Auditory processing disorder: auditory perception beyond classical audiological testing

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ABSTRACT: Human auditory perception is accomplished with hearing, which is an ability and listening, which is a skill. Pure tone threshold evaluation is the most common test of hearing used in the clinical setting by audiologists. This test focuses on hearing sensitivity in simple sounds (pure tones) and may prove insufficient in identifying listening difficulties in everyday situations. Normal pure tone thresholds do not ensure normal functional hearing (listening), since problems such as reduced speech recognition in noise, or sound localization may be present but remain undetected. Auditory processing is the medical term of listening. This review paper presents the nature of Auditory Processing Disorder, the valid testing approach, its aetiology, clinical populations that may have the disorder and how intervention and management are achieved according to current scientific evidence and clinical practice.

Key words: auditory processing, auditory perception, hearing, neurodevelopment disorders, psychoacoustics, Alzheimer's disease, schizophrenia.

1. INTRODUCTION – WHAT IS APD

Communication between humans is usually accomplished through multimodal processing, where more than one sense may contribute, depending on the present circumstances (for example verbal face to face communication, talking on the phone, reading, watching TV or a movie); however most essential speech information is delivered through hearing and may be linked with cognitive abilities. Human auditory perception is accomplished with hearing, which is an ability and listening, which is a skill. Deficits in hearing and listening may result in impaired/reduced communication of the individual, which may lead to a variety of problems, such as learning disabilities for school aged children and adolescents[1,2,3] or depression of the elderly population[4,5,6]. Research is being done on the presence of APD in psychiatric patients with Schizophrenia[7].

The auditory system includes the auditory periphery, i.e. outer, middle and inner ear, where conversion of the mechanical waves into chemo-electrical signals takes place. These signals are transferred through the auditory nerve to the Central Auditory Nervous System (CANS), in which Central Auditory Processing occurs[8]. Pure tone threshold evaluation is the most common test of hearing used in the clinical setting by audiologists. This test focuses on hearing sensitivity in simple sounds (pure tones) and may prove insufficient in identifying listening difficulties in everyday situations. Normal pure tone thresholds do not ensure normal functional hearing (listening), since problems such as reduced speech recognition in noise, or sound localization may be present but remain undetected[2,9].

Auditory Processing Disorder (APD) may present with a variety of symptoms. According to AAA[2] these may include "difficulty understanding speech in the

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presence of competing background signals (or noise) or in reverberant acoustic environments, problems with the ability to localize the source of a signal, difficulty hearing on the phone, inconsistent or inappropriate responses to requests for information, difficulty following rapid speech, frequent requests for repetition and/or rephrasing of information, difficulty following directions, difficulty or inability to detect the subtle changes in prosody that underlie humor and sarcasm, difficulty learning a foreign language or novel speech materials, especially technical language, difficulty maintaining attention a tendency to be easily distracted, poor singing, poor musical ability, and/or appreciation of music, and academic difficulties, including reading, spelling and/or learning problems." These symptoms may be present in different combinations or a single one may appear in isolation.

Auditory Processing Disorder is a neurodevelopmental disorder which may co-exist with other disorders of similar nature, such as Dyslexia, Specific Language Impairment, Attention Deficit Hyperactivity Disorder (ADHD), Speech Sound Disorder (phonological disorder) etc. Focusing in the pediatric population, it is essential that auditory processing is tested and differentiated from other neurodevelopmental disorders, in order to ensure optimal management and adequate academic opportunities of children with the disorder.

2. HOW TO TEST

As APD is a neurodevelopmental disorder, diagnosis is not easy and should be based on multidisciplinary information about each individual. Diagnostic assessment is based on a behavioural psychoacoustic test battery with information from cognitive and language testing included in the interpretation of its results, supplemented by questionnaires and electrophysiological tests to assess both patient/parent concerns and cochlear plus central auditory nervous system integrity.

The diagnostic approach to APD follows the cross check principle[10] which stresses the importance of testing with a number of tests to ensure the best sensitivity and specificity of the overall diagnostic result. Test batteries may include behavioral tests (5 or 6 mostly), addressing different auditory processing skills[2]. Batteries are designed in a way to test as many auditory processing elements as possible, but in the same time, testing duration should be kept low (i.e. 45 to 60 minutes) to avoid patient's fatigue[2]. Number of tests are kept low for another reason as well; specificity (i.e. correct rejection rate) generally decreases as tests are added in the test battery[11].

Behavioral tests use speech and non-speech material for testing auditory processing. Skills that are tested include: dichotic listening, temporal processing, binaural interaction, monaural low redundancy, auditory discrimination, sound localization, performance in competing acoustic signals and performance with degraded acoustic signals[1,12]. Both speech and non-speech tests are essential for diagnosing APD; AAA[2] points out that "it is likely that speech signals provide access to different processing mechanisms in the CANS than do non-speech signals and that the processing of speech signals may be more vulnerable to disruption by CANS dysfunction, resulting in atypical neurophysiologic responses and/or hemispheric asymmetries in CANS function that are apparent for speech signals, but not for non-speech signals"[13,14,15,16,17,18,19,20]. Non-speech tests should be also included since failing in only speech tests might be due to impaired language cognitive processing, rather than to Auditory Processing Deficits[1,21].

Several tests have been developed for assessing each auditory skill. Binaural interaction is tested using speech material (words or sentences), different for each ear, that are presented simultaneously. Subject's task is to recall as many as words or sentences presented to one specific ear or both. 'Dichotic digits', a commonly used test for assessing binaural interaction was developed by Musiek[22]. 'Dichotic Digits test' is a similar test in Greek and was developed by Tzavaras et al.[23]. This test is used as a laterality index, exhibiting hemispheric dominance and is influenced by auditory attention[24].

Several tests assessing auditory discrimination have been developed. Pitch and duration discrimination is usually tested through the Frequency (pitch) Pattern Test (FPT) and the Duration Pattern Test (DPT), both developed by Musiek[25]. In these tests tones are presented differing in pitch and duration respectively (high vs low, and short vs long). Subject's task is to recognize these tones and verbally label them. Pattern recognition and labelling may be influenced by cognition and/or language abilities, however results are interpreted measuring possible differences between the right and left ear and thus tapping more into auditory processing.

Temporal processing is tapping into an individual's

ability to identify consonants in different acoustic conditions[26]. Patient's task is to identify whether or not a gap is present either between two tones Random Gap[27] or in noise (Gaps-In-Noise [GIN][28,29]).

Speech in noise/babble testing is the most essential part of the evaluation showing objective listening difficulties[30,31]. Cases exist were an individual is concerned about hearing in noise and yet has normal speech in babble results and others were parents are mentioning that their child is hearing perfectly well and the resulting testing shows severe perceptual difficulties[32]. Results are interpreted with the use of normal mean values and standard deviations measured and are different in children of different ages with those being 12-13 years old showing similar normal data as adults with normal auditory processing.

3. WHICH CLINICAL POPULATIONS MAY HAVE APD?

In children it is common to have cases diagnosed with Speech Sound (phonological) Disorder, Dyslexia, Autism Spectrum Disorder, ADHD which co-exist with APD. Controversy exists as to the possibility of APD being an etiological factor leading to the other disorder, merely co-existing or auditory processing deficit being the result of the above mentioned disorders.

In adults there is indication that mild cognitive impairment may be linked with APD. In Alzheimer's research it has been documented that APD may exist one or two decades before the onset of the disease. Cognition is generally linked and may be influenced by auditory processing as has been shown in young adults with First Episode Psychosis which may lead to Schizophrenia.

4. AETIOLOGY OF APD

According to BSA[1], there are three types of APD; developmental APD, which is present since early childhood, acquired APD, which may be caused by a trauma or infection, and secondary APD, which is caused by periphery's hearing loss. In all cases central auditory nervous system is involved even though specific topographic lesions are hard to find but not impossible. There are cases were no clear etiological factor can be found in APD.

5. INTERVENTION AND MANAGEMENT OF APD

Intervention refers to "actions taken in order to produce an effect and alter the course of a disease, disorder, or pathological condition", while management is "compensatory approaches (e.g., strategies, technologies) used to reduce the impact of deficits that are resistant to remediation"[2]. BSA[1] suggests three types of management, i.e. acoustic changes to the environment, assisted listening FM systems and teacher/speaker adaptations. Acoustic changes refer to noise and reverberation reduction, but one should keep in mind the cost of these solutions. Noise reduction in teaching or working rooms can be achieved using seals on doors, rubber shoes, double glazed windows and noise absorbent partitions[1]. Reverberation reduction can be achieved using carpets, curtains and acoustic paneling[1,33].

Two types of FM systems exist, e.g. personal ear level or desk top and classroom sound field. The speaker wears a microphone and sound is transmitted though FM band waves to the speakers, hence speech level is increased and noise is reduced at least at the listener's end. Sound field FM can be used in small rooms with low reverberation. Personal FMs skip reverberation (since microphone is very close to the speaker), and are useful in larger rooms with greater reverberation. Note that both systems improve signal (speech) to noise ratio. Teacher/speaker adaptation refers to changes in speech, such as speaking more clear, improve emphasis and repeat when needed (see BSA 2011 for details[1]).

Intervention (therapy) consists in training (learning) of the Central Auditory Processing system, exploiting brain's plasticity. Stimulation and practice induce 'cortical reorganization (and possible reorganization of the brainstem), which is reflected in behavioral change (i.e. learning)'[2,34,35,36]. There are two types of training, i.e. formal (computerized training programs and CDs) and informal training (training activities). It should always kept in mind that APD is a multidimensional condition, meaning that not all patients share the same characteristics; hence intervention, should be always individualized based on specific auditory processing deficits[1,33,37]. This is the approach used in Greece with specific auditory training according to the patient's specific auditory processing deficits. This training includes both non-verbal and verbal stimuli, as material complexity is essential in neuroplasticity and learning.

Dichotic Interaural Intensity Difference training[37] (DIID) is a CD format training tool for dichotic listening, i.e. when different stimuli is presented for

each ear. Right ear advantage (REA) (better speech recognition from right ear for dichotic listening) is present in children until around the age of 12. DIID may be used when REA is present beyond this age, or when it is larger than normal. Stimuli is presented with a 20-30HL dB interaural difference (lower for the better ear) in order for the performance to be equal between ears. In proceeding sessions, interaural difference is minimized in small steps until typical dichotic listening is achieved.

Several types of informal training intervention have been proposed. Dichotic listening and binaural interaction training targets on binaural integration/separation activities, speech-in-noise training and sound localization training, while auditory closure training includes listening activities involving speech with missing words, syllables or phonemes, speech in noise, speech in different accents and telephone simulated speech. Temporal patterning and prosody training includes non-speech sound, targeting in pitch, loudness and rhythm recognition, syllabic stress and musical training[33,39,40,41].

Conclusion: Complaints of listening difficulties, prosody comprehension, limited attention, fatigue, difficulty following multistep instructions, short-memory issues, academic and learning difficulties in both children and adults should be addressed through psychoacoustical evaluation. Testing should extend beyond the pure tone audiogram in order to obtain elements of auditory perception and functional hearing that are representative of everyday situations with the possibility of presence of different competing auditory signals. Diagnosis of Auditory Processing Disorder permits rehabilitation approach strategies to be implemented that are effective as a consequence of central nervous system plasticity in general and in particular plasticity of the central auditory nervous system.

Διαταραχή Ακουστικής Επεξεργασίας: έλεγχος ακουστικής αντίληψης που δεν καλύπτεται από τις κλασσικές ακουολογικές εξετάσεις.

Βασιλική (Βίβιαν) Ηλιάδου, Χρήστος Σιδηράς, Ιωάννης Νηματούδης

ΠΕΡΙΛΗΨΗ: Η ακουστική αντίληψη στον άνθρωπο επιτυγχάνεται μέσω της ακοής (ικανότητα) και της ακρόασης (δεξιότητα). Η πιο συνηθισμένη εξέταση ακοής, η οποία χρησιμοποιείται στην κλινική πράξη από τους ακουολόγους είναι το τονικό ακουόγραμμα. Η συγκεκριμένη εξέταση προσφέρει στοιχεία για την ακουστική ευαισθησία απλών ήχων (τόνους) και μπορεί να είναι ανεπαρκής στην αναγνώριση προβλημάτων ακουστικής αντίληψης σε καθημερινές συνθήκες. Ο φυσιολογικός ουδός ακοής δεν εξασφαλίζει φυσιολογική λειτουργική ακοή (ακρόαση), καθώς προβλήματα όπως μειωμένη αντίληψη ομιλίας σε θόρυβο ή εντόπιση ήχων μπορεί να παραμένουν αδιάγνωστα. Η ακουστική επεξεργασία αποτελεί τον ιατρικό όρο της ακρόασης. Το παρόν ανασκοπικό άρθρο περιγράφει την φύση της Διαταραχής Ακουστικής Επεξεργασίας, την ορθή διαγνωστική προσέγγιση, την αιτιολογία της, τους κλινικούς πληθυσμούς στους οποίους μπορεί να εμφανίζεται και τον τρόπο αντιμετώπισης και θεραπείας με βάση την τρέχουσα επιστημονική τεκμηρίωση και την κλινική πρακτική.

Λέξεις κλειδιά: ακουστική επεξεργασία, ακουστική αντίληψη, ακοή, νευροαναπτυξιακές διαταραχές, ψυχοακουστική, νόσος Alzheimer, σχιζοφρένεια.

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