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Report of the Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children

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BACKGROUND

A group of 14 senior scientists and clinicians met at the Callier Center in Dallas over the 2-day period, April 27–28, 2000, in an attempt to reach a consensus on the problem of diagnosing auditory processing disorders in school-aged children. The conference was organized by James Jerger and Frank Musiek. The following individuals participated:

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Susan Dalebout, PhD	University of Virginia, Charlottesville,VA
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Meeting both as separate groups and in plenary session, the conferees reached the consensus summarized below.

INTRODUCTION

Some school-aged children appear to have hearing problems. They are described by their parents and teachers as children who are uncertain about what they hear, have difficulty listening in the presence of background noise, have difficulty following oral instructions, and have difficulty understanding rapid or degraded speech. Some of these children will have a significant loss in peripheral hearing sensitivity. In others, however, auditory thresholds will be within normal limits. It is assumed that, in a significant proportion of the latter group of children, the listening problems result from an auditory processing deficit, the defective processing of auditory information in spite of normal auditory thresholds. In the past, children with such problems have been labeled as having "central auditory processing disorder" (CAPD). In keeping with the goals of maintaining operational definitions, avoiding the imputation of anatomic

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‡Dr. Chermak was unable to come to Dallas for the meeting but participated via telephone link.

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loci, and emphasizing the interactions of disorders at both peripheral and central sites, however, it seems more appropriate to label such problems as "auditory processing disorder" (APD).

An APD may be broadly defined as a deficit in the processing of information that is specific to the auditory modality. The problem may be exacerbated in unfavorable acoustic environments. It may be associated with difficulties in listening, speech understanding, language development, and learning. In its pure form, however, it is conceptualized as a deficit in the processing of auditory input.

The diagnosis of APD is presently complicated by three factors:

- Other types of childhood disorders may exhibit similar behaviors. Examples are attention deficit hyperactivity disorder (ADHD), language impairment, reading disability, learning disability, autistic spectrum disorders, and reduced intellectual functioning.
- Some of the audiologic procedures presently used to evaluate children suspected of APD fail to differentiate them adequately from children with other problems. Test procedures requiring the child to respond behaviorally may be subject to this criticism.
- In assessing children suspected of having an APD, one is likely to encounter other processes and functions that confound the interpretation of test results. Examples are lack of motivation, lack of sustained attention, lack of cooperation, and lack of understanding. It is vital to ensure that such confounding factors do not lead to the erroneous diagnosis of an auditory problem.

Because of these complications, the differential diagnosis of APDs requires the systematic acquisition of a body of data sufficient to identify an auditory-specific perceptual deficit. The purpose of the present document is to assemble a body of recommendations directed toward that goal.

The deliberations of the group are summarized under four headings:

- Screening for APD—a review of basic principles relevant to screening children for APD
- Differential Diagnosis of APD—a review of basic principles relevant to the differential diagnosis of this complex disorder
- Minimal Test Battery—a proposed minimal test battery for the audiological diagnosis of APD
- Directions for Future Research

SCREENING FOR APD

Screening for APDs in school children is not currently addressed in any policy statement by national professional organizations. A number of checklists and questionnaires have been used for the purposes of screening, but there is a lack of consensus on how the ideal screening procedure should be structured and what tasks it should contain. Moreover, these checklists and questionnaires are not highly specific to APD. Performance is often influenced by nonauditory factors (e.g., language, memory), resulting in over-referral of children with nonauditory problems for APD assessment. The present document suggests methods for minimizing these confounds in order to improve screening for APD.

It is important to distinguish between screening tests and diagnostic tests. In the past, screening test outcomes have sometimes been used to identify and label children as having an APD. This is an inappropriate use of screening tools. The goal of any screening procedure is to identify children who may have an APD. Children who are so identified should be referred to an audiologist for diagnostic evaluation. Since the goal of screening is to identify as many children as possible who may have APD, screening tests are purposely designed for maximal sensitivity. Such sensitivity is usually achieved at the expense of lack of specificity. Thus, a high false-positive rate is common, indeed expected, from a properly designed screening procedure. When such screening data are used to *identify* rather than to *refer*, the result is an abundance of false-positive identifications, leading inevitably to loss of credibility among parents and among professionals in related specialties.

In view of the limitations of existing screening tools, it seems appropriate that a new screening procedure be developed and validated for school-aged children. The following principles are to be followed in the design of any APD screening procedure:

- Screening questionnaires and instruments should emphasize the tasks essential to the processing of complex auditory stimuli. Examples of such processes include, but are not limited to, temporal processing and spatial resolution.

- Acceptable psychometric standards should be met by any screening instrument. These standards include the concepts of sensitivity, and specificity, the predictive values of positive and negative results, interobserver reliability, intertest consistency, and validity.
- The following variables should be considered in the development of any new screening test:
  - (a) the number of items/trials needed for satisfactory reliability
  - (b) stimulus intensity
  - (c) type of response
- A new screening instrument should address such factors as examiner training, hearing loss, middle ear dysfunction, equipment quality control and maintenance, and test environment, all of which can affect screening test results.
- Screening procedures should have minimal cognitive, attentional, and linguistic demands.
- Procedures should be brief (ideally 8–12 minutes).

With these caveats in mind, the following sections summarize recommendations for the development of effective APD screening procedures. Screening may take one of three forms: screening by questionnaire, by testing, or by a combination of questionnaire and testing. Which of these alternatives is most useful will depend on a number of factors, including the age range of the children being screened, available resources, and the setting in which the screening is carried out.

Screening by Questionnaire

Procedures for screening can include observation of suspect behaviors via questionnaires. Examples of suspect behaviors include

- Difficulty in hearing and/or understanding in the presence of background noise or reverberation,
- Difficulty in understanding degraded speech (e.g., rapid speech, muffled speech),
- Difficulty in following spoken instructions in the classroom in the absence of language comprehension deficits,
- Difficulty in discriminating and identifying speech sounds, and
- Inconsistent responses to auditory stimuli or inconsistent auditory attention.

The development and validation of screening questionnaires for school-aged children should be based on accepted psychometric principles. There should be clearly defined pass/refer criteria, and questions should reflect identified suspect behavior.

Screening by Test

A direct screening test procedure should include the following elements:

- A dichotic digit test consisting of two digits in each ear, using a free-recall response mode. The use of digits minimizes the linguistic load imposed by less well-learned speech tokens.
- A gap-detection test in which a short silent gap is inserted in a burst of broad-band noise. Gap detection samples temporal processing, a key dimension of speech processing.

Screening tests for children under age 6 years also need to be developed but are limited at this time by the paucity of research regarding effective diagnosis in this age group. In this age range, screening by questionnaire may be a more appropriate procedure.

DIFFERENTIAL DIAGNOSIS OF APD

The following assumptions are basic to the differential diagnosis of APD:

- Auditory processing problems can occur independently or can coexist with other, nonauditory disorders in the following combinations:
  - (a) A pure auditory processing disorder,
  - (b) An auditory processing disorder and a disorder or disorders in other modalities (i.e., multisensory),
  - (c) A disorder that initially appears to be auditory, but actually is nonauditory, or
  - (d) A disorder that initially appears to be nonauditory but is actually auditory.
- Auditory processing and methods of assessing auditory processing can be influenced by deficits in other disorders that impact auditory function, including
  - (a) ADHD,
  - (b) Language impairment,
  - (c) Reading disability,
  - (d) Learning disability,
  - (e) Autistic spectrum disorder, and
  - (f) Reduced intellectual functioning.

- Some of the audiologic procedures presently used to evaluate children who "do not seem to hear well" fail to differentiate children with auditory versus nonauditory problems.
- In assessing children suspected of having an APD, one is likely to encounter other processes and functions that may confound the interpretation of test results.

In order to effectively differentiate APD from other disorders with similar symptomatology, the examiner must consider the following relevant listener variables:

- Attention
- Auditory neuropathy (Appendix A)
- Fatigue
- Hearing sensitivity (Appendix B)
- Intellectual and developmental age
- Medications
- Motivation
- Motor skills
- Native language, language experience, language age
- Response strategies and decision-making style
- Visual acuity

The design of effective test instruments requires consideration of the following task variables:

- Cognitive demands (memory, attention)
- Floor and ceiling effects
- Learning and/or practice effects
- Linguistic demands
- Response mode

Although a number of diagnostic procedures are in current use, many have problems because listener and task variables are not satisfactorily controlled. The following principles should be considered to improve strategies in APD assessment:

- It is important to compare analogous tasks from multiple sensory modalities. For example, a child with an APD might perform poorly on an auditory task but not a visual task, whereas a child with both auditory and visual processing deficits might perform poorly on both tasks. Some children with either reduced intellectual function or ADHD might also perform poorly on both tasks.
- It is important to employ test materials that control for linguistic variables, ranging from tasks with minimal or no linguistic demand to those that systematically manipulate linguistic variables. The linguistic parameters should be clearly specified. These strategies will assist in differentiating APD from poor performance related to language difficulties.
- It is important to use contemporary psychophysical methods that permit the control of stimulus presentation and response selection and allow the flexibility to employ a variety of feedback options.
- It is important to minimize memory load. If a test depends on remembering information, poor performance may be the result of a memory deficit rather than an auditory processing deficit. For example, deficits in memory processes have been identified in children with learning disabilities and in children with attention deficits.
- It is important to employ a simple response mode in order to minimize the confounding effects on auditory processing of sensorimotor impairments, speech production disorders, and problems in motor learning.
- Computer-controlled adaptive psychophysical procedures are recommended. The use of such techniques maximizes test efficiency and minimizes floor and ceiling effects.
- A team approach to assessment provides further validation of the differential diagnosis. Moreover, it is important for management planning. At a minimum, the team should include an audiologist and speech-language pathologist along with parents and teachers. Other specialists can be consulted as needed.

MINIMAL APD TEST BATTERY

There are three possible approaches to the construction of a minimal test battery for APD in school children: (1) behavioral tests, (2) electrophysiologic and electroacoustic tests, and (3) neuroimaging studies.

Behavioral tests have the advantage of being widely available and relatively easy and inexpensive to administer. There is also a body of information relative to performance characteristics. There is a disadvantage, however, that results may be easily confounded by extraneous variables (see above).

Electrophysiologic and electroacoustic tests have the advantage of being influenced less by extraneous variables. The disadvantage, however, is that they are more time consuming and more expensive to administer. Moreover, facilities for such testing are not widely available. It is noteworthy, nonetheless, that many behavioral test paradigms can be incorporated within electrophysiologic procedures, thus providing both performance measures and gross site-specific information from the same test session.

Neuroimaging holds great promise as a tool for the assessment of auditory processing. A number of the tasks that have been defined in the behavioral domain are already in clinical use in imaging laboratories, with well-defined norms. Others, particularly tasks involving discrimination paradigms, are evolving toward clinical applicability. All of these tasks have been applied in either clinical or experimental settings. It is the case, however, that neuroimaging shares with electrophysiologic testing the disadvantage of relatively high cost and limited availability.

This said, the participants felt that an approach focusing on behavioral tests and supplemented by electrophysiologic and electroacoustic testing held the greatest promise as a test battery for APDs.

Potential behavioral measures include

- Measures of detection (e.g., the pure-tone audiogram and temporal integration tasks);
- Measures of suprathreshold discrimination (e.g., difference limens for frequency, intensity, and/or duration; temporal ordering/ sequencing tasks; temporal resolution tasks; backward/forward masking tasks; masking level difference [MLD]); sound lateralization; and spatial localization; and
- Measures of identification (e.g., the recognition of phonemes, syllables, words, phrases, and sentences).

There are three possible modes in which auditory tasks can be presented:

- Monotic, stimulus to each ear separately
- Diotic, same stimulus to both ears simultaneously
- Dichotic, different stimuli to the two ears simultaneously

There are differing circumstances in which each of these delivery modes is most appropriate. In the case of dichotic tests, the dichotic mode is obviously essential. However, monotic assessment is also essential to ensure that significant ear asymmetries are detected. Some measures (e.g., tests of spatial localization) may entail diotic stimulation. Finally, some tasks (e.g., temporal ordering) may be presented in all three modes.

Participants considered the following potential electrophysiologic and electroacoustic procedures:

- Otoacoustic emissions
- Immittance audiometry
- Auditory brainstem response (ABR)
- Auditory middle latency response (AMLR)
- Auditory late response (ALR)
- Mismatched negativity response (MMNR)
- Event-related responses (ERP)

From this pool of potential test procedures, the participants created two entities: (1) the minimum test battery necessary to arrive at a differential diagnosis of APD in school-aged children and (2) optional procedures potentially useful in strengthening the diagnosis.

Minimal Test Battery

The following test battery is recommended in order to provide the minimum amount of information necessary for the diagnosis of APD in school-aged children. Some clinicians may choose to carry out additional testing; however, the set of procedures listed below is suggested as the minimum necessary test battery.

Behavioral Measures

- Pure-tone audiometry—essential for assessing presence and degree of peripheral hearing loss (see Appendix B).
- Performance-intensity functions for word recognition—essential for the exploration of word recognition over a wide range of speech levels and for comparing performance on the two ears.
- A dichotic task (e.g., dichotic digits, dichotic words, or dichotic sentences)—a sensitive indicator of an auditory processing problem.
- Duration pattern sequence test—a key measure of auditory temporal processing.
- Temporal gap detection—a key measure of auditory temporal processing.

Electroacoustic and Electrophysiologic Measures

- Immittance audiometry—essential to rule out middle ear disorder and to identify acoustic reflex abnormalities.
- Otoacoustic emissions—useful in ruling out inner ear disorders.

- Auditory brainstem response and middle latency response—key measures of the status of auditory structures at brainstem and cortical levels.

If a child fails a screen for APD, he/she should be referred to an audiologist or audiologic testing facility with the capability to provide each of these essential procedures and to interpret their results.

The participants acknowledge that this minimal test battery lacks an important dimension in relation to the problem of differentiating an auditory-specific disorder from other disorders that may impact auditory processing. There is a clear and pressing need for analogous behavioral and/or electrophysiologic test procedures in a nonauditory modality (e.g., vision). Until such measures are widely available, the minimal test battery summarized above represents a reasonable compromise. The optional procedures described in the following section suggest possible future approaches to the issue of modality specificity.

Optional Procedures

In order to demonstrate that the processing disorder is specific to the auditory modality, it is desirable to compare performances on analogous auditory and visual tasks. One possible approach is to compare behavioral performance scores on comparable auditory and visual continuous performance measures. For example, duration patterns of long and short light flashes might be compared with analogous duration patterns of long and short noise bursts. Another potentially useful approach is the event-related evoked potential. An example is the P_{300} event-related response in the familiar "oddball" paradigm. One might, for example, structure analogous auditory and visual temporal processing tasks in order to test whether a deficit is present in both modalities or is confined to the auditory modality.

FUTURE RESEARCH NEEDS

There is a clear need for further research to address

- The normal psychophysical development of the discrimination, recognition, and recall of visual and auditory information,
- The prevalence of APD in children,
- The appropriate age at which to begin APD screening,
- The age at which diagnostic tests for APD can be used reliably,
- Performance characteristics of existing tests in different clinical groups,
- Adaptation of psychophysical discrimination paradigms to the clinical evaluation of APD,
- The relationship between APD test outcomes and management strategies,
- Outcomes of early intervention for APD,
- The relative efficacy of intervention approaches at various ages, and
- Collaborative research to examine relations among APD and disorders in other systems that impact auditory function.

APPENDIX A

Auditory Neuropathy

One auditory disorder that can exhibit symptomatology similar to more centrally based APDs is the disorder presently referred to as "auditory neuropathy." Auditory neuropathy is characterized by normal cochlear function at the level of the outer hair cells but dysynchronous auditory brainstem responses, placing this functional disorder in the peripheral auditory system (inner hair cells of the cochlea and/or auditory nerve). Auditory neuropathy can coexist with other motor and sensory neuropathies as a component of known disease syndromes or can be unique to the auditory system. It is important to distinguish auditory neuropathy from APDs and to determine whether it is coexisting with other motor and/or sensory neuropathy. It is presently possible to separate auditory neuropathy from other APDs with available diagnostic auditory tests. Determination of coexisting neural disorders in other systems can be made through referral for appropriate medical and physiologic tests.

APPENDIX B

Hearing Sensitivity

Ordinarily, APDs are associated with normal peripheral hearing sensitivity. However, APDs may coexist with peripheral hearing loss or as a result of conductive hearing loss. Moreover, peripheral auditory disorders can impact language development, reading, and learning.

APPENDIX C

Suggested Readings

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