Evaluation of ClearVoice speech enhancement algorithm in children using cochlear implant

Thesis

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بسم الله الرحمن الرحيم

قالوا

سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم

صدق الله العظيم

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List of Abbreviations

Abb.	Full term
CI	Cochlear implant
SNR	Signal to noise ratio
MMN	Mismatch negativity
AB	Advanced Bionics
HiRes	HiResolution sound processing strategy
ACE	Advanced combinational encoder
CIS	Continuous interleaved sampling
FECSS	Four electrode current steering schemes
TECSS	Two electrode current steering schemes
NRA	Noise reduction algorithm
SSN	Speech-spectrum shaped noise
ERP	Event related potentials
NMDA	N-methyl-D-aspartate
MMR	Mismatch response
SLI	Specific language impairment
ASD	Autism spectrum disorder
ISI	Inter-stimulus interval
CNS	Central nervous system
MMNm	MMN and its magnetoencephalographic equivilant
REM	Rapid eye movement
AEP	Auditory evoked potentials
IT-MAIS	Infant-Toddler Meaningful Auditory Integration Scale
HA	Hearing aid
SRT	speech reception threshold
SD	Standard deviation
WIPI	Word intelligibility by picture identification
PBKG	Phonetically balanced kindergarten
DS	Discrimination score
LTASS	long term average speech spectrum

INTRODUCTION

Cochlear implant (CI) technology continues to afford increasingly higher levels of speech Understanding. Cochlear implant recipients, however, continue to exhibit considerable difficulty understanding speech in background noise ***(Nelson et al., 2003).*** Possible means to improve the ability to understand speech in noise include utilization of multi-microphone technology and coupling the sound processor to a frequency modulation system. These methods have been shown to be effective in improving speech recognition in noise in cochlear implant users ***(Spriet et al., 2007),*** but the incorporation of a noise reduction algorithm as a preprocessor to the cochlear implant speech processor may be a more convenient and cost saving strategy ***(Buechner et al., 2010).***

Several recent approaches have been proposed to enhance speech intelligibility under adverse conditions. A dynamic range controller was introduced to increase the perceived loudness while maintaining the original intensity range ***(Bonardo and Zovato, 2007).*** An alternative appro-ach developed aimed to improve intelligibility by amplifying transient components extracted using a set of time varying filters whose center frequencies and bandwidths were controlled to identify the strongest formants ***(Boston et al., 2007).*** Speech intelligibility was boosted in by raising the average speech spectrum over the average noise spectrum using frequency dependent and independent signal-to-noise ratio (SNR) recovery ***(Sauert and Vary, 2006).***

ClearVoice is a recent proprietary algorithm from Advanced Bionics, based on the HiResolution sound processing strategy, and has been designed to improve speech understanding in difficult listening environments by reducing the stationary noise and emphasizing the dynamic channels containing more speech. The algorithm acts on the signal after it has been passed the band filters, and is based on the assumption that the speech envelope is modulated and the noise envelope is unmodulated. From the analyses of the modulation frequency and modulation depth, the signal-to-noise ratio is estimated in each frequency band separately and bands with low modulation depths and thus low SNRs are attenuated. There are three levels of ClearVoice algorithm attenuation available: low level (-6dB), medium level (-12dB) and high level (-18dB) ***(Advanced Bionics, 2012).***

Auditory evoked potentials provide objective evidence of central auditory processing differences across experienced cochlear implant users. One of these potentials is the mismatch negativity test (MMN) which reflects the pre-attentive detection of the differences between the neural representations of the standard stimuli in memory and the deviant stimuli in the sensory input. ***Zhang et al. (2011)*** found that good performers in a speech perception task displayed large MMN responses, while moderate to poor performers had small or absent responses. These results indicate that MMN may be used to assess the functional status of the auditory cortex in terms of auditory memory and discrimination in children with cochlear implants and may provide an objective mechanism for differentiating good from poor performers.

Preliminary studies showed very promising results for improvement of hearing performance in noise with ClearVoice strategy in adults ***(Kam et al., 2013).*** However, Limited research is available on the use of ClearVoice in children using cochlear implant. Accordingly, this study is designed to evaluate the objective and subjective benefits and level of satisfaction with ClearVoice speech enhancement algorithm in children using cochlear implant.

Aim of the Work

1) To measure the potential additional improvement, if any, in speech recognition in noise using ClearVoice speech enhancement algorithm in children using HiResolution sound processing strategy.
2) To study the result of the mismatch negativity test with ClearVoice speech enhancement algorithm.

Chapter 1

SPEECH PROCESSING STRATEGIES IN COCHLEAR IMPLANT

Cochlear implants (CIs) are surgically implanted neural prosthetic devices used to treat severe to profound hearing loss ***(NIDCD, 2011).*** They stimulate the hearing nerve with patterns of electrical currents so that speech and sounds can be perceived by profoundly deaf people. The use of a CI does not restore hearing to a normal level but enables a different course of development of speech and language function, than would have been possible without the CI ***(Geers et al., 2003; Spencer, 2004).***

Results of cochlear implantation are variable among individuals from sound detection to understand a conversation over the telephone and may be influenced by age at cochlear implantation, duration of deafness and presence of residual hearing ***(Govaerts et al., 2002).***

Understanding speech in noise is one of the most difficult tasks for CI users. Poor frequency selectivity, frequency discrimination, and electrode discrimination contribute to poor speech perception for CI users ***(Nelson et al., 1995; Donaldson and Nelson 2000; Henry et al., 2000).***

Several researchers have shown that the loss of fine spectral information, spectral smearing, and poor auditory segregation affect CI users ability to perceive speech in quiet and noise ***(Fu et al., 1998; Fu and Nogaki, 2005; Hong and Turner, 2006; Litvak et al., 2006).***

Results using normal hearing subjects listening to CI simulations showed that 16 to 20 channels of processing were required to optimize speech perception in noise ***(Dorman et al., 1998; Friesen et al., 2001).***

Shannon et al. (1995); Dorman and Loizou (1997, 1998), however, have shown that CI users have only 3–9 functional channels. Further-more, ***Loizou and Poroy (2001)*** showed that CI users need a larger spectral contrast for vowel identification than normal hearing listeners, and similar effects have been observed in the hearing impaired ***(Leek et al., 1987).***

Parikh and Loizou (2005) additionally reported that background noise reduces spectral contrast, making it even more difficult for CI users to hear speech in noise. Thus, it is expected that CI users with better spectral resolution will have better speech understanding in noise.

Stimulating strategy review

In the cochlear implant system, the stimulating strategy plays an extremely important role in generating the sounds heard by users ***(Wilson et al., 1991; Kiefer et al., 2001; Koch et al., 2004; Wilson & Dorman, 2008).*** It functions to convert sounds into a series of electric impulses which determines