Annals of General Hospital Psychiatry

Review

Contribution of psychoacoustics and neuroaudiology in revealing correlation of mental disorders with central auditory processing disorders

V Iliadou* and S Iakovides

Address: 3rd Department of Psychiatry, Aristotle University of Thessaloniki, AHEPA University Hospital, Greece

Email: V Iliadou* - vivian_iliadou@yahoo.gr; S Iakovides - Iakovides@auth.med.gr

* Corresponding author

Published: 20 May 2003

Annals of General Hospital Psychiatry 2003, **2**:5

Received: 23 April 2003

Accepted: 20 May 2003

This article is available from: http://www.general-hospital-psychiatry.com/content/2/1/5

Abstract

Background: Psychoacoustics is a fascinating developing field concerned with the evaluation of the hearing sensation as an outcome of a sound or speech stimulus. Neuroaudiology with electrophysiologic testing, records the electrical activity of the auditory pathways, extending from the 8th cranial nerve up to the cortical auditory centers as a result of external auditory stimuli. Central Auditory Processing Disorders may co-exist with mental disorders and complicate diagnosis and outcome.

Design: A MEDLINE search was conducted to search for papers concerning the association between Central Auditory Processing Disorders and mental disorders. The research focused on the diagnostic methods providing the inter-connection of various mental disorders and central auditory deficits.

Measurements and Main Results: The medline research revealed 564 papers when using the keywords 'auditory deficits' and 'mental disorders'. 79 papers were referring specifically to Central Auditory Processing Disorders in connection with mental disorders. 175 papers were related to Schizophrenia, 126 to learning disabilities, 29 to Parkinson's disease, 88 to dyslexia and 39 to Alzheimer's disease. Assessment of the Central Auditory System is carried out through a great variety of tests that fall into two main categories: psychoacoustic and electrophysiologic testing. Different specialties are involved in the diagnosis and management of Central Auditory Processing Disorders as well as the mental disorders that may co-exist with them. As a result it is essential that they are all aware of the possibilities in diagnostic procedures.

Conclusions: Considerable evidence exists that mental disorders may correlate with CAPD and this correlation could be revealed through psychoacoustics and neuroaudiology. Mental disorders that relate to Central Auditory Processing Disorders are: Schizophrenia, attention deficit disorders, Alzheimer's disease, learning disabilities, dyslexia, depression, auditory hallucinations, Parkinson's disease, alcoholism, anorexia and childhood mental retardation. Clinical awareness should be high in order for doctors of the two specialties, psychiatry and otorhinolaryngology-audiology to collaborate.

Background

Evaluation of the central auditory nervous system (CANS) is essential in order to obtain information on its anatomical and functional integrity. Both, children and adults may suffer from central auditory processing disorders (CAPD). This fact has been underestimated but as research in this field progresses, it shows that specific mental disorders may be the outcome of a CAPD or that CAPD can co-exist with a neurological or mental disorder [1].

Assessment of the CANS begun at the mid-1950s with the confirmation by Bocca and his colleagues [2] that CANS disorders do exist and that there are sensitive tests to reveal them. However, at that time acceptance of the new diagnostic methods by the audiologists, who were the first to be interested in this field was limited. This can be attributed to the slow acceptance of each new method before it is fully validated. Better understanding of the anatomy and physiology of the CANS was gained by advances concerning the presence and physiology of neurotransmitters and the accumulation of data on the psychoacoustic and electrophysiologic tests [3]. As a result audiologists started applying the new diagnostic tests more often and appreciated their contribution. Other medical specialties became aware and interested in the disorders of the CANS. These were mainly psychiatry and neurology. The assessment of the CANS is also of great value concerning neuropsychology and special education [4–6].

Anatomy and physiology of the CANS

Clinical evaluation of central auditory function requires understanding of the anatomy and physiology of the CANS and appreciation of its complexity. The CANS extends from the anterior and posterior cochlear nuclei which are situated on the surface of the inferior cerebellar peduncle to the auditory cortex. In between important structures through which nerve fibers pass are: the trapezoid body, the lateral lemniscus, the inferior colliculus, the medial geniculate body and the acoustic radiation of the internal capsule. The auditory cortex includes the gyrus of Heschl on the upper surface of the superior temporal gyrus, the planum temporale and the Silvian fissure.

It is essential to point out that nerve impulses from each ear proceed along auditory pathways on both sides of the brainstem. Both ipsilateral and contralateral pathways are important in ensuring interchange of auditory information. The contralateral pathway exhibits dominance as opposed to the ipsilateral one [7]. Thirty thousand afferent auditory nerve fibers with different range of frequency response are responsible for conveying auditory information to the cortex [8]. Many components of the stimulus are analyzed separately. There is an increasing complexity of the whole process in the auditory cortex. One should keep in mind that, understanding of the exact way of processing the auditory information at the level of the auditory cortex, is still incomplete. It is in this understanding that Phychoacoustics helps as it is the science concerned with the evaluation of the sensation of hearing as an outcome of the sound or speech stimulus.

Components of central auditory processing

Central auditory processing occurs prior to language comprehension [9]. It consists firstly of auditory discrimination, which is responsible for the ability to group sounds according to how similarly or differently they are heard. Auditory memory is the component responsible for storing and recalling auditory information. Auditory perception concerns the reception and understanding of sounds and words. It plays a significant part in reading skills, managing verbal information, communication and social relationships. Auditory-vocal association consists of the interaction between what is heard and verbal response. Auditory synthesis is responsible for combining sounds or syllables to formulate comprehensible patterns (words) and de-combining words into separate sounds. Auditory-vocal automaticity is the ability to predict how future linguistic events will be heard by utilizing past experience. Auditory figure-ground plays a role in diminishing sounds which are not important while focusing on others [10]. It is due to this component that someone can listen to another person talking in a railway station, where a lot of environmental noise exists.

Material and methods

The medline research revealed 564 papers when using the keywords 'auditory deficits' and 'mental disorders'. 79 papers were referring specifically to CAPD in connection with mental disorders, as this is a new term for auditory deficits and one mostly used by audiologists. Auditory deficit is a more general term used mostly by psychiatrists. Both terms refer to the same disorder. It is essential to point out that 25 of the 79 papers are published between 2000 – 2003.

Schizophrenia is found related to CAPD in 175 papers, 49 of them are published between 2000 – 2003 showing the research focus of the last three years. Learning disabilities were found related to CAPD in 126 papers. Parkinson's disease was related to CAPD in 29 papers. Dyslexia is related to CAPD in 88 papers, 37 of them are between 2000–2003. Alzheimer's disease and auditory deficits are connected in 39 papers. The remaining articles are on depression, alcoholism, anorexia and childhood mental retardation, all being related to some extend to CAPD.

Assessment of the CANS is carried through a great variety of tests that fall into two main categories: psychoacoustic and electrophysiologic testing. Psychoacoustic tests are

considered more subjective. Electrophysiologic ones are more objective with the exception of P300 component.

Results

psychoacoustic tests

Learning disabilities, attention deficit disorders and dyslexia are assessed through a great variety of psychoacoustic tests. Age limitations have to be considered [11] and specially designed tests are used for different age groups. When evaluating children who are less than 12 years old an important step is the Pediatric Speech Intelligibility (PSI) Test. This consists of single words and sentences presented with a competing message at varying levels of difficulty [12]. In this test it is essential that performance is adjusted for language age according to previously determined normative data [13]. Evaluation of this test may provide the cause of learning disabilities including dyslexia [14,15].

Children older than 12 years old are assessed through a more complex test battery that contains several tests. These tests are based on the stimulation of the auditory system with tones, numbers, syllables, words and sentences. Evaluation is made according to the different components of the auditory processing. One widely used test is that of the dichotic digits which consists of different pairs of numbers presented simultaneously to each ear [16]. The person under examination has to repeat all four numbers regardless of order. This test is easy to use in order to detect the auditory deficit of dyslexia particularly since it does not contain language and phonological parameters [17].

The Staggered Spondaic Word Test (SSW) consists of two-syllable spondaic words that are presented simultaneously to each ear [18]. This involves the diagnosis of auditory deficits in attention disorders, autism, learning disabilities and chronic alcoholism [19,20].

A series of experiments were planned by Nielzen and Olsson on the basis of psychoacoustic handling of auditory stimulation. The results of these psychacoustic experiments show significant differences between a group of schizophrenic patients and a group of reference subjects thus indicating central auditory processing disorders even in a phase of illness remission or during treatment with neuroleptics [21].

electrophysiologic tests

In all mental disorders assessed with the suspicion of CAPD an objective measure of the peripheral auditory system is mandatory. The Auditory Brainstem Responses (ABR), measure the electrophysiologic activity from the 8th cranial nerve to the medial geniculate body of the brainstem [22]. A very important element of ABR evaluation is the morphology and synchronization of the waveform. One should always begin his evaluation while observing waveform changes on real time [23].

The Auditory Middle Latency Responses (AMLRs) provide an electrophysiologic measure of the primary auditory cortex function [24]. The AMLRs can diagnose central auditory processing disorders in children with learning disabilities [25], patients with Alzheimer's disease [26], adult autistic subjects [27,28] patients with Schizophrenia [29] The Auditory P_{300} Response, which consists of the measure of the hippocampal and auditory cortex function again from an electrophysiological point of view [30]. The P300 response has been considered an endogenous event-related potential. Endogenous responses depend both on the context within which the auditory stimuli are presented and the psychologic condition and attention of the subject. P300 has been used in diagnosing CAPD in patients with dementia of the Alzheimer type [31], in monitoring long-term effects of donepezil in patients with Alzheimer's disease [32], in anorexic patients [33], in children with mental retardation during a selective attention task to auditory stimuli [34] and in first episode and chronic schizophrenia [35]. Mismatch Negativity Response (MMN) is an event-related evoked potential that measures the electrophysiologic activity of the auditory cortex function [36]. The MMN is always elicited 100–250 msecs from stimulus change onset. Its application is in detecting CAPD in alcoholism [37], in Schizophrenia [38–43], in attention deficit and in developmental dyslexia [44].

psychoacoustic and electrophysiologic testing according to type of lesion

In the selection of tests for the evaluation of brainstem lesions the examiner should keep in mind that all psychoacoustic tests have been reported to aid in the diagnosis. According to the studies of Kartz [45] the Staggered Spondaic Words Test may help differentiating brainstem from cortical lesions and upper from lower brainstem lesions. Musiek et al [46] concluded that Auditory Brainstem Responses in combination with either Masking Level Differences or Dichotic Digits Test may be as sensitive in evaluating a group of patients suffering from multiple sclerosis as a seven test battery. Jerger et al [47] reported that for patients suffering from multiple sclerosis the best test battery was a combination of stapedial reflex measures and speech audiometry.

The usual finding in central auditory tests regarding cortical lesions is a deficit or impairment in the ear contralateral to the side of lesion. Psychoacoustic tests such as Dichotic Digits and SSW in patients with well documented cortical and hemispheric lesions demonstrate primarily contralateral ear deficits and impairments [48]. Two

exceptions that the examiner should always keep in mind are when frequency and duration tests are applied and when compromise of auditory fibers of the corpus callosum has occurred [49].

Regarding interhemispheric dysfunction, test results may be difficult to evaluate. Representation of auditory information at the cortical level is mostly contralateral as is clearly depicted in dichotic listening situations. When speech responses are required by the subject auditory information from the right ear are projected through to the left hemisphere without the participation of the opposite hemisphere for the production of a speech response. On the contrary auditory stimuli from the left ear must cross the midline through the corpus callosum for the production of a speech response. Patients with split brain disorders subjected to dichotic testing have interestingly demonstrated decreased scores regarding the left ear and enhanced scores in the right ear [50,51].

Considerable evidence has been reported that indicates a relation between various learning disabilities, including dyslexia, attention deficit hyperactivity disorder and poor performance scores on central auditory tests Learning disabilities in children might be the expression of various underlying central auditory disorders such as maturational, developmental or neurological as depicted by abnormal CAPD test results [52].

Conclusions

CANS assessment represents a fascinating field. Cooperation of professionals in psychiatry, neurology, neuropsychology and pediatric psychology, with the otolaryngologist-audiologist is a prerequisite. Central auditory processing disorders may co-exist with various mental disorders such as: learning disabilities, attention deficit hyperactivity disorder, dyslexia, autism, chronic alcoholism, Alzheimer's disease, adult autistic disorder, Schizophrenia, anorexia and mental retardation. Assessing these disorders is difficult due to the complex anatomy and physiology of the CANS. This explains the great variety of existing methods of testing with two main categories: those of psychoacoustic methodology and those based on electrophysiologic measures. Physiology of CANS is still not completely understood and further research is needed on development of new tests and validation of their clinical applicability.

Conflict of interest

none declared

References

1. Musiek FE and Lamb L **From Central Auditory Assessment, an overview In Handbook of Clinical Audiology** *(Edited by: Katz J) Philadelphia Lippincott Williams & Wilkins* 1994, 197-211
2. Bocca E, Calearo C and Cassinari V **A new method for testing hearing in temporal lobe tumors** *Acta Otolaryngol* 1954, **44:**219-221
3. Musiek F and Hoffman D **An introduction to the functional neurochemistry of the auditory system** *Ear Hear* 1990, **11:**395-402
4. Scherg M and Von Cramon D **Psychoacoustic and electrophysiologic correlates of central hearing disorders in man** *Eur Arch Psychiatry Neurol Sci* 1986, **236:**56-60
5. Demarco S, Harbour A, Hume G and Givins G **Perception of time-altered monosyllables in a specific group of phonologically disordered children** *Neuropsychologia* 1989, **27:**753-757
6. Bamiou DE, Musiek FE and Luxon LM **Aetiology and clinical presentations of auditory processing disorders – a review** *Arch Dis Child* 2001, **85:**361-365
7. Kaprinis G **The experimental neurosis model. A revision of its significance in psychopathology** *PhD thesis. Aristotelian University of Thessaloniki, A' Department of Psychiatry and Neurology* 1981,
8. Zwicker E and Fastl H **Psychoacoustics Facts and Models** *Springer* 1999,
9. Hall JW III and Mueller HG III **Audiologist's Desk Reference** *Vol I San Diego: Singular Publishing Group, Inc* 1997,
10. Gillet P **Auditory processes** *Novato CA: Academic Therapy Publications* 1993,
11. Musiek FM, Gollegly KM and Baran JA **Myelination of the corpus callosum and auditory processing problems in children: theoretical and clinical correlates** *Semin Hear* 1984, **5:**231-240
12. Jerger S, Lewis S, Hawkins J and Jerger J **Pediatric speech intelligibility test. I. Generation of test materials** *International J Pediat Otorhinolaryngol* 1980, **2:**217-230
13. Jerger S, Johnson K and Loiselle L **Pediatric central auditory dysfunction: Comparison of children with confirmed lesions versus suspected processing disorders** *Am J Otol* 1988, **Suppl 9:**63-71
14. Gascon GG, Johnson R and Burd L **Central auditory processing and attention deficit disorders** *J Child Neurol* 1986, **1:**27-33
15. Welsch LW, Welsh JJ and Healy MP **Central auditory testing and dyslexia** *Laryngoscope* 1980, **6:**972-984
16. Musiek FM, Gollegly KM, Kibbe KS and Verkest-Lenz SB **Proposed screening test for central auditory disorders: Follow-up on the dichotic digits test** *Amer J Otol* 1991, **12:**109-113
17. Katz J and Smith PS **The Staggered Spondaic Word Test. A ten-minute look at the central nervous system through the ears** *Ann N Y Acad Sci* 1991, **620:**233-251
18. Wetherby AM, Koegel RL and Mendel M **Central auditory nervous system dysfunction in echolalic autistic individuals** *J Speech Hear Res* 1981, **3:**420-429
19. Spilzer JB and Ventry IM **Central auditory dysfunction among chronic alcoholcs** *Arch Otolaryngol* 1980, **4:**224-229
20. Jerger J and Jerger S **Clinical validity of central auditory tests** *Scand Audiol* 1975, **4:**147-163
21. Nielzen S and Olsson O **Psychoacoustic investigations in schizophrenia** *SchizophreniaResearch* 1997, **1–2:**119
22. Neijenhuis KA, Stollman MH, Snik AF and Van der Broek P **Development of a central auditory test battery for adults** *Audiology* 2001, **40:**69-77
23. Arnold SA **Objective versus visual detection of the auditory brain stem respone** *Ear and Hearing* 1985, **6:**144-150
24. Eleftheriades N **The contribution of auditory evoked potentials in the diagnosis of sensorineural hearing loss in infancy and early childhood** *PhD Thesis. Aristotelian University of Thessaloniki, Otorhinolaryngologic Department* 2001,
25. Ors M, Lindgren M, Blennow G and Rosen I **Auditory event-related brain potentials in parents of children with specific language impairment** *Eur J Paediatr Neurol* 2002, **6:**249-60
26. Arehole S, Augustine LE and Simhadri R **Middle latency response in children with learning disabilities: preliminary findings** *J Commun Disord* 1995, **28:**21-38
27. O'Mahony D, Rowan M, Feely J, Walsh JB and Coakley D **Primary auditory pathway and reticular activating system dysfuction in Alzheimer's disease** *Neurology* 1994, **11:**2089-2094
28. Buchwald JS, Erwin R, Van Lancker D, Guthrie D, Schwafel J and Tanguay P **Midlatency auditory evoked responses: P1 abnormalities in adult autistic subjects** *Electroencephalogr Clin Neurophysiol* 1992, **2:**164-171

29. Grillon C, Courchesne E and Akshoomoff N **Brainstem and middle latency auditory evoked potentials in autism and developmental language disorder** *J Autism Dev Disord* 1989, **2:**255-269
30. Erwin RJ, Mawhinney-Hee M, Gur RC and Gur RE **Midlatency auditory evoked responses in schizophrenia** *Biol Psychiatry* 1991, **5:**430-442
31. Schochat E, Scheuer CI and Andrade ER **ABR and auditory P300 findings in children with ADHD** *Arq Neuropsiquiatr* 2002, **60:**42-47
32. Pokryszko-Dragan A, Slotwinski K and Podemski P **Modality-specific changes in P300 parameters in patients with dementia of the Alzheimer type** *Med Sci Monit* 2003, **4:**130-134
33. Katada E, Sato K, Sawaki A, Dohi Y, Ueda R and Ojika K **Long-term effects of donepezil on P300 auditory event-related potentials in patients with Alzheimer's disease** *J Geriatr Psychiatry Neurol* 2003, **1:**39-43
34. Dodin V and Nandrino JL **Cognitive processing of anorexic patients in recognition tasks: An event-related potentials study** *Int J Eat Disord* 2003, **3:**299-307
35. Horimoto R, Inagaki M, Yano T, Sata Y and Kaga M **Mismatch negativity of the color modality during a selective attention task to auditory stimuli in children with mental retardation** *Brain Dev* 2002, **7:**703-709
36. Brown KJ, Gonsalvez CJ, Harris AW, Williams LM and Gordon E **Target and non-target ERP disturbances in first episode vs chronic schizophrenia** *Clin Neurophysiol* 2002, **11:**1754-1763
37. Kujala T and Naatanen R **The mismatch negativity in evaluating central auditory dysfunction in dyslexia** *Neurosci Biobehav Rev* 2001, **25:**535-543
38. Sanchez-Turet M and Serra-Grabulosa JM **Auditory evoked potentials and alcohol: characteristics of the mismatch negativity component in alcoholism** *Rev Neurol* 2002, **11:**1049-1055
39. Umbricht D, Vollenweider FX, Schmid L, Grubel C, Skrabo A, Huber T and Koller R **Effects of the 5-HT2A agonist psilocybin on mismatch negativity generation and AX-continuous performance task: implications for the neuropharmacology of cognitive deficits in schizophrenia** *Neuropsychopharmacology* 2003, **1:**170-181
40. Youn T, Park HJ, Kim JJ, Kim MS and Kwon JS **Altered hemispheric asymmetry and positive symptoms in schizophrenia: equivalent current dipole of auditory mismatch negativity** *Schizophr Res* 2003, **2:**253-260
41. Michie PT, Innes-Brown H, Todd J and Jablensky AV **Duration mismatch negativity in biological relatives of patients with schizophrenia spectrum disorders** *Biol Psychiatry* 2002, **7:**749-758
42. Salisbury DF, Shenton ME, Griggs CB, Bonner-Jackson A and McCarley RW **Mismatch negativity in chronic schizophrenia and first-episode schizophrenia** *Arch Gen Psychiatry* 2002, **8:**686-694
43. Shinozaki N, Yabe H, Sato Y, Hiruma T, Sutoh T, Nashida T, Matsuoka T and Kaneko S **The difference in Mismatch negativity between the acute and post-acute phase of Schizophrenia** *Biol Psychol* 2002, **2:**105-119
44. Baldeweg T, Klugman A, Gruzelier JH and Hirsch SR **Impairement in frontal but not temporal components of mismatch negativity in schizophrenia** *Int J Psychophysiol* 2002, **2:**111-122
45. Demonet JF and Habib M **Developmental dyslexia: contribution of modern neuropsychology** *Rev Neurol* 2001, **8:**847-853
46. Katz J **From Clinical use of central auditory tests In Handbook of Clinical Audiology** *Baltimore Lippincott Williams & Wilkins Katz J* 1978, 490-497
47. Musiek F, Gollegly K, Kibbe K and Reeves A **Electrophysiologic and behavioral auditory findings in multiple sclerosis** *Am J Otol* 1989, **10:**343-350
48. Jerger J, Oliver T, Chimiel R and Rivera V **Patterns of auditory abnormality in multiple sclerosis** *Audiology* 1986, **25:**193-209
49. Kandori A, Oe H, Miyashita K, Date H, Yamada N, Naritomi H, Chiba Y, Miyashita T and Tsukada K **Abnormal auditory neural networks in patients with right hemispheric infarction, chronic dizziness, and moyamoya disease: a magnetoencephalogram study** *Neurosci Res* 2002, **3:**273-283
50. Musiek F, Baran J and Pinheiro M **Duration pattern recognition in normal subjects and patients with cerebral and cochlear lesions** *Audiology* 1990, **29:**304-313
51. Musiek FE, Kurdziel-Schwan S, Kibbe KS, Gollegly KM, Baran JA and Rintelmann WF **The dichotic rhyme task: results in split-brain patients** *Ear Hear* 1989, **1:**33-39
52. Schulte-Korne G, Deimel W, Bartling J and Remschmidt H **Pre-attentive processing of auditory patterns in dyslexic human subjects** *Neuroscience Letters* 1999, **276:**41-44