LETTER TO THE EDITOR

Pediatric Central Auditory Processing Disorder: Considerations for Diagnosis, Interpretation, and Remediation

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Several speech recognition tests available to the audiologist appear to be sensitive to auditory processing disorders in children. Performance on these special tests often suggests auditory learning disability (ALD). The population labeled ALD is heterogeneous, making it imperative that an appropriate remediation strategy be found for each child based on a specific diagnosis and understanding of the rationale and procedures. This paper presents a theoretical model for central auditory processing based on Luria (1973) in which mental activity is a complex of interrelated functions subserved by specific areas of the brain. Tests are categorized according to hypothesized associated skills. Profiles of test results are interpreted in terms of specific diagnosis and remediation by use of environmental modification, compensation techniques, behavior modification, and assistive filtering devices.

Willeford (1977) was among the first to report that learning disabled children performed substantially poorer than their normally-achieving age-mates on tests of central auditory processing (CAP). Special tests have since been developed to assess the auditory function of children with known or suspected learning disabilities (Ferre & Wilber, 1986; Johnson, Ettfield, & Sherman, 1981; Musick & Guerkink, 1980; Pinheiro, 1977; Stubblefield & Young, 1975; Willeford & Bilger, 1978). Children who perform below normal limits on these tests are said to have an auditory processing disorder (APD) and are often referred to as auditory learning disabled (ALD).

The population labeled ALD represents a heterogeneous group whose deficits require varying remediation strategies (Leon, Watson, Reing, & Porch, 1981; Ferre & Wilber, 1986; Jerger, Martin, & Jerger, 1987). The effectiveness of remediation, however, depends upon the appropriateness of the diagnosis. In order to interpret test results accurately, an understanding of the theoretical rationale behind the procedures is necessary. The purpose of this paper is (a) to review briefly a theoretical model for CAP testing, (b) to hypothesize the specific diagnostic value of CAP tests based on

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implications of that model. (c) to illustrate test-interpretation with some sample cases.
and (d) to recommend intervention strategies matched to diagnostic findings.

THEORETICAL MODEL

Luria (1977) suggested that higher mental processes represent complex-functional
systems based on jointly working units of the brain. The brain may be conceptualized
as an interdependent system/network and all mental activity may be considered the
result of the combined workings of individual and interrelated functional brain units.
Thus, any mental activity can be represented as a set of operations and may suffer as a
result of the destruction of any link in the system. A task may be more difficult, even
impossible, to perform if one or more of its operations is impaired. In order to under-
stand the nature of the impairment of the higher mental activity and determine which
link has been broken, one must examine each of the operations of which it is composed.
According to Luria, there are three functional brain units consisting of the attention/
 arousal unit (Unit 1), the sensory reception unit (Unit 2), and the organization/plan-
ing unit (Unit 3). Each unit contributes to every higher level task, with the amount of
contribution of each determined by the nature of the task.

In this model, auditory processing as a form of mental activity may be represented
by a set of interdependent operations, each of which is subserved in a specific and pre-
dictable manner by a unit of the brain. According to Luria, Unit 1, the attention unit,
maintains optimal waking conditions, inhibits irrelevant stimuli, responds to novel
stimuli, assists in sustaining concentration on a task, and aids in retention of interfering
stimuli. This unit "provides the necessary cortical tone" for perception to take place
(Luria, 1973, p. 100). One may hypothesize that the auditory processing skills associ-
ated with these functions may include selective attention, divided attention, and the
ability to recall information that is presented aurally. With respect to audition,
Luria suggested that Unit 2, the sensory reception unit, is responsible for the reception,
analysis, and storage of auditory information, including detection, discrimination,
short-term storage, sound sequencing, retention of word series, and analysis and syn-
thesis of sound. Functional Unit 3 is responsible for creation of intentions, formula-
tion of plans, regulation of behavior, organization of external stimuli, regulation of
state of activity, and verification of action (Luria, 1973). Auditory processing skills
that may be associated with these functions include organization of output sustai-
ned concentration, decision-making, and organization of phonemic input according
to linguistic-cognitive rules in order to allow comprehension to occur.

This theoretical grouping of operations represents auditory processing as a complex
chain of events through which the human system deals with stimuli received via the
sense of audition. A break in any link of this chain may result in an A-P-D. By knowing
which operations or levels of auditory processing are being tested by various CAP tests
and by examining patterns of performance across these tests, it is possible to determine
which operation (as operations) is "at fault." In the case of an adult patient, for whom
it is assumed that all brain units are fully functioning before onset of a given disorder,
a diagnosis of behavioral deficit usually leads to identification of a specific site of lesion.
However, in the case of a child, deficient auditory processing skills may exist in the ab-
sence of neurological damage (Wilfert & Bilger, 1978). In the evaluation of children,
consideration must be given to the developmental nature of the growing brain. Because
children develop through succeeding stages, each of which is qualitatively different from
the others, not all skills exist, nor are they expected to exist, at a given age. Thus, disorders of auditory processing skills may be the result of either developmental lag or the failure of some precursors to have developed adequately.

Additionally, we label APE itself as a vague one. The child with an APD may suffer from weaknesses in one or more of many underlying function areas including attention, memory, discrimination, and comprehension, among others. Poorer-than-normal scores on CAP tests may suggest only a problem in general. In order to determine the specific nature of the APD, the evaluation must focus on the underlying skills associated with various tests of auditory function.

TEST INTERPRETATION

Given this theoretical framework, one may expect that any measure of auditory function taxes skills associated with each of Luria's functions) units, at least to some extent. However, careful control of stimuli, recording parameters, and instructions may be used to develop procedures that take more heavily the skills of one functional unit over the others (Ferre & Wilber, 1986). It is possible to analyze several CAP tests in order to determine the underlying operations most associated with each one. When such tests are administered in a battery, performance on those believed to tax the same underlying skills may be used to infer the nature of a suspected APD. Table 1 presents an auditory processing test battery. Hypothesized associated skills for each test, and results for two representative cases. Ferger et al. (1987) used a similar approach in the identification of a specific perceptual (Unit 2) deficit of an AEP child.

In both cases illustrated, performance one standard deviation or more below the mean score for the child's age was used as the pass-fail criterion per test. A diagnosis of APD was made if the child failed three or more tests within the battery (Ferre & Wilber, 1986). For Case A, test performance was within normal limits on all but one measure that primarily taxed skills associated with signal perception (Unit 2) and language comprehension (Unit 3). One of the failed tests associated with either of these areas — the Binaural Fusion test — appears not only to tax a child's ability to decode an auditory signal but also to design to assess an individual's ability to integrate complementary information that is presented dichotically (Matzker, 1962). Matzker found that word identification in the Binaural Fusion Test is not possible if only one channel is received. Therefore, one possible explanation for poor performance on a test of binaural fusion may be an inability to divide attention between two ears. This test result was consistent with Case A's below-normal performance on all other measures requiring attention-based skills, either selective or divided. Based on this performance profile, the examiner concluded that Case A suffered from an attention-based APD.

For Case B (Table 1) there was normal performance on most measures associated with attention skills. However, abnormal performance was observed on measures testing perceptual and/or linguistic skills. Although this is a less-clear-cut case, the examiner made an initial diagnosis that Case B's poor performance on measures of word recognition and sentence comprehension (Goldman-Fristoe-Weinlock Auditory Discrimination Test and the Token Test) were the result of a more primary difficulty in the ability to acoustically analyze the auditory signal. These diagnoses were confirmed by further interpretation of test performance relative to specific errors made on each failed test. Clinical experience and research (Ferre,
<table>
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<tr>
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<th>Lurian Brain Unit(s) Required</th>
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<th>Results Case B</th>
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<tbody>
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<tr>
<td>Goldman-P inside-Wordcock (GFW) Selective Attention Test (Goldman, Patten, &amp; Woodcock, 1976)</td>
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<td>Staggered Spondaic Word Test (Katz, 1962)</td>
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<td>BNL</td>
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<tr>
<td>GFW Auditory Discrimination Test (Goldman et al., 1976)</td>
<td>word recognition</td>
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<td>WNL</td>
<td>BNL</td>
</tr>
<tr>
<td>GFW Auditory Attention Test (Goldman et al., 1976)</td>
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<td>Peabody Picture Vocabulary Test (Dunn &amp; Dunn, 1981)</td>
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<table>
<thead>
<tr>
<th>Assessment Instrument</th>
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<tr>
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<td></td>
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<td></td>
<td>sentence comprehension</td>
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Note: Based on theory proposed by Luria (1973).

*WNL = within normal limits re national or local norms.
*BNL = below normal limits re national or local norms.

*Author's modification of Boca, Coltraro, & Casarotto (1954) technique.
*Author's modification of Marker (1963) technique.
1987) have suggested that specific APD is characterized not only by unique performance patterns across tests but also by peculiar error patterns within tests. For children with attention-based APD (Case A), errors tend to consist primarily of omission of the target item, particularly on those tests requiring the reporting of dichotic or competing signals. On the Staggered Spondaic Word (SSW) Test, for example, Case A omitted a competing item (right or left ear) 2 out of 40 times and, in fact, reported to the examiner that words had been presented to only one ear. Eighteen of those errors involved the omission of the left-ear item in favor of reporting competing right-ear item. A similar tendency to omit was observed on all other tests failed by Case A. In only a few instances was a substitution of the target word found as the error type. Conversely, children such as Case B, whose APD appears to be perceptually-based, rarely omit the target. They tend to substitute a word that is phonemically similar to the target (e.g., fight for white, beard for red, and phool for school). This error pattern suggests adequate attention to the signal(s) but failure to perceive critical acoustic cues necessary to identify the phoneme.

Other possible performance patterns not illustrated here include those of children (c) who perform normally on attention- and perceptually-based tests out abnormally in language-based measures and (d) who fail tests associated with memory skills while passing others. The error pattern associated with the latter case is characterized by substitution of the target word with a word previously heard in the test or with one that is semantically related to the target item (e.g., nest-ball the near-cause and croak for frog). In addition, on tests requiring sequential memory (Token Test, SSW Test) the child with memory-based deficits may reverse the order of items or respond only to the first (or last) portion of the item.

These cases illustrate that by examining CAP test performance in light of a specific theoretical model, it’s possible to identify sub-groups of children within the A.L.D population who present with unique forms of APD that may be relatively identified. Once test interpretation is complete, suggestions for intervention may be made.

INTERVENTION STRATEGIES

In general, remediation of APD may fall into one or more of four categories: environmental modification, compensation techniques, behavior modification, and passive listening devices. While specific activities associated with any area depend upon the nature of the observed disorder, some recommendations may be helpful regardless of the type of disorder. These involve altering the child’s learning environment in order to improve auditory processing. Environmental modification suggestions are based on the assumption that children with APD, in general, require a more redundant auditory signal than do voice-disordered children in much the same way as does the child with peripheral hearing loss. Examples of modifications are preferential classroom seating, reduction of extraneous distraction, increased size of visual aids and cues, use of simple sentences, and rephrasing and repetition of information.

Compensation techniques need to avoid the specific disability area and either work toward the child’s strengths or work around the deficit. For example, if a child has difficulty remembering strings of information presented auditorily, then information may be written down. This information also may be compensated by chunking the information as one does with phone or social security numbers. In this way many pieces of information can be compressed into relatively easy-to-remember bits. With respect to
those children who appear deficient in their acoustic analysis skills and sound out words while reading, one may wish to replace a traditional phonetic approach with analytic phonics in which known words and/or sight vocabulary are used to decode unknown words (Pratt, Young, & Byrne, 1980). Other activities that may be considered indirect compensation involve the use of verification, having the child repeat verbatim a set of commands or target words given by a parent/teacher; and contextual cues, instructing the child to use sentence and situational context, body language, and facial expressions to fill in what may have been missed. Finally, the acceptance of accurate but alternative responses serves as a means of compensation when exactness of response is not at issue.

Behavior modification techniques involve the use of direct therapy procedures to alter the child's listening behavior. Numerous training programs using games, drill, and similar activities with set levels of competency are available in order to improve a child's skills in various areas of audition; processing such as localization, auditory discrimination, sound awareness, sound blending, sequential memory, short-term recall, selective attention, vocabulary, and comprehension (Barry, 1961; Euler, Green, & Hansen, 1973; Flowers, 1983; Jones, 1974; Perry, 1969; Reagen, 1973; Simon, 1980; Sloane, 1984).

Finally, sensitive listening devices have a place in the remediation of APD in children. Wilford (1980) reported success in reducing distracting background noise through the use of sound attenuating earmuffs and earplugs. More recently has been the use of personal FM auditory trainers and mild gain hearing aids in an effort to improve the signal-to-noise ratio reaching a child. Success with this approach has been reported by Jerger (personal communication, November, 1989) and Simpson and Mason (1985, 1986). In the latter case, children who displayed attention-based or perceptually-based processing deficits improved substantially in recognition of speech-in-noise when fitted with mild gain in-the-ear hearing aids designed to enhance frequencies between 250 Hz and 600 Hz. One obvious concern of the auditory trainer method is the risk of providing amplification to children whose hearing sensitivity is within normal limits. In addition one may argue that, without proper control and guidance, a child may become overly dependent upon the device. Finally, the cost of such a device may be prohibitive if it is intended to be used by only one child for only one or two hours a day.

Cast may be less of an issue if the device is shared by several children, each using the trainer at designated times during the day.

Whatever intervention techniques are tried, one must keep in mind the importance of the child's age and IQ, maturation, home environment, parental attitude, and the involvement of other education personnel. It is not unrealistic to expect improvement due to these factors as well as direct intervention by appropriate specialists.

**SUMMARY**

A theoretical model has been presented that suggests that every mental activity, including auditory processing, can be represented by a complex of interconnected behaviors, each supported by a specific area of the brain. Inability to perform adequately one or more of these sub-tasks may result in an auditory processing disorder (APD). In the evaluation of children's central auditory function, it is important to identify the specific sub-tasks associated with the specific diagnostic measure used. With the information, the clinician will be able to examine the patterns of performance across tests in order not
only to determine the presence or absence of a processing disorder but also to obtain information concerning the nature of the disorder. Using this approach it is possible to identify children who present with specific attention-based, perceptually-based, memory-related, or linguistic-cognitive-based auditory processing deficits. In addition, unresponsive patterns within and across tests appear to be associated with specific disorders. Only after careful test interpretation can a realistic and meaningful remediation plan be devised. Although the specific activities differ according to the nature of the deficit, remediation of APD in children generally includes the use of environmental modifications, management strategies, direct therapy techniques, and or passive listening devices. In addition, successful remediation depends not only upon inappropriate diagnosis but also upon active involvement of the child, parent(s), and/or other educational personnel.

For children labeled auditory learning disabled, an understanding of test rationale and procedures allows specific diagnosis to be made. From this diagnosis, remediation strategies can be developed that meet the individual needs of each child in this population.

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