratio, the number of correct responses from the right ear divided by the number of correct responses from the left ear, and (b) percentage of total accuracy. Percentage of total accuracy was used rather than raw scores in order to enable comparisons between the CV and the digit formats. It was necessary to use percentage scores because of the difference in the number of possible correct responses for each ear and for the total test on each format. Table 1 shows the mean, standard deviation, and range for both groups on the two test formats for the REA, percentage of total accuracy and raw right and left ear scores.

In the analysis of variance of the R/L ratio for REA, there was no significant Group by Format Inter-

| Table 1: Mean, Standard Deviation (SD), and Range of REA (R/L), Percentage of Total Accuracy, Raw Right and Left Ear Scores on the CV, and Digit Formats for Normal and Learning-Disabled (LD) Groups |
|---------------------------------|--------|--------|--------|--------|--------|
|                                |        |        |        |        |        |
|                                | CV     | Normal | LD     | Normal |
| REA (R/L)                      | Mean   | SD     | Range  | Mean   | SD     | Range  |
|                                | 1.76   | 1.51   | 0.59 to 7.00 | 1.86   | 1.12   | 0.28 to 4.89 |
| Percentage                     | Mean   | 77     | 86     | 65     | 77     |
| Total Accuracy                 | SD     | 08     | 06     | 10     | 12     |
| Range                          | 63 to 80| 63 to 88| 47 to 92| 55 to 95 |
| Right Ear                      | Mean   | 28.1   | 8.1    | 16 to 49| 9 to 44| 13 to 56 |
| Raw Score                      | SD     | 28.8   | 7.5    | 9.2    | 9.0    |
| Range                          | 10 to 54| 10 to 56| 24 to 58|
| Left Ear                       | Mean   | 19.3   | 5.1    | 7 to 29| 9 to 32| 17 to 54 |
| Raw Score                      | SD     | 18.3   | 5.5    | 8.3    | 7.4    |

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There was a significant Group effect, \( F(1, 58) = 28.62, p < .001 \), which revealed that both groups attained higher ratios on the CV format than on the digit format.

In the analysis of variance of the percentage of total accuracy, the Group by Format Interaction was significant, \( F(1, 58) = 8.08, p < .01 \). There was a significant Group effect, \( F(1, 58) = 9.56, p < .01 \) and a significant Format effect, \( F(1, 58) = 25.93, p < .001 \). Inspection of the Group means for each format on Table 1 indicates that the learning-disabled group scored similarly to the normal group on the CV format, but significantly lower than the normal group on the digit format.

Four \( t \) tests were computed to compare right and left ear raw scores between the two groups on the CV and on the digit format. There was a significant difference between the two groups on the left ear raw score of the digit format, \( t(58) = 3.75, p < .001 \) with the learning-disabled group scoring significantly lower than the normal group. The other three between-group \( t \) tests were not significant, digit right ear raw score, \( t = 1.74 \); CV left ear raw score, \( t = 0.57 \); and CV right ear raw score, \( t = 0.18 \). The Format effect in the analysis of variance of the percentage of total accuracy appeared to be due to the significant difference between the two groups on the left ear raw score of the digit format.

**Table 2**

<table>
<thead>
<tr>
<th>Format</th>
<th>Group</th>
<th>( N )</th>
<th>Percentage of Subjects with REA</th>
<th>Percentage of Subjects with LEA</th>
<th>Percentage of Subjects with No Ear Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
<td>LD</td>
<td>30</td>
<td>83</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>30</td>
<td>83</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Digit</td>
<td>LD</td>
<td>30</td>
<td>76</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>30</td>
<td>70</td>
<td>23</td>
<td>7</td>
</tr>
</tbody>
</table>

In exploring consistency of ear advantage on retesting, 26 of the 30 subjects (87%), 14 normal subjects (93%) and 12 learning-disabled subjects (80%), retained their initial ear preferences on the CV format. On the digit format, 22 of the 30 subjects (73%), 12 normal subjects (80%) and 10 learning-disabled subjects (67%), retained their initial ear preferences. However, only 16 of the 30 subjects (53%), 8 normal subjects (53%) and 8 learning-disabled subjects (53%), showed the same ear preference on both the initial administrations of the CV and digit formats as well as the retest administrations of both formats.

The second method to determine test stability was test-retest reliability. The test-retest reliability coefficients were computed with the Pearson's product-moment correlation method. They were computed for raw right and left ear scores and four laterality coefficients, in order to enable comparisons with other test-retest reliability studies, and for percentage of total accuracy scores. The four laterality coefficients were the \( R/L \) ratio, the \( R/L/R+L \) ratio, the number of correct responses from the right ear minus the number of correct responses from the left ear divided by the number of correct responses from the right plus the left ears; the POE (Percentage of Error) ratio, the number of errors from the left ear divided by the errors from the right plus the left ear; and the \( R-L \) formula, the number of correct responses from the right ear minus the number of correct responses from the left ear. Correlations were computed for normal and learning-disabled groups separately and as a group combined. Table 3 shows the results of the Pearson's product-moment correlations.

**Discussion**

The results of this study are consistent with research in which it was found that 1. normal and learning-disabled children have a similar direction and degree of right ear preference on CV and digit formats of the dichotic listening test, and 2. that a REA is shown for linguistic stimulus material (15-17). Although there were not significant differences on REA between the learning-disabled and normal groups on either format, the range of REA for the learning-disabled group appears more variable than the normal group on both formats, with both groups showing more variability on the CV format than on the digit format.

The CV REA ratios were significantly higher than the digit ratios for both groups. It is possible that the differences in response modes, which require selection of one stimulus versus as many stimuli as can be remembered, may have caused this discrepancy. However, Ayres (6) used the CV format with a one-choice preferred response mode and
obtained ratios similar to the ratios on the digit format in this study. It is also possible that the relatively small sample size used in the present study in comparison to other studies of similar design (6, 50) caused a distortion of the results on the CV format. Subjects who obtained much higher right ear than left ear scores achieved very high ratios that may distort the mean. A larger sample can minimize the effects of a few subjects with REA ratios at either end of the range.

The percentage of the total accuracy score was similar for the learning-disabled and normal groups on the CV format, which has been found in several studies (15, 19, 20). However, on the digit format, the learning-disabled group had a significantly lower percentage of total accuracy than the normal group, which has been seen frequently in the literature (12, 19, 17). The learning-disabled group had a significantly lower left ear but not right ear raw score than the normal group on the digit format, which apparently was not sufficient to affect the REA, but may contribute to the learning-disabled group’s lower percentage of total accuracy score.

It has been suggested that the CV format may measure abilities that mature early and do not change after ages 4 or 5 years, whereas the digit format may measure abilities that mature late and show significant change between ages 4 and 12 years (7). It may be that 7-year-old to 10-year-old learning-disabled children do not have difficulty with earlier maturing auditory language functions, as measured by the percentage of total accuracy on the CV format, but they may have difficulty with some aspects of later maturing auditory language functions, as measured by the percentage of total accuracy on the digit format.

It may be that the auditory memory component of the digit format is causing the learning-disabled group particular difficulty. Theories explaining the REA support the belief that linguistic information from the right ear will have an advantage in being processed over information from the left ear (3, 5). Therefore, a child with a poor auditory memory may score as many correct responses through the right ear as a child without memory difficulties. However, information from the left ear may be processed second and, therefore, may be affected by the memory deficit that results in a lower left ear score for the learning-disabled child. This appears to be the case in this study.

It is also possible that the period of sensory integration treatment, which each learning-disabled child received, affected the development of some aspect of auditory language function that is measured by the REA ratio score on both formats and by the percentage of total accuracy score on the CV format but not the digit format. Kawar’s study employed word stimuli with three pairs of words per trial.

The test-retest reliability coefficients in this study appear to compare to results of other studies (24, 31, 36). It is apparent that the test-retest reliability results of the learning-disabled group tend to be lower than for the normal group, although both groups are consistently more reliable on the CV format than on the digit format. One explanation for the lower reliability coefficients in measuring lateralization of language in the learning disabled may be that it is a reflection of the fluctuating or unstable capacities of the central nervous system of some of the learning-disabled children (40).

Test-retest reliability may be higher for the CVs than the digits for both groups because the CV format is a simpler task, involving a very limited memory component, whereas the digit task involves a substantial memory component. The possibility of developing different response strategies on the digit format may also lower test-retest reliability. For example, a subject might use the strategy of reporting one ear before the other on the initial test administration and reporting alternating ears on the second administration, two strategies that could yield different REAs.

The test-retest reliability of the percentage of total accuracy scores is high for both groups and both test formats with coefficients ranging from .85 to .92, with the exception of the normal group’s perfor-
mance on the CV test that elicited a coefficient of .61. The higher stability of the percentage of total accuracy score may indicate that this parameter should be considered when measuring change in adequacy of language processing after a period of therapy.

It is important to note how varied the test-retest reliability coefficients are depending on which laterality coefficient is used. When examining the four formulas, for assessing REA, the normal group’s test-retest coefficients range from .82 to .89 for the CV format and from .32 to .68 for the digit format. The coefficients for the learning-disabled group range from .41 to .88 for the CV format and from .26 to .66 for the digit format. It appears that, because the left ear score is less reliable than the right ear score, those formulas emphasizing the left ear raw score, such as POE, tend to yield less reliable results. The use of several different laterality coefficients in the literature may contribute to the variety of dichotic listening test results that have been obtained in other test-retest studies (32, 33, 36).

**Diagnostic Use of the Dichotic Listening Test**

The dichotic listening test has been recommended for use in diagnosing hemispheric specialization for language of individual learning-disabled children. It is important to establish the stability of the dichotic listening test with normal and learning-disabled children in order to use it with confidence as a diagnostic tool. From this study, it appears that the CV format is the most reliable measure with normal and learning-disabled children and, therefore, may be the most useful for diagnostic purposes. However, only the digit format elicited significant differences between the two groups on the REA. Unless the test formats can distinguish between some types of learning-disabled children and normal children, they probably are not useful diagnostically. The learning-disabled group achieved a wider range of ear advantage on both formats, in particular on the CV format, than the normal group. This may reflect a tendency for learning-disabled children to have abnormally high and possibly abnormally low ear advantages. If so, this would substantiate the need to divide learning-disabled children into subgroups in order to determine the predictive capacity of the dichotic listening test (6, 21).

Knox, Syrdal-Lasky, and Roesser (20) found significant differences on both the CV and digit formats when dividing the learning-disabled population into those with and without language problems. If these results can be confirmed, the CV format seems to be the most useful as a diagnostic tool due to its higher reliability. However, if the digit format is indeed measuring auditory language functions that mature later than those measured by the CV format, it may be important to use both measures in conjunction with one another in order to provide a complete picture of a child’s specialization for language.

Despite the fact that the CV format was more reliable, there was considerable fluctuation in ear advantage for some individuals, particularly in the learning-disabled group. Therefore, more than one administration of the dichotic listening test is recommended before using the test scores as part of a diagnostic work-up.

It is important that ceiling effects do not occur with any format of the dichotic listening test. If the child shows a high degree of accuracy with both ears, the results might appear to represent a lack of laterality for language; however, the test may be too easy for the child. It is important to obtain accuracy scores as well as laterality coefficients when attempting to determine a child’s laterality for language from dichotic listening scores.

While the dichotic listening test has been used to determine between-group differences, its usefulness for individual diagnostic measures has not been fully established. Results on REA ratios in this study differ from those found by Ayres (6) and Berlin, Hughes, Lowe-Bell and Berlin (30). The variability could be caused by any number of differences in subject or administration and stimuli parameters between the three studies. It appears necessary to standardize and develop norms for a specific format of the test to be used for diagnostic purposes. The validity of the dichotic listening test must also be determined. This is difficult because lateralization of language is complex, and may appear to vary depending upon the demands of a task (5).

Further research is needed to clarify what the dichotic listening test is measuring, what differences there may be between subgroups of the learning-disabled population, and what relationships the dichotic listening scores have to improvements in learning.

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