

INTRODUCTION

Auditory channel is one of the main avenues for learning, through which both peripheral and central auditory mechanisms share in language acquisition and learning process. Central Auditory Processing (CAP) refers to the efficiency and effectiveness by which the central nervous system (CNS) utilizes auditory information (**Bellis, 2003; Chermak and Musiek, 1997**).

CAP includes the auditory mechanisms that underlie the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination (e.g., temporal gap detection), temporal ordering, and temporal masking; auditory performance in competing acoustic signals (including dichotic listening) and auditory performance with degraded acoustic signals (**ASHA, 1996**).

Central Auditory Processing Disorder CAPD refers to difficulties in the perceptual processing of auditory information in the CNS as demonstrated by poor performance in one or more of the above mentioned skills and the most prevalent presenting picture of CAPD is difficulty in discrimination in background noise which is termed "selective auditory attention disorder" (**Chermak and Musiek, 1992; Stach et al., 1993**).

One of the consequences of CAPD is learning disability (LD), teachers and other professionals concerned with LD indicated that attention problem is the most important difficulty faced by these children (**Koegh, 1973**). Several studies have demonstrated the association between CAPD and LD (**Sawyer, 1981; Jerger et al., 1987; Katz and Wilde, 1994; Shalaby, 1998**). The percentage of learning disabled children with CAPD is high but still not precisely known (**Bench, 1997**). Furthermore, learning disabled children tend to be more distractable in the classroom than normal children and have understanding problems in any poor acoustic environment (**Katz and Kusnierczyk, 1993**).

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Management of central auditory processing disorders was recommended to focus on three main categories namely: environmental modification by decreasing background noise in classroom, remediation therapy to alleviate the disorder through specific training, and compensatory strategies such as using assistive listening devices (**Bellis, 1996**).

During the last few years, there has been great interest in the area of using computer-based training program for children with language learning impairment (*Tallal et al., 1996 and Merzenich et al., 1996*). Computerized training programs offer the advantages of multisensory stimulation that provides generous feedback and reinforcement and facilitates intensive training. Despite the potential of computerized approaches, additional data are needed to demonstrate the effectiveness and efficacy of these approaches (*Musiek et al., 2002; Philips, 2002*).

An Arabic CAPD remediation program was developed including a protocol for rehabilitation of selective auditory attention ability developed in order to improve the ability to discriminate in background noise using non verbal simple, verbal and complex verbal remediation test materials. This program was developed by cooperation between Audiology unit, Ain Shams University and Horizon Interaction (soft ware computer company) funded by Information and Communication Technology (ICT) in (*2006*).

Before the application of developed material on children with selective auditory attention disorder it is mandatory to test this program on normal Arabic speaking children and evaluate the performance and outcome of these materials at different age groups. Consequently, this study was designed to address these issues and resolve any conflicting outcome related to the experimental study.

AIMS OF THE WORK

- 1- To standardize the newly developed computer-based program for remediation of selective auditory attention disorder on normal Egyptian children
- 2- To study the effect of age on the performance of children on the newly developed computer-based program

Chapter (I)

CENTRAL AUDITORY PROCESSING (CAP)

Central Auditory Processing is the ability of the brain (central nervous system) to process incoming auditory signals. The brain identifies sounds by analyzing the distinguishing physical characteristics: frequency, intensity, and temporal features that we perceive as pitch, loudness, and duration. After analyzing the physical characteristics, the brain constructs an "image" of the signal from the component parts for comparison with stored "images." If a match occurs, we can understand what is being said or recognize sounds with important meanings (sirens, doorbells, crying) (*Chermak and Musiek, 1997*).

Central auditory processing can be defined as the manipulation and utilization of sound signals by the central auditory nervous system, in other words, it is what we do with what we hear. It involves a range of activities from the awareness of the presence of sound to the analysis of linguistic information (*Lasky and Katz, 1983*). Broadly stated, central auditory processing (CAP) refers to the efficiency and effectiveness by which the central nervous system utilizes auditory information. Narrowly defined, CAP refers to the perceptual processing of auditory information in the CNS and the neurobiologic activity that

underlies that processing and gives rise to electrophysiologic auditory potentials (*ASHA, 1996*).

CAP includes the auditory mechanisms that underlie the following abilities or skills, sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition including temporal integration, temporal discrimination, temporal ordering and temporal masking, auditory performance in competing acoustic signals and auditory performance with degraded acoustic signals (*ASHA, 1996; Bellis, 2003*).

Neurochemistry and Auditory Processing

All aspects of audition, from pure-tone hearing to complex spoken language processing, rely on the transmission of neural information across synapses. Information about sound representation at the cochlea must be transmitted to the brain through a complex network of neural synapses. Synaptic transmission, from neurotransmitter synthesis, through binding and activation of receptors, to reuptake and degradation of neurotransmitters, is dependent on chemical processes. These neurochemical processes play an important role in the structure and function of the brain, including structural and functional hemispheric asymmetry and plasticity (*Morley and Happe, 2000; Syka, 2002*).

Research in auditory neurochemistry has intensified over the last decade as scientists have recognized the potential for pharmacological treatments of auditory disorders. Recently, research has also demonstrated that pharmacologic intervention can alter physiologic and behavioral aspects of audition, including selective auditory attention and signal detection in noise (*Gopal et al., 2000., Feldman et al., 1996; Musiek & Hoffman, 1990; Sahley et al., 1996; Sahley & Nodar, 1994; Wenthold, 1991*), underscoring the potential of pharmacologic intervention for treatment of (C)APD. Although several drugs have been shown to improve behavioral regulation and vigilance in ADHD, which may lead to improved performance on a number of behaviors including auditory processing, no pharmacologic agent has been demonstrated as effective specifically for CAPD (*Tillery et al., 2000*).

Central auditory Abilities

1) Sound localization and lateralization

Sound localization ability is defined as identification of the direction of sound source outside the head while lateralization ability occurs when headphones are used and the sound appears to come from within the head. Head turning behavior started to appear at 4 months of age. Children reach the adult performance of this ability at 5 years of age (*Bellis, 1996*). Sound localization and

lateralization and the principle of inter-aural timing are involved in many central auditory tests (***Chermak and Musiek, 1997***).

When presenting two stimuli binaurally, the ear presented with the stimulus with the greater intensity results in lateralization to that side. If the stimuli are of equal intensity, a mid-line image is perceived. Regarding inter-aural timing, the stimulus that lead in time will lateralize the acoustic image to its side of the head. Time delay between the two stimuli can be quantified to provide images at different loci between sound sources (***Moor et al., 1990***).

2) Auditory discrimination and auditory pattern recognition

Auditory discrimination is one of the most fundamental auditory processes. It is the ability of the auditory system to perceive acoustic similarities and differences between sounds (***Sloan, 1986***). This ability starts in the intrauterine life (***Kolata, 1984***) and reaches adult like accuracy for high frequencies around 4 years, whereas for the lower frequencies around 8 years of age (***Maxon and Hochberg, 1982***). Discrimination of frequency, intensity and duration of tonal stimuli is critical to the discrimination of more complex acoustic stimuli such as speech segments or phonemes. Auditory discrimination

and phoneme analysis are also important to spoken language comprehension (*Musiek et al., 2002*).

The brain identifies sounds by comparing their physical characteristics (frequency, intensity and temporal features) that we perceive as pitch, loudness and duration and constructs an image of the signal from these components, the discrimination and recognition of auditory inputs follows the analysis of these images rather than analysis of the initial input itself, if a match occurs, we can recognize sounds that have important meanings in our life (*Bellis, 1996*).

3) Temporal auditory processing

It is the auditory mechanism responsible for temporal resolution, temporal summation, temporal masking and temporal ordering (*ASHA, 1996*). At birth and during infancy the efficacy of temporal processing is poorer than that of adults. It continues to grow with the child's age to reach maturity between 8 and 10 years of age (*Irwin et al., 1985*). Temporal auditory processing constitutes the time related aspects of acoustic signal.

The most critical aspect of temporal auditory processing is temporal resolution. It is the recognition of subtle changes in the acoustic contour of sound and it is mediated via gap detection ability, modulation detection and frequency discrimination. Gap detection task is also

considered an important measurement for temporal resolution (**Ahissar et al., 2000**). Temporal resolution is very critical for speech perception and consequently for developing normal speech and reading abilities (**Lorenzi et al., 2000**).

4) Auditory performance with competing acoustic signals

It is the ability of the auditory system to separate desired from undesired acoustic signals which is very important in improving the intelligibility of acoustic signals and in proper comprehension of auditory messages. It is generally known that the two ears are better than one in accurate detection of signals in noise as the auditory system can use both of inter-aural time difference (ITD) & inter-aural level difference (ILD) to separate between signals (**Bellis, 1996**). This ability reaches an adult like performance around 10 years (**Stollman et al., 2004**).

5) Inter-hemispheric transfer of auditory information

Inter-hemispheric transfer via the corpus callosum is employed in tasks requiring interaction between processed information in each hemisphere such as binaural separation and binaural integration. Inter-hemispheric transfer process grows with age to reach maturity nearly at 11 years and sometimes at adolescence (**Chermak and Musiek, 1997**). More obviously in dichotic listening, defective inter-

hemispheric transfer leads to accentuation of right ear advantage that present in young children. Also it is difficult to integrate supra-segmental information (in the right hemisphere) with linguistic one (in the left hemisphere). Moreover, integration of different modalities such as auditory and visual modalities may be affected in impaired inter-hemispheric function (*Medwetsky, 2002*).

6) Auditory performance with degraded acoustic signals (auditory closure)

Normal listener is able to achieve closure and discrimination even when a portion of the auditory signal is missed or degraded due to the redundancy of the auditory system. This ability is compromised in listeners with CAPD (*Bellis, 1996*). It seems that auditory closure ability reaches adult like performance around 6 years of age (*Stollman et al., 2004*). Many neuro-cognitive processes such as attention, memory and inter-hemispheric transfer of information are also deployed in the processing of acoustic signals (*ASHA, 1996*).

7) Auditory memory

Auditory memory is the way past auditory events affect future functions, i.e., it represents the way the brain is affected by experience and consequently alters its responses. The first impact of experience exposure is memory encoding that followed by another memory

process, which is memory storage. When the subject exposed to a resembling experience, the process of memory retrieval occurs (**Siegel, 2001**). Auditory memory is highly contributive to most of auditory processes (**Musiek et al., 1999**).

Auditory memory is divided into three types basing on the duration of information holding: Echoic memory, short-term memory and long term memory. In echoic memory, an auditory image is stored for 250 msec. It is assumed that processing of auditory inputs relies mainly on the analysis of this echo rather than the initial input. After analysis of auditory message, auditory percepts can be retained in the short-term memory up to approximately 2 seconds. This period can be prolonged by rehearsal and using familiar messages. Auditory percepts can be stored for longer time periods in the long-term memory so as they are ready to be matched with the future coming auditory percepts (**Medwetsky, 2002**).

8) Auditory attention

Auditory attention is a neuro-cognitive process in which one focuses selectively on the stimulus of interest while ignoring irrelevant stimuli, so limiting the amount of information processed to resolution. It is a gateway to conscious experience, maintains primacy of certain information in ongoing information processing. It has a

critical role in properly functioning central auditory abilities especially auditory performance with competing stimuli. The auditory attention process include selective auditory attention and sustained auditory attention (*Medwetsky, 2002*).

Selective (focused) attention is the ability to focus on relevant stimuli while ignoring simultaneously presented, but irrelevant stimuli (i.e., distractors) (*Butler, 1983*). On the other hand, divided attention is the ability to attend to multiple stimuli simultaneously.

Sustained auditory attention (auditory vigilance) is the process of maintaining attention on a certain auditory stimulus over a period of time to detect infrequently occurring signals impeded in background of regularly occurring stimulus events. Vigilance process has three important dimensions: alertness (availability of central nervous system to a stimulus input), selective attention (specific response for previously assigned stimuli) and effort (the degree of conscious effort the person invests in a task) (*Musiek and Chermak, 1995 and Chermak and Musiek, 1997*).

Chapter 2

SELECTIVE AUDITORY ATTENTION

It is the ability to focus on the desired auditory stimuli and to ignore the background noise or competing stimuli. In other words, it is the ability to attend to relevant auditory stimuli in the presence of competing acoustic cues (*Bryan and Bryan, 1975; Shiffrin, 1976; Midler and Kaslen, 1978; ASHA, 1996*).

Mechanism

This phenomenon is accomplished by various brain mechanisms. In order to hear certain acoustic message in a noisy environment or in the presence of competing message, the information from the selected stimuli must be enhanced and the irrelevant one from the competing stimuli must be suppressed (*Hillyard et al., 1973*). This means that selective auditory attention seems to be the system that turning different brain area on and off.

Brain structures involved in auditory attention

Many researches suggested that Olivo-Cochlear Bundle (OCB) could influence selective auditory attention (*Dewson, 1968; Nieder and Nieder, 1970; Wiederhold,*

1986). Studies have shown that when the OCB is compromised, animals can not hear in noise as well as it does when this system is intact (**Musiek and Hoffman, 1990; Musiek, 1992**). Reticular formation system also appears to have important reaction to relevant stimuli than irrelevant ones (**Chermak and Musiek, 1997**). On the other hand, the involvement of cerebrum in selective auditory attention has been faced with debate and controversy. The frontal lobe has a major role in selective auditory attention function.

Studies of regional cerebral blood flow demonstrated that attention increases blood flow in the frontal lobe as well as in auditory-association cortical areas (**Naatanen, 1987**). Recently, Positron Emission Tomography (PET) was used to investigate functional anatomy of selective auditory attention. **Tzourlo et al. (1997)** investigated 17 male volunteers during selective auditory attention using PET and concluded that two major networks seemed to be involved during selective auditory attention namely local temporal network and frontal network which could mediate the temporal cortex modulation by attention.