

INTRODUCTION

Selective auditory attention (SAA) or selective hearing is defined as the ability to acknowledge some stimuli while ignoring other stimuli that occur at the same time. It is characterized as the action in which people focus their attention on a specific source of a sound or spoken words. The sounds and noise in the surrounding environment is heard by the auditory system but only certain parts of the auditory information are processed in the brain (*Acoustical Society of America, 2012*).

Difficulty in understanding speech in the presence of background noise is a commonly reported problem. This perceptual difficulty becomes increasingly severe as competing background noise levels increase (i.e., signal-to-noise ratio (SNR) decreases). As with speech recognition performance, neural responses as measured by evoked potentials are typically weakened when increasing levels of noise. It is not surprising then, that strong correlations exist between cortical auditory evoked potentials (CAEPs) and speech perception-in-noise measures (*Billings et al., 2015*).

The cortical auditory evoked potentials (CAEPs) are brain responses evoked by sound and are processed in or near the auditory cortex (*Van Dun et al., 2012*). There has been considerable clinical and scientific interest in CAEPs to probe threshold and suprathreshold auditory processes because they

are believed to reflect the neural detection and/or discrimination of sound underlying speech perception. These measures include obligatory evoked potentials such as P1- N1-P2 complex, and discriminative potentials such as mismatch negativity (MMN) and P300 (*Kim, 2015*).

The neural processing underlying behavioral discrimination capacity can be measured by modifying the traditional methodology for recording the P1-N1-P2. When obtained in response to an acoustic change within a sound or in response to stimulus that contains multiple time-varying acoustic changes such as speech, the resulting waveform has been referred to as the acoustic change complex (ACC) (*Martin et al., 1999*).

The Acoustic Change Complex (ACC) has been obtained in response to intensity, frequency, and phase modulations in sustained tones (*Dimitrijevic et al., 2008*). It has also been obtained in response to spectral and intensity changes within speech or speech-like stimuli (*Tremblay et al., 2003*). Cortical potentials were recorded for consonant-vowel syllable and tonal complex stimuli with varying pre-transition durations (*Narne et al., 2013*).

Many studies were done in adults and to lesser extent in young children to record CAEPs in noise. CAEP peaks recorded from speech sound onset are generally reduced in amplitude and delayed in latency for adults (*Cunningham et*

al., 2001; Anderson et al., 2010; Billings et al., 2013; Small et al., 2018). Only two researches recorded ACC in noise in normal hearing adults (*Billings et al., 2017; Iverson et al., 2016*).

The present research is designed to study the ACC in two groups of children; the normal hearing children representing the control group and children with SAA deficit representing the study group. The speech stimulus vowel /o/ was used in presence of pink noise with different signal to noise ratios (SNRs) +8, +4, 0 -4 & -8 for eliciting ACC. Besides, audiological evaluation, Words in Noise (WIN) test was done. The aim of this study is to assess if that ACC provoked by specifically designed speech in noise stimuli can be used as an objective tool for assessment of cortical auditory discrimination in normal individuals and to apply the developed ACC protocol in children with SAA deficit, in order to assess its validity. Hopefully, this would help in the evaluation of SAA in young children and children who can't be evaluated behaviorally.

AIMS OF THE WORK

The aims of the present research are:

- 1- To assess if ACC provoked by specifically designed speech in noise stimuli can be used as an objective tool for assessment of cortical auditory discrimination in normal individuals.
- 2- To apply the developed ACC protocol in children with SAA deficit in order to assess its validity.

Chapter One

SELECTIVE AUDITORY ATTENTION

S*elective auditory attention (SAA) or selective hearing* is a type of selective attention that involves the auditory system of the nervous system. SAA is described as the action in which people focus their attention on a specific source of a sound or spoken words. The sounds and noise in the surrounding environment are heard by the auditory system but only certain parts of the auditory information are processed in the brain (*Acoustical Society of America, 2012*). Most often, auditory attention is directed at sounds that people are most interested in hearing (*Bess & Humes, 2008*).

Also, it is defined as the ability to acknowledge some stimuli while ignoring other stimuli that occur at the same time. This could occur when a student focuses on a teacher giving a lesson and at the same time ignoring the sounds of classmates in a crowded classroom.

It was also named as “bottlenecking”. This means that information cannot be processed simultaneously, so only some sensory information that gets through the “bottleneck” is processed. A brain simply cannot process all sensory information that occurs in an environment, so only the most important is thoroughly processed (*Karns et al., 2015*).

1. Theories of Selective Auditory Attention:

Over the years, there has been increased research in the theories and neural basis of selectivity of auditory attention. *Historically*, SAA was known as “the cocktail party problem” which was first brought up in 1953 by **Colin Cherry**. This common problem is how our minds solves the issue of knowing what is important in the auditory scene and combining those in a coherent whole (*Eysenck, 2012*).

In early-selection theories, **Broadbent (1958)** assumed that stimuli are briefly stored and analyzed in parallel for elementary characteristics at the pre-attentive level, with only a selected subset ("selected channel") allowed by the filter to be processed at higher levels (*Broadbent, 1970*)

Later, another study was done by **Albert Bregman** and he came up with the auditory scene analysis model. The model has three main characteristics: segmentation, integration, and segregation (*Bregman, 1990*).

First segmentation; which involves the division of auditory messages into segments of importance.

Second integration; the process of combining parts of an auditory message to form a whole message.

Third segregation; which is the separation of important auditory messages from the unwanted information in the brain.

It is important to note that **Bregman** also made a link back to the idea of perception; making a useful representation of the world from sensory inputs around us. Without perception, an individual will not recognize or have the knowledge of what is going on around him.

Although Begman's work is critical to understand selective auditory attention, his studies did not describe the way in which an auditory message is selected, if and when it was correctly segregated from other sounds in a mixture, which is a critical stage of selective auditory attention.

Then ***Posner and Dehaene (1994)*** stated that the control of selective attention requires targeting some sensory dimension for focal processing while effectively inhibiting others. This should be associated with two related brain phenomena. ***First***, cognitive systems that control the attention shift and the engage/disengage operations which is active when task demands stress on any or all of these component operations. ***Second***, these controlling operations should produce consequent changes in the responsiveness and activation states of cortical and/or subcortical regions that process information relevant to a particular sensory dimension.

2. Neural Basis of Selective Auditory Attention

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 turning different brain areas on and off.

Many researches suggested that olivocochlear bundle (OCB) could influence selective auditory attention (*Wiederhold, 1986*). Studies have shown that when the OCB is compromised, animals cannot hear in noise as well as it does when this system is intact (*Musiek and Hoffman, 1990*). The 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 cerebral cortex 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 have demonstrated that attention increases blood flow in the frontal lobe as well as the auditory association cortical areas (*Naatanen, 1987*).

3. Maturation of Selective Auditory Attention Ability:

The peripheral auditory system appears to provide the brain with an accurate representation of sound by about 6

months of age, but human auditory development is a prolonged process. This development requires increasing sophistication in the skills needed to separate and select target sounds in complex acoustic environments. What infants and children hear when they listen to complex sounds is different than what adults hear (*Leibold, 2011*).

Behavioral studies have indicated that auditory selective attention skills develop throughout childhood (3-12 years) at least until adolescence (12-17 years). Both the abilities to selectively attend to relevant stimuli and to successfully ignore irrelevant stimuli improve progressively with increasing age across childhood (*Lane & Pearson, 1982*).

While some aspects of attention are clearly present in some form in infancy, the ability to deploy and control selective attention continues to develop into early adulthood. For example, background noise creates greater interference effects for younger children and adolescents who also show larger effects of flanker stimuli relative to adults. There is some evidence that background noise at level (50-70 dB A) creates greater masking effects for younger children as compared with adolescents or adults. (*Elliott, 1979*)

Interestingly, it was found that when the background noise is repetitive and predictable, children are often as good as adults at detecting an auditory signal (*Wightman et al, 2003*). However, when the background noise is unpredictable,

children's hearing declines markedly. For example, in the presence of a noise that varies randomly between every presentation, 4- to 5-year-old children require a fivefold increase in signal intensity relative to adults (**Oh et al., 2001**). **Jones et al. (2015)** reported that older children (8–11 years old) were similar to adults in their ability to ignore irrelevant information. In contrast, younger children (4–7 years old) were less able to filter out (i.e., gave greater weight to) noise that was similar in frequency to the target tone. This indicated that attention improves substantively within the first 7 years of life (**Ruff & Rothbart, 1996**).

4. SAA as a part of central auditory ability

Generally, central auditory processing (CAP) is defined by **Katz and Wilde (1994)** as what we do with what we hear. Recently, **ASHA (1996)** established the definition of CAP as the auditory system mechanisms and processes responsible for the following phenomena:

- Sound localization and lateralization
- Auditory discrimination,
- Auditory pattern recognition
- Temporal aspect of audition, including: temporal resolution, temporal masking, temporal integration and temporal ordering.

- Auditory performance decrements with competing acoustic signals
- Auditory performance decrements with degraded acoustic signals

All these mechanisms are mastered and coordinated by higher cognitive processes such as attention, memory and recognition (*Musiek and Lamb, (1992)*).

Attention is important for most, if not all, information processing. Attentional processes are involved in determining which internal and external stimuli are singled out for further processing and, consequently, which stimuli warrant a response. This process of selecting stimuli from an extremely complex, ever changing, multisensory environment is determined not only by the physical characteristics of the stimuli themselves, but also by the individual interests, motives, and cognitive strategies of the person perceiving the stimuli. (*Hilary et al, 2000*)

There are four types of attention:

- Sustained attention which is the ability to focus on one specific task for a continuous amount of time without being distracted.

- Selective Attention which is the ability to select from many factors or stimuli and to focus on only the one that you want.
- Alternating Attention which is the ability to switch your focus back and forth between tasks that require different cognitive demands.
- Divided Attention which is the ability to process two or more responses or react to two or more different demands simultaneously.

The attention is critical for learning and development. Identifying and attending to the important aspects of the environment are essential for the acquisition of new skills. For example, investigators have shown that infants attend to the stress patterns of language and have argued that this facilitates language acquisition (**Gerken, 1994**). The selection of stimuli for further processing also has implications for what information is stored in memory and the level of detail associated with particular memory traces.

Attentional processes, however, are complicated by the fact that it is often difficult to separate attention from encoding, memory, decision making, and response systems in the information processing stream (**Cooly and Morris, 1990**). This difficulty has two primary implications for the developmental study of attention. First, it is often difficult to identify which

aspect of information processing is responsible for a developmental change in behavior (*Halperin et al., 1994*). Second, if infants or children are unable to perform a task accurately, it can be difficult to identify where in the information-processing stream the failure occurred (*Molholm et al., 2001*).

Young infants exhibit selective attending in certain circumstances. They are also able to attend to features that are critical for discrimination of complex stimuli in many situations. Further development probably involves improved automatic discrimination, possibly due to more precise representations of stimuli in memory. Increases in automatic processing would free attentional resources for employment in other ways. Development in this system is also associated with advancements in higher cognitive functions involved in the ability to plan, regulate, and direct one's own attention according to the demands of specific situations (*Ruff and Rothbart, 1996*).

5. Selective Auditory Attention Disorders:

Auditory Processing Disorder (APD) is an abnormal processing of auditory information within the central auditory nervous system. It affects about 5% of school-aged children as they can't process all what they hear because their ears and brain don't fully coordinate. This condition occurs either in normal peripheral or impaired hearing (*Martin and Keith,*

2009). Poor auditory attention span and distractibility are also symptoms in children with APD (*American Speech-Language-Hearing Association, 2005a; American Academy of Audiology, 2010*).

The influence of cognitive top-down functions on Auditory Processing (AP) tests is a point of scientific debate between the British Society of Audiology (*British Society of Audiology, 2011*) and the American Speech-Language Hearing Association (*American Speech-Language-Hearing Association, 2005*).

American Speech-Language Hearing Association states that deficits in the auditory pathway alone should define APD (*American Speech-Language-Hearing Association, 2005*). This discussion directly impacts selection of diagnostic tests and APD diagnosis.

6. Impact of Selective Auditory Attention disorder

6.1. *Selective Auditory Attention disorder and learning disability (LD):*

Several studies have demonstrated the association between CAPD and learning disability (LD) (*Shalaby, 1998*). The percentage of learning disabled children with CAPD is high but still not precisely known (*Bench, 1997*).

Shalaby (1998) applied Arabic central test battery on 50 learning disabled children with normal hearing, their ages ranging from 6 to 12 years. The central test battery included Low passed Filtered Speech (LPF) test and Speech In Noise (SPIN) test. The results showed that 86% of learning disabled children had abnormalities in one or more of the central auditory abilities. Children with selective auditory attention disorder were 60% and with auditory separation disorder were 68% of the study.

Also **Garcia et al. (2007)**, found poorer results of Pediatric Speech Intelligibility Test (PSI) with an ipsilateral competing message (ICM) at speech/noise ratios of 0 and -10 poor with the group of children presented with learning disabilities than normal language and learning development.

6.2. Selective Auditory Attention disorder and language disorders:

The **ASHA** since **1996** has linked CAPD generally to language disorders.

Behavioral studies suggest that children with poor language abilities have difficulty with attentional filtering, or noise exclusion. However, as behavioral performance represents the summed activity of multiple stages of processing, the temporal locus of the filtering deficit remains unclear. So, event-related potential (ERP) paradigm was used