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Auditory processing disorders: Relationship to cognitive processes and underlying auditory neural integrity

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ABSTRACT

Background: Auditory processing disorder (APD) in children has been reported and discussed in the clinical and research literature for many years yet there remains poor agreement on diagnostic criteria, the relationship between APD and cognitive skills, and the importance of assessing underlying neural integrity.
Purpose: The present study used a repeated measures design to examine the relationship between a clinical APD diagnosis achieved with behavioral tests used in many clinics, cognitive abilities measured with standardized tests of intelligence, academic achievement, language, phonology, memory and attention and measures of auditory neural integrity as measured with acoustic reflex thresholds and auditory brainstem responses.
Method: Participants were 63 children, 7–17 years of age, who reported listening difficulties in spite of normal hearing thresholds. Parents/guardians completed surveys about the child's auditory and attention behavior while children completed an audiologic examination that included 5 behavioral tests of auditory processing ability. Standardized tests that examined intelligence, academic achievement, language, phonology, memory and attention, and objective tests auditory function included crossed and uncrossed acoustic reflex thresholds and auditory brainstem responses (ABR) were also administered to each child.
Results: Forty of the children received an APD diagnosis based on the 5 behavioral tests and 23 did not. The groups of children performed similarly on intelligence measures but the children with an APD diagnosis tended to perform more poorly on other cognitive measures. Auditory brainstem responses and acoustic reflex thresholds were often abnormal in both groups of children.
Summary: Results of this study suggest that a purely behavioral test battery may be insufficient to accurately identify all children with auditory processing disorders. Physiologic test measures, including acoustic reflex and auditory brainstem response tests, are important indicators of auditory function and may be the only indication of a problem. The results also suggest that performance on behavioral APD tests may be strongly influenced by the child's language levels.

1. Introduction

Many individuals, although they have normal hearing sensitivity, have difficulty in understanding what they hear, especially if the material is unfamiliar or if the environment in which it occurs is noisy or distracting. If they are a young child, learning from what they hear may be difficult. These individuals typically seek audiologic evaluation for their difficulties and the goal of that assessment is often to determine if there is an auditory processing disorder (APD [1]).

Although the existence of APD has been discussed in the clinical and research literature for well over 50 years, there remains very poor agreement on when an APD diagnosis should be made and what a diagnosis means. There is also concern whether the condition is separate from other learning disorders commonly observed in children for which the behavioral complaints are often similar (e.g. [2–8]). It is difficult, operationally and theoretically, to separate purely auditory from cognitive disorders, especially when the listening tasks use complex stimuli, such as speech.

During an audiologic assessment the audiologist's goal must not simply be to apply a label of APD to a child. The audiologist, as part of a multidisciplinary team, is in a position to determine if and when a child's communication or learning difficulties have at least

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part of their origin in poor hearing or reduced auditory processing abilities. But how this is accomplished is often the topic of much debate. Unlike the assessment of hearing sensitivity for which clear and widely accepted protocols are in place even for very young children [9], the situation with APD is much less prescriptive. Professional guidelines [1,10,11] allow for considerable variability in test selection although some general suggestions are made. For example, a qualitative description of functional difficulties in real world situations should be obtained. This is often accomplished through the use of behavioral checklists. Behavioral tests that quantitatively evaluate sound processing ability in a clinical setting are also necessary. Such tests should address aspects of auditory discrimination, temporal processing and patterning, the perception of dichotic and monaural low-redundancy information, and binaural processing. These tests may ask the listener to repeat auditory patterns, to discriminate between fine differences in acoustic features or to repeat sounds presented in difficult listening situations such as when noise is added, when different sounds are presented to each ear, or when the sounds are degraded by filtering or time altering. Recommendations also include the use of objective procedures that evaluate the integrity of the auditory nervous system as it is not simply deficits in functional skills that suggest an APD but deficits in the underlying neural processes that serve these skills.

In a recent survey of clinical practice [12], the majority of respondents reported using a fairly narrow clinical battery. Most respondents noted they primarily used tests that assessed speech perception in difficult listening environments (dichotic or monaural low redundancy) and/or temporal patterning. Very few reported using any objective measures. Arguments against the use of objective measures [13] have suggested a lack of evidence supporting their use and that little has been published examining the relationship between objective measures and auditory skills.

Unraveling the relationship between auditory processing test performance, cognitive function and auditory neural integrity through examination of published studies is difficult. There are often significant differences across published reports in subject inclusion criteria, the definition of APD varies, and it is rare that hearing, cognitive, and objective tests are available on each participant.

This paper examines the relationship between a clinical diagnosis of APD made based upon a battery of behavioral tests, as is typical in many clinics [12], cognitive skills as measured through standardized tests of language, phonology, intelligence, academic achievement, memory and attention, and measures of neural function including acoustic reflexes and auditory brainstem responses. The participants were children referred for APD evaluation because they were experiencing difficulties in school and were suspected of having a hearing problem that was not related to a loss of sensitivity.

2. Method

2.1. Subjects

Sixty three children between the ages of 7 and 17 years were referred to this study at the Child Hearing Research Laboratory at Western University's National Center for Audiology. Thirty-nine of the children were males and 24 were females. Most children were reportedly achieving academically below expectations and were suspected of suffering from an APD. Referrals were made from local pediatricians, elementary schools, community audiologists, parents, and family friends. The proposal was approved by Western University's Ethics board, approval No. 13629E. Parents or guardians signed letters of consent for their child to participate in the study and the children gave verbal assent. Children were rewarded for their participation by the presentation of small toys. Their families were reimbursed for travel expenses and were provided with the results of the testing for their individual use.

2.2. Procedure

Audiologic evaluation included basic audiometric assessment (pure tone air and bone conduction thresholds, quiet word discrimination, and tympanometry) and 5 clinically accepted tests of central auditory processing (dichotic listening, temporal resolution, temporal patterning, and speech degraded via noise or filtering). Cognitive evaluation examined intelligence, academic achievement, language, phonology, memory, attention using standardized psychological or speech-language tests. Objective measures of auditory neural integrity included auditory brainstem responses to supra threshold click stimuli and acoustic reflex threshold assessment.

Audiometric assessment always occurred first and electrophysiologic testing was most often completed at the end of a test day. Remaining tests were completed in a random order with all subtests within a test completed together. The entire assessment took an average of 12 h to complete and was spread over a period of several days spaced over 1–2 weeks. All testing was conducted in laboratories at the National Center for Audiology. Breaks were provided as often as required. Test inclusion details were as follows:

Audiometric assessment. Audiometric evaluation was completed with the Interacoustics AC40 diagnostic audiometer and included estimation of pure tone thresholds in each ear at octave intervals from 250 to 8000 Hz. Word discrimination in quiet was assessed in each ear using the NU-Chips compact disk recorded word lists presented at SRT+40 dB. Tympanometry was completed using a GSI TympStar v2 middle ear analyzer. Tests of central auditory processing included the *Staggered Spondaic Word Test* (SSW [14]), which evaluates dichotic listening; the *Auditory Fusion Test-Revised* (AFT-R [15]), a test of temporal gap detection ability; the *Pitch Pattern Sequence test* (PPS [16]), which assesses the perception of temporal order for 3 tone sequences; the *Filtered Speech* test (FS [17]) which assess the perception of monaural speech low pass filtered at 500 Hz (18 dB/octave); and *Words in Ipsilateral Competition* (WIC [18]), an auditory figure ground test. All tests were administered according to test manuals and evaluated according to published normative data. Performance on these auditory tests was considered abnormal if it was at least 2 standard deviations below expectations for the child's age. Children's caregivers completed the Children's Auditory Performance Scale (CHAPS [19]) to assess perceived difficulty with hearing in a variety of situations and the Screening Identification for Targeting Educational Risk (SIFTER [20]) to assess the children for educational risk from hearing problems. The thirty-six items of the CHAPS question six listening conditions (quiet, ideal, multiple inputs, noise, auditory memory and attention). Behaviors are rated for each item on a scale of 1 (less difficulty than other children) to 5 (cannot function). An average score in an area less than or equal to −1 is considered significant. The SIFTER has fifteen items (3 in each of 5 categories including academics, attention, communication, class participation and school behavior). Each item is rated on a scale of 5 (good performance/skill) to 1 (poor performance/skill). The items within each category are summed. To achieve a "pass" in a category a score of 9 or better is required.

Cognitive assessment. An estimate of intelligence was obtained by using the Wechsler Abbreviated Scales of Intelligence (WASI [21]) which provided a verbal, performance, and an overall IQ. Academic achievement was evaluated via the spelling, reading, and arithmetic subtests of the Wide Range Achievement Test (WRAT 3 [22]).