Dichotic Listening Performance in Normal Children and Adults
(cerebral specialization, lateralization, auditory processing)

The purpose of this study was to investigate normative expectations on the dichotic listening test in order to determine the influence of sex and development on dichotic listening performance. Thirty 5-to-6 year olds, thirty 11-to-12 year olds, and 30 adults, 15 males and 15 females in each group, were tested by using consonant-vowel dichotic stimuli. There were no significant differences between males and females except for the 11- to 12-year-old females who were significantly more accurate than the males. Degree of ear asymmetry did not differ among the three age groups; however, the adults and 11-to-12 year olds were significantly more accurate than the 5-to-6 year olds. Guidelines are suggested for the interpretation of dichotic listening test data.

The dichotic listening test, probably most often identified with the disciplines of audiology and speech pathology, is also relevant to occupational therapy. As one means of assessing the adequacy of cerebral dominance for language, results of this test have assisted therapists in interpreting the Southern California Sensory Integrative Tests (SCSIT) (1). An example of this practice is illustrated in the Manual of the SCSIT (2) in which case presentations include scores on the dichotic listening test that are then shown to be of value in analyzing whether or not a child seems to have a sensory integrative dysfunction. Regardless of whether therapists are administering the tests themselves or using the results obtained by an
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Review of the Literature

The Definition and Importance of Cerebral Dominance. The term cerebral dominance refers to a greater influence of one hemisphere over a bodily function than of the other (6). Despite their anatomical similarity, the cerebral hemispheres tend to differ functionally. Kinsbourne and Hiscock (7) distinguish between the terms cerebral dominance and cerebral lateralization, claiming that the former implies an executive function of one hemisphere over the other, whereas the latter refers simply to some qualitative or quantitative asymmetry. Regardless of whether one hemisphere performs an executive function or simply has greater responsibility for a function, there is considerable evidence of a lack of equipotentiality between the hemispheres. For example, the left hemisphere is thought to be more responsible for verbal sequential ordering, writing, and calculating (8), whereas the right hemisphere has been shown to play a greater role in the processing of visual and spatial information, simple language comprehension, and nonverbal ideation (9). In this study, the terms are used in relation to the function of language.

Learning of language along with symbolic and abstract conceptualization are thought to depend upon the optimum functioning of each cerebral hemisphere. In this view, as each hemisphere is specializing and taking various degrees of responsibility for different functions, it is assumed there must be ongoing interhemispheric communication. De Quiros (8, 10) hypothesized that cerebral specialization may be impeded by deficits in the proprioceptive and vestibular systems. In such instances, he believes, voluntary cortical control is then needed to maintain posture and equilibrium, and the hemispheres may be so consumed with these functions that they are unable to specialize and communicate for more abstract thoughts and processes.

Although de Quiros' views are highly theoretical, they are supported by research. For example, he found that neonates identified as having vestibular deficits later demonstrated learning disabilities and language delay (10). Ayres (11) found that some learning-disabled children with auditory-language problems demonstrate a lack of well-established laterality together with vestibular dysfunction. Children hypothesized to have this syndrome seem to be better responders to sensory integrative procedures, improving academically as sensory processing theoretically improves (11, 12). Other research (13-19) has shown a relationship between atypical lateralization and learning disability. Thus lateralization seems to be important to the acquisition of learning ability and, when it is not well established, may interfere with academic achievement.

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There are several approaches to the assessment of cerebral specialization. Until the early 1960s, most of what was known about cerebral specialization was gathered from pathological cases. Descriptions of those symptoms associated with unilateral lesions, hemispherectomies, and commissurotomies were the major sources of this information. Since then, research methodologies involving sodium amytal injections, electroencephalographs, visual half-field tachistoscopic exposure tests, dichotic listening tests, dichaptic tests, and positron-emission tomography have been used to study cerebral specialization in normal subjects.

Specifically, the dichotic listening test has been used to investigate several dimensions of cerebral specialization for language, such as whether or not cerebral dominance has been adequately established, which hemisphere may be specializing for the function of language, and the relative contribution of each hemisphere in language processing. There are two major theories proposed to explain the meaning of performance on the dichotic listening test. The structural theory from which dichotic listening scores are interpreted as indices of lateralization was proposed by Kimura (20). It suggests that information traveling over contralateral pathways from the ears to the hemispheres is more easily processed than information from ipsilateral pathways. In contrast, the attentional theory proposes that it is attention rather than auditory processing alone that determines how dichotic stimuli will be processed (7). A more extensive explanation of these theories, guidelines on interpretation of dichotic listening results, test reliability estimates, and an explanation of the problems inherent in dichotic listening studies are thoroughly reviewed by Koo­mar and Cermak (21). Koomar and Cermak (21) point out that studies using dichotic listening have been difficult to compare due to variation in stimulus format, scoring procedures, and response mode. Of several approaches to dichotic listening testing, they demonstrated that the consonant-vowel format with right/left ratio scoring was the most reliable.

In summary, whether one is referring to cerebral dominance or to cerebral specialization, the lack of equipotentiality of the two hemispheres is well established. It seems that the left hemisphere in most individuals is lateralized for language. A lack of well-established lateralization has been implicated in at least one type of learning disability, and this type seems to be the most responsive to sensory integrative procedures. Finally, assessment of lateralization for language is frequently accomplished through the dichotic listening test.

The Establishment of Cerebral Dominance. Although researchers tend to agree that language does seem to be lateralized in the adult, controversy exists about just when it is established in childhood. Lenneberg (22), in his classical writings on the foundation of language, argues that language acquisition takes place during a "critical period" lasting from age 2 to puberty. In his view, lateralization for language is first slightly detectable between the ages of 3 and 5, becoming incrementally stronger until puberty when it is fully established in the left hemisphere. Thus, for Lenneberg, the so-called "critical period" encompasses both language acquisition and the establishment of cerebral dominance.

Krashen (23) has challenged Lenneberg's notion that the critical period for language acquisition and the establishment of cerebral dominance are the same. Although he agrees with Lenneberg that the critical period for language acquisition is between 2 and puberty, he hypothesizes that cerebral dominance for language is fully established by 5.

The Krashen and Lenneberg positions predict somewhat different age trends in the normative performance on the dichotic listening test. Although the Lenneberg position predicts a steady increase in degree of lateralization from 4 to 13, the Krashen position suggests a ceiling effect at 5. However, results of studies that have looked at age trends in dichotic listening have been contradictory and suggest that such trends may be affected by sex (24, 25-28) and socioeconomic status (26, 29, 30-33).

Some studies on dichotic listening show that language may be lateralized as early as age 3 (24, 34); others have found that it emerges in 4-to-6 year olds (29, 30, 33, 35) or as late as in 9 year olds (36). Variations in results can be accounted for in two different ways. Krashen and Harshman (37); Satz and others (36); and Marshall and others (38) suggest that statistical or mathematical procedures were not consistent in determining the degree of ear asymmetry across studies. Porter and Berlin (39) attribute discrepant findings to the complexity of stimuli presented. They distinguish between different levels of language processing and argue that more complex stimuli may be lateralized at a later age than
Table 1
The Mean Ratio and Accuracy Scores, Standard Deviations, and Ranges of Dichotic Listening Test Scores for Each Age Group

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Right Ear Accuracy</th>
<th>Left Ear Accuracy</th>
<th>Right &amp; Left Ears Total Accuracy</th>
<th>R/L Ear Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>5-6</td>
<td>24</td>
<td>4.9</td>
<td>13-33</td>
<td>18</td>
</tr>
<tr>
<td>11-12</td>
<td>28</td>
<td>6.6</td>
<td>13-42</td>
<td>22</td>
</tr>
<tr>
<td>Adults</td>
<td>30</td>
<td>6.3</td>
<td>17-47</td>
<td>23</td>
</tr>
</tbody>
</table>

Simple stimuli. Simple stimuli that lack semantic content and have low memory requirements, such as nonsense syllables and one or two digit pairs, may be associated with earlier establishment of cerebral specialization than complex meaningful stimuli.

On the basis of the studies reviewed, researchers agree that lateralization is associated with language acquisition, but they disagree on just when such lateralization is established. Although a number of studies suggest that, for simple stimuli, lateralization is established by age 5, it appears that, for a more complex auditory stimuli, specialization could occur 3 or 4 years later. Moreover, developmental trends in dichotic listening may be influenced by sex and age.

Because occupational therapists are being called upon to treat children with learning problems who are in early identification programs as well as in primary grades, it is imperative that they refine their understanding of developmental trends in all areas they evaluate. Use of the dichotic listening test can increase therapist precision in making sound professional judgments, provided interpretation is based on carefully collected data that take into account age, sex, socioeconomic status, and potential developmental trends. The purpose of the present study was, therefore, to gather normative data, taking sex into account, beyond that which is already available. The effects of socioeconomic status were controlled through delimitation of the sample. The following hypotheses were tested: 1. that there would be no significant difference between the sexes on mean Right (R) and Left (L) accuracy and mean R/L ratio scores; and 2. that there would be no significant differences in mean R and L accuracy and mean R/L ratio scores between 5-to-6 year olds, 11-to-12 year olds, and adults.

Methods

Subjects. A total of 90 right-handed normal subjects participated in this study. Of these, 60 were children, and 30 were adults, all of whom were of middle socioeconomic status. The children were divided into two groups, thirty 5 and 6 year olds, and thirty 11 and 12 year olds, with an equal number of boys and girls in each group. The 30 adults, 15 males and 15 females, were between the ages of 18 and 40. All subjects were without diagnosed audiological handicaps, but, in addition, the children had received an audiogram before inclusion in the sample. Children were considered normal if they scored age appropriately on the Wide Range Achievement Test. The adults were attending a local college.

Stimulus Materials

Procedure. Each subject was administered a dichotic listening test using 30 pairs of six English consonant-vowel stimuli prepared by the Kresge Hearing and Research Laboratory (40). The six stimuli were: pa, ba, ta, ka, da, and ga. Each subject repeated the stimuli before the test began in order to familiarize the examiner with individual pronunciations. A free recall method of response was used as each subject was asked to report what was heard and told not to worry if he or she was able to report only one sound. The verbal responses were recorded by the examiner. After a subject had been presented with 30 pairs of stimuli, the earphones were reversed, and the same 30 stimuli were presented but this time to the opposite ear. Through this procedure, any existing difference between the two channels of the equipment was controlled.

Scoring. For each subject, the total R and L accuracy score was calculated by adding the number of correct responses for the right ear and the left ear, respectively. The R and L ratio score was ob-
tained by dividing the total correct right-ear responses by the total correct left-ear responses. The total possible correct for the right ear was 60, the total possible for the left ear was 60, with the total possible accuracy for both ears being 120. A R/L ratio score of greater than 1.0 was interpreted as a right-ear advantage (REA), and a R/L ratio score of less than 1.0 was interpreted as a left-ear advantage (LEA). A R/L ratio score of 1.0 was interpreted as indicating no ear advantage.

**Results**

For the most part, there were no significant differences in dichotic listening scores between males and females. Results of a series of two-sample t-tests revealed that the only group to show a sex difference was the 11-to-12 year olds for the R and L Accuracy Scores ($t = 1.847$, $p < .05$), with the girls being more accurate. Since the right/left ratio scores were not normally distributed, Chi-square analyses were used to test Hypothesis 1 for each age group. Results revealed that sex and ear advantage were not significantly associated in any of the age groups. Scores obtained on males and females were therefore combined in further statistical analyses.

Mean accuracy and mean ratio scores with respective standard deviations and ranges are presented in Table 1. Results of a one-way analysis of variance of mean total R and L accuracy scores with alpha set at .05 revealed that there was at least one significant difference between two of the age groups ($F = 2.87$, $p < .05$). To determine which groups differed, a Scheffé post hoc comparison was used and indicated that the 5-to-6 year olds were significantly less accurate than the 11-to-12 year olds ($s = 3.00$, $p < .05$) and the adults ($s = 3.06$, $p < .05$). No significant differences were found between the 11-to-12 year olds and the adults.

Since inspection of the data revealed that the frequencies of ratio scores within age groups were not normally distributed, analysis of variance was not used to determine whether the respective age groups differed significantly from one another in mean ratio score. Instead, a Chi-square analysis was employed and, as reported in Table 2, revealed that age and frequency of right ear, left ear, and no ear advantage were not associated.

In Table 3, the definition of right ear advantage is further restricted so that it excludes not only those with a left ear or no ear advantage, but also those with excessively high ratios, thought to be suggestive of inadequate left ear rivalry. Seventeen, or 56 percent, of the 5-to-6 year olds, 16 or 53 percent, of the 11-to-12 year olds, and only 13, or 43 percent, of the adults demonstrated a R/L ratio within the range of 1.1 and 1.5. Ratios of 1.6 and above were found in 23 percent of the 5-to-6 year olds, 23 percent of the 11-to-
Because of the presence of a number of R/L ratio scores in the extreme ranges, the median was considered a more accurate indicator of central tendency than the mean. The median dichotic listening ratio score for all age groups was 1.25. Finally, to obtain reasonable normative expectations, semi-interquartile ranges indicating half the distance between the 25th and the 75th percentile were calculated and then used to construct ranges within which approximately the middle 50 percent of the scores were contained for each age group. Because the distributions were asymmetrical, these ranges tended to capture 70 percent of the scores and are represented by the areas within brackets denoted in Table 4. Those scores within the bracketed areas are interpreted as indicating expected “normal” performance.

Discussion
The findings of this study suggest that, with the exception that 11- to 12-year-old girls were more accurate than boys of their age, on R and L accuracy score there were no significant differences between males and females in dichotic listening performance. Also, there was no significant association between the presence of a right ear advantage, a left ear advantage, or no ear advantage and age, but 5- to 6-year-olds were less accurate than both 11- to 12-year-olds and adults.

That there were no significant sex differences on most of the statistical tests is consistent with findings of numerous other studies (20, 33–35, 41), but a few researchers have found earlier establishment of ear asymmetry in girls (24, 27, 31). The finding that accuracy scores improve with age is consistent with those of earlier studies (20, 35). In this study, when dichotically presented with consonant-vowel stimuli, adults and 11- to 12-year-old children were significantly more accurate than 5- to 6-year-olds. It seems that accuracy of auditory processing of simple stimuli improves sometime in middle childhood and then levels off, supporting the position that some aspects of language acquisition are well established by adolescence without substantial change through adulthood.

That all of the groups demonstrated the same median dichotic listening ratio is in support of the lateralization-by-5-years-of-age hypothesis endorsed by Krashen (23). It is also consistent with earlier studies on children in which simple dichotically presented stimuli were used. Had more complex stimuli been presented, differences between respective age groups may have been detected. At least for the type of stimuli presented to the subjects in this study, cerebral specialization seems to be established by 5 years of age, but accuracy of processing improves sometime in the interim between the 5th and 6th and the 11th and 12th years.

Some controversy exists about whether the construct of laterализation as measured by the consonant-vowel format of the dichotic listening test is meaningful for use with learning-disabled clients (21). Koomar and Cermak (21) found that the mean R/L ratio score did not differentiate learning-disabled children from normals when the consonant-vowel (CV) format was used. In contrast, Ayres (4) and Bissell (16) presented data suggesting that the R/L ratio score does meaningfully discriminate between learning-disabled and normal children. As such, some data are available to support the validity of the use of the CV format in diagnostic work-ups with learning-disabled children when the test is administered in accordance with procedures outlined in this study.

If we assume that the CV format prepared by the Kresge Hearing Laboratory that was employed in this study is valid for clinical use as described, then guidelines for test interpretation on individual clients are needed. Although the normative R/L ratio means obtained in this study closely parallel those reported by Ayres (4), they do not resemble the mean R/L ratios reported by Koomar and Cermak (21). This discrepancy probably reflects the influence of a few extreme scores on the mean and the tendency for some dichotic listening scores in the normal population to fall into atypical ranges. For this reason, the median may be considered a more accurate indicator of central tendency than the mean in interpreting group dichotic listening data.

The decision to use the median as a measure of central tendency led to the development of guidelines for interpretation of individual client scores based on this statistic and the semi-interquartile range around it. Table 4 presents these ranges. For all age groups the median score was 1.25, but considerable variability existed. Most 5- to 6-year-olds scored between 1.0 and 1.4, most 11- to 12-year-olds obtained 1.2, whereas adults most frequently obtained 1.0 or 1.5. Scores within the semi-interquartile ranges shown within
Table 4
Summary of Data: Scores on the Dichotic Listening Test and Number of Subjects with Each Score

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Advantage</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>1.5</th>
<th>1.6</th>
<th>1.7</th>
<th>1.8</th>
<th>1.9</th>
<th>2.0</th>
<th>2.1</th>
<th>2.2</th>
<th>2.6</th>
<th>2.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>Left Ear</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>n = 30</td>
<td>No</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11-12</td>
<td>Right Ear</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td>2</td>
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<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>n = 30</td>
<td>Advantage</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Adults</td>
<td></td>
<td>2</td>
<td>[2]</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
</tr>
</tbody>
</table>

The results of this study are important to occupational therapists for reasons that go beyond clinical interpretation of dichotic test results. In addition to their role as clinicians, therapists are involved in research, either directly through participation in studies, or indirectly through review of research reports. This study demonstrated that lateralization inferred from ratio scores on the CV format of the dichotic test is maturationally established by age 5. Changes in dichotic listening performance in children age 5 or older reported in studies on learning-disabled children as a consequence of therapy are reasonably attributed to a treatment rather than to a developmental effect. It is expected that the results of this study will enhance therapists' understanding of dichotic listening studies conducted by other occupational therapists, linguists, audiologists, and members of other disciplines. In this way, therapists may become better consumers of research in this area.

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