Auditory Abilities and Language Acquisition in Cochlear Implant Users with Bimodal Stimulation

Essay

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Abbreviations

ABR	Auditory Brainstem Response
ASSR	Auditory Steady State Responses
BEA	Better Ear Average
CHL	Conductive Hearing Loss
CNC	Consonant Nucleus Consonant
CI	Cochlear Implant
dB	Decibel
EAM	External AuditoryMeatus
EAS	Electric Acoustic Stimulation
Fo	Fundamental Frequency
F1	Formant 1
F2	Formant 2
HA	Hearing Aid
HI	Hearing Impairment
HL	Hearing Loss
ILDs	Interaural Level Differences
ITDs	Interaural Time Differences
IQ	Intelligence Quotient
LP	Low Passed Speech
MHL	Mixed Hearing Loss

PTA **SNR** **SNHL**	Pure Tone Average Signal To Noise Ratio Sensory Neural Hearing Loss
SPL **TF0-env** **TM**	Sound Pressure Level Amplitude Envelope of the Maximum Frequency of the F0 contour Tympanic Membrane
WHO	World Health Organization

Introduction

People with normal hearing typically listen with both ears. This enables sounds to be heard regardless from which direction they come, and provides two inputs to the binaural auditory system so that it can selectively attend to the ear receiving the clearer signal. The system can also partially reduce the negative impact of noise on speech intelligibility by combining inputs from both ears ***(Dillon, 2001)***.

Binaural hearing is a fundamental property of the normal auditory system. Many individuals with hearing loss in one or both ears have difficulty with this situation. Evidence for binaural benefits when both ears are stimulated compared with stimulation of one ear alone is well documented in normal listeners ***(Durlach, 1978)***.

Hearing impairment refers to a condition in which the subject is unable to detect or distinguish the range of sounds normally available to the human ear ***(Justice, 2006)***. The incidence of permanent hearing loss in children ranges from 1.2 to 6 per 1,000 live births worldwide. ***(Olusanya et al., 2006)***.

The early hearing detection and intervention program found 5 to 6 infants per 1000 children as born with hearing loss. Estimates from research in the last 2 decades suggested that about 8% of school children have hearing loss that is educationally significant. This term refers to a hearing loss that is serious enough to impact a child's ability to perform well educationally ***(American-Speech-Hearing Association [ASHA], 2005)***. The prevalence of hearing loss in Egypt is about 16% ***(Abdel-hamid et al., 2007).***

Recognition and management of hearing loss is imperative. Untreated hearing loss in a child has a significant impact on their auditory brain development that results in serious consequences for speech, language, literacy, academic achievements, and social emotional development for the child's life term. These chronic disabilities also impact significantly on the family and community ***(Olusanya et al., 2006)***.

Children with hearing impairment are at risk of language delay due to receiving insufficient auditory information during the critical period ***(Nicholas and Geers, 2007). Perkell et al., 2000***, stated that there is a well-documented relationship between the severity of hearing loss and intelligibility of speech.

Intervention of hearing impaired children aims at developing healthy, socially and emotionally balanced individuals who are able to integrate into the society and become more generally productive in their societies. ***(Scheetz, 2001)***.

Hearing aids and cochlear implants are the two ways to enhance one's hearing abilities. Hearing aids are small electronic devices inside the ear. They are placed in the entrance to the ear in the external auditory meatus. They are typically molded to fit each individual ear and amplify sound as it is delivered to the ear canal ***(Roseberry- McKibbin & Hedge, 2011).***

A cochlear implant is a hearing prosthesis designed to restore or provide a level of auditory sensation to adults and children who have severe to profound sensory-neural hearing impairment and who get limited benefit from hearing aids ***(Waltzmann, 2006)***.

Children who receive an implant early in life, followed by a period of appropriate rehabilitation, achieve language and speech skills that exceed levels observed in profoundly deaf children with hearing aids ***(Geers, 2004).*** Children who receive CIs at a young age (i.e., under 24months of age) can be expected to achieve some language skills at a rate comparable to hearing age-mates ***(Svirsky et al, 2004 & Nicholas &Geers, 2007).*** These children are entering mainstream classrooms in the early primary grades ***(Geers & Brenner, 2003).***

But as good as they are, cochlear implants have not completely eliminated the problems arising from childhood hearing loss. Gaps persist in the language capabilities of children with hearing loss compared to those of children with normal hearing One treatment option that has been considered as a way of further closing the gap between children with normal hearing and those with hearing loss is bimodal stimulation ***(Geers, 2004 & Nittrouer, 2009).***

Severe to profound hearing impaired individuals typically derive substantial benefit from a CI for speech understanding and quality of life. Conventional CI users may use a HA in the contralateral ear (bimodal condition) if sufficient residual hearing is present. This listening condition has the potential to improve speech recognition, particularly in noise. Results in these patients show that bimodal listening is of significant benefit, and a strong synergistic effect of using both devices is particularly noticeable during speech testing in noise ***(Gstoettner et al., 2008).***

Aim of the Work

The aim of this work is to review the effects of bimodal stimulation in cochlear implant user when a hearing aid is fitted in the contralateral ear in order to clarify its advantages in auditory abilities, language acquisition and communicative functioning in everyday life.

THE AUDITORY SYSTEM

Anatomically, the auditory system can be divided into four parts: External ear, Middle ear, Inner ear, and Neural pathway The primary structures of the outer ear include the pinna (or auricle) and the external auditory meatus (EAM, or ear canal). The middle ear consists of the tympanic membrane (TM; commonly known as the eardrum, which forms the boundary between the outer and middle ears), ossicles (malleus, incus, and stapes; collectively known as the ossicular chain), Eustachian (or auditory) tube, and the middle ear cavity (a space). The inner ear includes the cochlea, vestibule, and semicircular canals. Finally, the neural pathway includes the vestibulocochlear nerve (cranial nerve VIII), which consists of the combined cochlear and vestibular branches as it courses through different levels of the brainstem (***Fuller et al, 2012).***

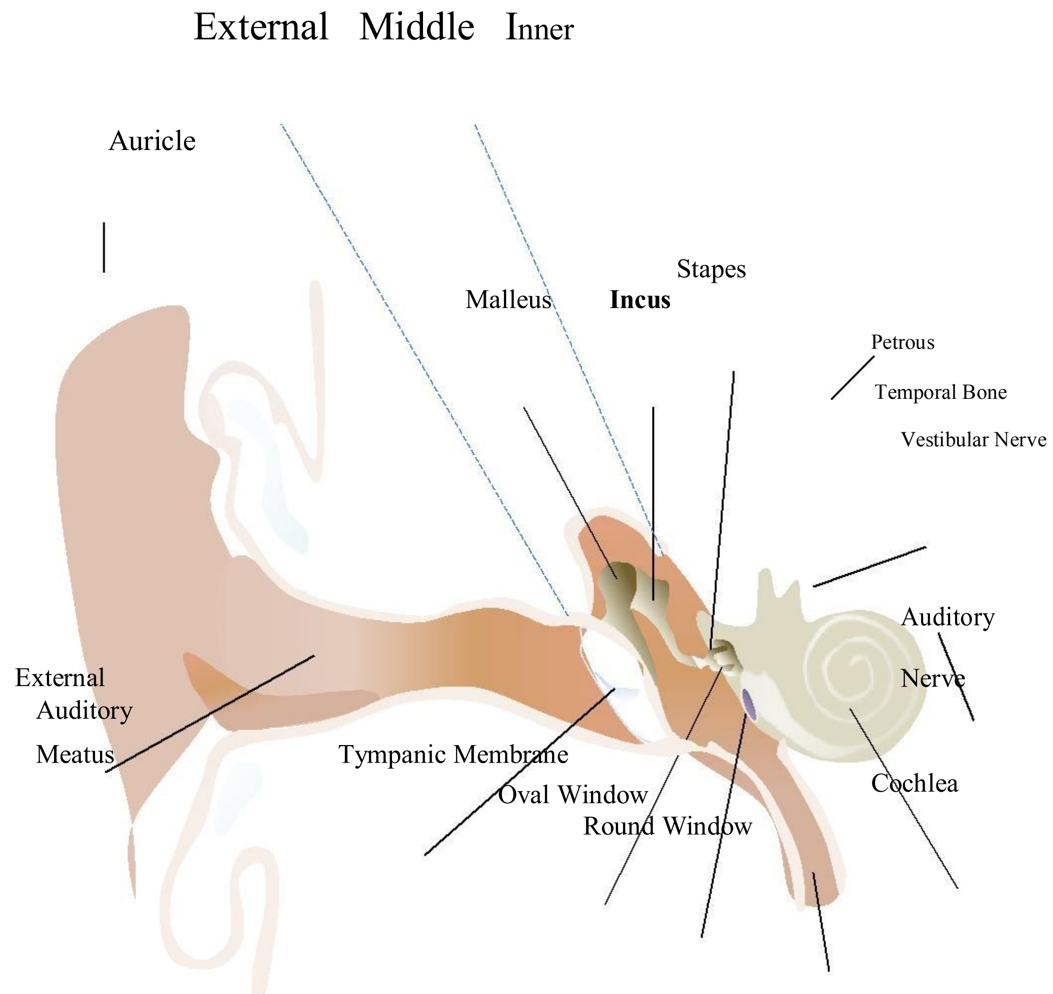

Figure 1: **Illustration of the gross anatomy of the peripheral auditory system.**
Re-drawn and adapted from Papsin & Gordon (2007)

The external ear

The external ear gathers the sounds arriving at the ear and directs these acoustic signals to the tympanic membrane. Because of the configuration of the external auditory meatus, which is much like a pipe or tube that is closed at one end and open at the other, it generates an ear canal resonance, which is important for the natural perception of sound ***(Musiek and Baran, 2007).***

Another important function of the pinna and concha is to selectively filter different sound frequencies in order to provide cues about the elevation of the source of the sound. The vertically asymmetrical convolutions of the pinna are shaped so that the external ear becomes able to transmit more high frequency components from an elevated source than from the same source at ear level ***(Purves et al., 2004).***

The middle ear

It can be described as an air-containing space with bony walls except for the tympanic membrane laterally. The middle ear has four main anatomical structures: the tympanic membrane, the ossicular chain, two middle ear muscles, and the Eustachian tube. The tympanic membrane vibrates in response to the sound waves and sends the signal on to the ossicular chain. The malleus, the incus, and the stapes compose the ossicular chain. The three ossicles are interconnected. The malleus is attached to the tympanic membrane. Therefore, when the tympanic membrane vibrates the ossicles also vibrate, this transfers sound through the middle ear. The two primary muscles of the middle ear are the stapedious and tensor tympani muscles. The two muscles connect to the ossicular chain and act as a protective mechanism. The Eustachian tube travels from the middle ear to the nasopharynx. It does not directly transfer sound waves, but it does help in the protection of the auditory pathway by equalizing air pressure, draining