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 test 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 listening 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, Enfield, & Sherman, 1981; Musiek & 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 auditorily learning disabled (ALD).

The population labelled ALD represents a heterogeneous group whose deficits require varying remediation strategies (Lyon, Watson, Reitta, & 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 (1973) suggested that higher mental processes represent complex functional systems based on jointly working zones of the brain. The brain may be conceptualized as an interdependent systemic 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 understand 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/planning 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 predictable 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 to 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 associated with these functions may include selective attention, divided attention, and the ability to recall information that is presented dichotically. 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 synthesis of sounds. Functional Unit 3 is responsible for creation of intentions, formulation 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 to be associated with these functions include organization of output, sustained 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 APD. By knowing which operations or levels of auditory processing are being taxed by various CAP tests and by examining patterns of performance across these tests, it is possible to determine which operation (or 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 absence of neurological damage (Willeford & 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 qualitively different from

the others, not all skills exist, nor are they expected to exist, at a given age. Thus, disordered auditory processing skills may be the result of either developmental lag or the failure of some precursory skill to have developed adequately.

Additionally, the label APD itself is a vague one. The child with an APD may suffer from weakness 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 functional units, at least to some extent. However, careful control of stimuli, recording parameters, and instructions may be used to develop procedures that tax 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 operation(s) 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. Jerger et al. (1987) used a similar approach in the identification of a specific perceptual (Unit 2) deficit of an ALD 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 is designed 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 (channels). 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 for measures taxing 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-Woodcock Auditory Discrimination Test and the Token Test) were the result of a more primary deficiency 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 1

Sample Results on Selected Auditory Processing Assessment Instruments and Hypothesized Associated Skills

Assessment Instrument	Hypothesized Associated Skill(s)	Lurian Brain Unit(s) Required	Results Case A	Results Case B
Speech-in-Noise Test (Ferre, 1987)	selective attention	Unit 1	BNL[a]	WNL[b]
Goldman-Fristoe-Woodcock (GFW) Selective Attention Test (Goldman, Fristoe, & Woodcock, 1976)	selective attention	Unit 1	BNL	WNL
Low Pass Filtered Speech Test[c]	analysis/synthesis of sounds	Unit 2	WNL	BNL
Binaural Fusion Test[d]	analysis/synthesis divided attention	Unit 2 Unit 1	BNL	BNL
Staggered Spondaic Word Test (Katz, 1962)	divided attention word series retention word recognition	Unit 1 Unit 2 Unit 2	BNL	BNL
GFW Auditory Discrimination Test (Goldman et al., 1976)	word recognition	Unit 2	WNL	BNL
GFW Auditory Attention Test (Goldman et al., 1976)	word recognition word series retention sustained concentration	Unit 2 Unit 2 Unit 3	WNL	BNL
Peabody Picture Vocabulary Test (Dunn & Dunn, 1981)	word recognition word meaning	Unit 2 Unit 3	WNL	BNL

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Table 1 *Continued*

Assessment Instrument	Hypothesized Associated Skill(s)	Lurian Brain Unit(s) Required	Results Case A	Results Case B
Token Test for Children (DiSimoni, 1978)	word recognition	Unit 2	WNL	BNL
	word series retention	Unit 2		
	word meaning	Unit 3		
	word order comprehension	Unit 3		
	sustained concentration	Unit 3		
	sentence comprehension	Unit 3		

Note. Based on theory proposed by Luria (1973).
[a]WNL = within normal limits re national or local norms.
[b]BNL = below normal limits re national or local norms.
[c]Author's modification of Bocca, Calearo, & Cassinari (1954) technique.
[d]Author's modification of Matzker (1962) 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) 23 out of 40 times and, in fact, reported to the examiner that words had been presented to only one ear. Eighteen of these 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, heard* for *bird,* and *ghoul* 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 (a) who perform normally on attention- and perceptually-based tests but abnormally on language-based measures and (b) 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 with a word previously heard in the test or with one that is semantically related to the target item (e.g., meat-*ball* for meat-*sauce* 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 is possible to identify sub-groups of children within the ALD population who present with unique forms of APD that may be selectively 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 assistive 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 listening 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 non-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 use of visual aids and cues, use of simple sentences, and rephrasing and repetition of information.

Compensation techniques tend to avoid the specific deficiency 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 weakness 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 synthetic phonics approach with analytic phonics in which known words and/or sight vocabulary are used to decode unknown words (Protti, Young, & Bryne, 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 closure, 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 behaviors. Numerous training programs using games, drillwork, and similar activities with set levels of competency are available in order to improve a child's skill in various areas of auditory processing such as localization, auditory discrimination, sound awareness, sound blending, sequential memory, short-term recall, selective attention, vocabulary, and comprehension (Barry, 1961; Eden, Green, & Hansen, 1973; Flowers, 1983; Heasley, 1974; Herr, 1968; Reagan, 1973; Simon, 1980; Sloane, 1984).

Finally, assistive listening devices have a place in the remediation of APD in children. Willeford (1980) reported success in reducing interfering background noise through the use of sound-attenuating earmuffs and earplugs. More recent 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, 1986) and Shapiro and Mistal (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 2500 Hz and 6000 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. Cost 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 used, one must keep in mind the importance of the child's age and IQ, maturation, home environment, parental attitudes, 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 interrelated behaviors, each subserved 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 each diagnostic measure used. With this 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, unique error 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 modification, management strategies, direct therapy techniques, and/or assistive listening devices. In addition, successful remediation depends not only upon appropriate diagnosis but also upon active involvement of the child, parent(s), and other educational personnel.

For children labelled 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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