AJHAS

https://albalqajournal.ammanu.edu.jo/SC.aspx
Vol.1 No.2 2022

Al-Balqa Journal
for Health & Applied Sciences

Effect of Signal to noise ratios on aided Acoustic Change Complex (ACC)

Amani Ahmed Shalaby[1], Rasha Hamdy El-kabarity[2], Noha Ali Shafik[3] & Mona Abd-Alfattah[4]

[1] Professor of Audiology, Audiology Unit, ORL Dept., Faculty of Medecine, Ain Shams University, Cairo, Egypt.
[2] Professor of Audiology, Audiology Unit, ORL Dept., Faculty of Medecine, Ain Shams University, Cairo, Egypt.
[3] Assistant Professor of Audiology, Audiology Unit, ORL Dept., Faculty of Medecine, Ain Shams University, Cairo, Egypt.
[4] * Assistant Specialist of Audiology, Audiology Unit, ORL Dept., Banha Teaching Hospital, anha, Egypt.

* e-mail: monaabdelfattah643@gmail.com

Abstract

Introduction: Children with hearing impairment are at risk for delayed language development, the risk increases with increasing severity of hearing loss. However, early amplification provides better early language outcomes. Monitoring the hearing-related outcomes of children with hearing loss and fitted with suitable H. As is essential and can be accomplished both objectively and subjectively. One of the objective measures is ACC.

Objectives: To study the effect of different SNRs on ACC in children who use H.As

Methods: 60 Arabic speaking children using binaural H.As. Their age ranged from 6 to 12 years. Evaluation of children was performed through ACC recordings. Speech (vowel /o/) in different signal to noise ratio (SNR) was used to elicit ACC response. The replicated ACC waveforms were collected and analyzed and the aided ACC responses were compared while utilizing different SNRS.

Results: ACC percent identification (%ID) was higher in favorable SNRs (+8 versus 0).

Conclusion: Hearing-impaired subjects can process speech stimuli at the level of the auditory cortex when they used their H.As. ACC can be used as an objective measure for speech perception of noise at the level of auditory cortex. ACC is more preferable at higher SNRs.

Keywords

Acoustic Change Complex (ACC), hearing impairment (H. I), Hearing Aids (H.As), percent identification (%ID), Signal to Noise Ratio (SNR).

1. Introduction

Children with mild-to-severe hearing loss are at risk for delayed language development. The risk increases with increasing severity of hearing loss. However, early amplification provides better early language outcomes, as well as Consistent hearing aid use provides some protection against language delay and supports auditory development (Tomblin et al., 2015).

Although improvement in speech intelligibility has been shown in aided compared to unaided listening conditions (Coez et al., 2010), it remains unclear how central auditory processing changes as a function of H.As usage. Monitoring the hearing-related outcomes of infants and children with hearing loss and fitted with suitable hearing aids is essential and can be accomplished both objectively and subjectively.

One of the objective tests is cortical auditory evoked potential (CAEP-P1). Aided CAEPs, or evoked potentials recorded from individuals while wearing their hearing aids, may be of value to evaluate hearing aid fittings as well as experience-related plasticity associated with amplification. It can provide information about speech sound detection and the benefit of hearing aid use as reported by Mehta et al. (2017). However, the neural processing underlying behavioral discrimination capacity can be measured by modifying the traditional methodology for recording the P1-N1-P2.The resulting waveform has been referred to as the acoustic change complex (ACC), the ACC is a CAEP evoked in response to a change in an ongoing sound (Martin & Boothroyd , 1999) . ACC could be elicited using different types of stimuli, El-Kholy et al., (2020)used speech embedded in background noise as a type of stimulus that reflecting selective auditory attention ability in normal hearing children.

Several studies have shown that the ACC can also be recorded in children with hearing aids (HAs) and cochlear implants (CIs) (Tremblay et al.,2006). They examined the effects of amplification on the ACC, the results indicated that the ACC can be recorded reliably in individuals using HAs.

The present study is designed to study ACC in children using H.As in response to speech stimulus. The aim is to provide an objective tool for assessment of speech perception in noise ability in hearing aid users and to compare ACC response parameters while using different SNRs to explore their effects on Aided ACC. This might be considered a step in guiding the H.As performance in children independent of the abilities or degree of cooperation of children

2. Method

- Research design: cross-sectional study.
- The test materials:

For ACC recording:

1st: The speech stimulus were developed and standardized by EL-Kholy et al.,(2020). The stimuli were Vowel /o/ embedded in background noise with different SNRs (0 +8). The vowel /o/ was selected from material used in the Arabic computer based remediation program for central auditory processing disorders developed at Ain Shams University (Tawfik et al.,2006) . It was generated by a natural voice of a native Egyptian male speaker, digitized at an acoustic lab, at Faculty of Engineering Ain Shams University. The vowel duration adjusted using the Audacity software system to be 500 msec. The /o/ vowel and pink noise were merged together, onset of change was at 200 msec. (where the response was evident). The duration of pink noise was 500 msec. and the /o/ vowel was 300 msec. inserted at 200 msec. from the onset of the stimulus and SNR was adjusted at (+8, 0).(Figure 1).

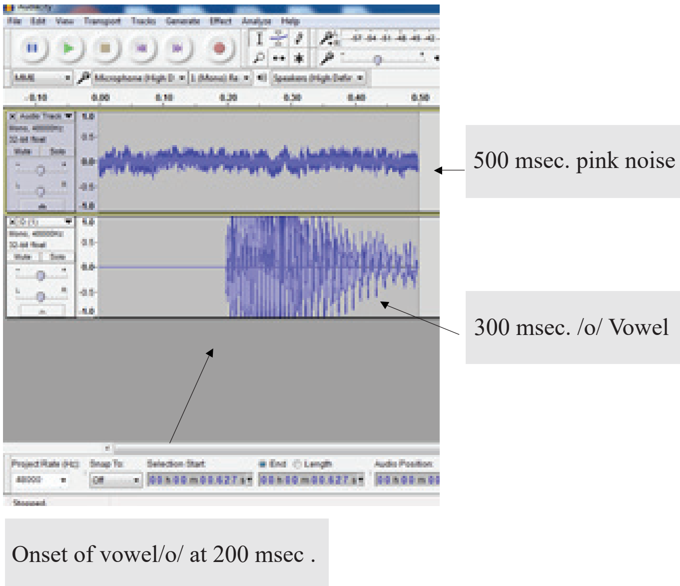

Figure (1): Schematic diagram of Vowel/O/ in noise stimulus (El-Kholy et al., 2020)

- Participants:

Sixty Arabic speaking children (26 boys and 34 girls) participated in the present study. Their age ranged from 6 to 12 years.

2.1. Inclusion criteria

- The degree of hearing loss should range from mild to moderately-severe.
- Regular use of binaural H.As for at least 1 year prior to contribution in the present study.
- Co-operative child, from whom reliable aided behavioral threshold could be obtained.
- Aided thresholds within long term average speech spectrum.
- Average or above average intellectual quotient (IQ) based on psychometric evaluation.

2.2. Exclusion criteria

- Children with history of middle ear problems
- Children with history of neurological disorder
- Children with below average psycho-intellectual ability

2.3. Study place & duration

All children were collected from the Audiology unit of Ain Shams University hospitals, ORL Department, Cairo, Egypt over the period from September 2018 to December 2020.

Informed oral consent was taken from the parents of the children with explanation of the test procedures, benefits, and risks according to the ethical rules.

2.4. Equipment

- Sound treated room IAC model 1602.
- For ACCrecording: Biologic Navigator Pro AEP system (version.7.0.0) connected to a loudspeaker.

2.5. Method

- **Detailed history taking with special emphasis on the duration of H.A use**
- **Aided ACC recordings.**

The stimuli were delivered through a loudspeaker connected by an external amplifier to the evoked potential equipment. The loudspeaker was set at 0 azimuth facing the patient one meter apart. During ACC recording, the children were seated comfortably watching a muted cartoon movie to distract them and to ignore the stimuli presented.

- Electrode montage: The active electrode was placed on the high forehead (Fz) referenced to the mastoid (Rt or Lt) and the ground electrode was placed on the low forehead (FPz).
- The impedance was less than 5 KΩ.
- The EEG data was digitized (Sampling rate: 512 Hz). The responses were filtered between (0.1-100 Hz) and amplified (1000 gain). Response analysis window was included -100 msec pre-stimulus and 710 msec post-stimulus, total 800 msec. The number of accepted sweeps was 50.

3. Data analysis

- Statistical analyses were performed using (SPSS) 16. The independent t-test was used to compare between two different (independent) groups. Chi square test was used examine the relationship between two qualitative variables.
- The Pearson correlation measures the strength of the linear relationship between two variables. A level of $p < 0.05$ was considered significant while $p < 0.01$ was highly significant. A statistician was used for guidance in the study.

4. Ethics

The Research Ethics Committee approved the study. The date of Research ethics committee approval was on 9/9/2018 (FMASU MD 285/2018).

5. Results

The following section shows the effect of Signal to Noise ratio on ACC detectability, morphology, latency and amplitude. The only item that shows significant difference is the detectability of the ACC response either in aided and unaided conditions.

Table (1): Comparison between detectability of ACC using Vowel /o/ with SNRs (+8) Versus SNR (0)

	Response	SNR +8 (n=60)	SNR 0 (n=60)	Total (n=120)	X^2	P Value	Sig.
In aided condition	No	15 (25%)	33(55%)	48(40%)	11.25	0.001	HS
	Yes	45 (75%)	27(45%)	72(60%)			

Table (1) showed highly statistically significant differences in ACC detectability when using SNR (+8) compared to SNR(0) in aided condition with better detectability % at higher SNR.

Table (2): Comparison between ACC morphology using vowel/o/ with SNRs (+8) Versus SNR(0)

	Response	SNR +8	SNR 0	Total	X^2	P Value	Sig.
In aided condition	P1,N2	24(53.3%)	11(40.7%)	35(48.6%)	1.86	0.394	NS
	Multi-peaks	16(35.6%)	14(51.9%)	30(41.7%)			
	Adult-form	5(11.1%)	2(7.4%)	7(9.7%)			
	Total	45	27	72			

Chi-Square Test

Table (3): Comparison between ACC (latency& amplitude) using vowel /o/ with SNRs (0) and (+8)

	Vowel o	Group	N	Mean	SD	t	P Value	Sig.
With HA	P_1 latency	SNR +8	45	153.3	45.0	0.54	0.592	NS
		SNR 0	27	159.6	52.0			
	N_1 latency	SNR +8	45	421.9	49.4	0.56	0.576	NS
		SNR 0	27	415.2	48.0			
	P1 amp	SNR +8	45	2.4	1.7	0.15	0.885	NS
		SNR 0	27	2.4	1.6			
	N_1 amp	SNR +8	45	-4.3	2.4	0.15	0.885	NS
		SNR 0	26	-4.2	2.6			

Independent-Samples T Test

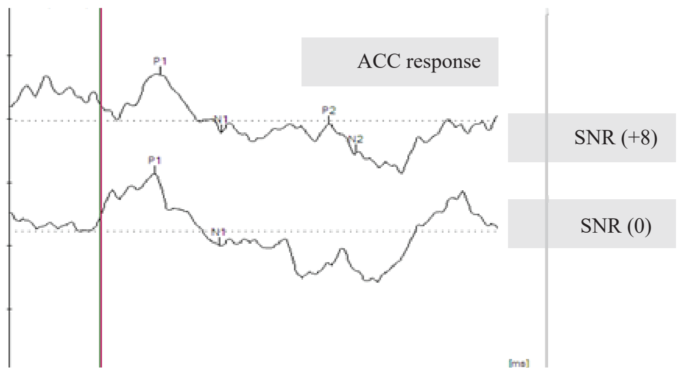

Figure (2): Aided ACC response using Vowel/o/ with (+8) SNR stimulus ''in the upper trace'' with preserved ACC response and Vowel/o/ with SNR (0) '' in the lower trace'' with absent ACC response in a female child (7 years) with moderate hearing loss.

Table (2) showed non-statistically significant differences between ACC morphology using SNR(+0) and SNR(0) in aided and unaided conditions.

Table (3) showed that there is no statistically significant difference of latencies and amplitudes using SNR(+8) and SNR(0).

6. Discussion

This study was designed to investigate the value of implementing ACC recording as a cortical discriminative tool for objective evaluation of speech perception in noise using different SNRs. Hopefully, this will aid in introducing ACC in assessment performance of H.As in Hearing-Impaired children.

- **ACC in Hearing-Impaired children:**

In order to achieve our aims, we investigated the feasibility and acceptability of measuring ACC response to speech stimuli. ACC was recorded using vowel at different (SNRs) as an objective tool for assessment of speech perception in noise . ACC response can be recorded using speech stimuli in presence of noise at different signal to noise ratio in normal hearing children (El-Kholy et al.,2020) and young adults (Yarali et al., 2020). Zhang et al., (2021) used Spectral Rippled Noise (SRN) in hearing impaired children and Han & Dimitrijevic (2020) who used amplitude modulated (AM) white noise in adults with cochlear implants to the best of the author's knowledge.

There is great individual variability in speech recognition performance in noise especially with presence of peripheral hearing loss. Physiological measures have been used to explore this variation by providing insight into how signals in noise are encoded in the auditory system (Billings et al., 2013). The goal was to investigate the effect of noise on the detectability, amplitude and latency of the ACC responses. This was studied by comparing vowel /o/ with SNRs (+8) to SNRs(0) stimuli.

- **Effect on ACC percent identification:**

The higher SNR was better for ACC detectability. As shown in table (1) , there was highly statistically significant difference either with amplification or not. This may be attributed to neural coding of complex speech in background noise and how it is affected by SNR even if it is relatively small and how the Hearing- Impaired children are affected by differences in SNR for ACC detection. Conversely, Billings et al. (2017) reported that neural coding of complex speech in background noise is not uniformly affected by SNR. Their finding may be attributed to using of higher S/N reach to 20 dB and different study population.

- **Effect on ACC morphology:**

Although ACC response to SNRs(+8) showed P1,N2 morphology and multi-peaked P1 morphology with SNRs(0), there was non statistically significant differences (table 2 &figure 2). This in agreement with numerous studies that focused on their analysis on ACC latency and amplitude rather than ACC morphology (Yarali et al., 2020 ; Zhang et al.,2021).

- **Effect on ACC latency & Amplitude:**

There is no statistical significant effect of S/N ratio change on ACC across latencies /amplitudes in aided condition (table 3). This is in agreement with other studies revealing that, as the noise increases (< +10 dB SNR) all three peaks decrease in amplitude and increase in latency (McCullagh et al., 2012; Kim et al., 2012 and Papesh et al., 2015). However, It has been observed consistently that for high signal to noise ratios (SNR > +30 dB SNR) the N1 peak increases in amplitude, whereas the P1 and P2 peaks decrease in amplitude and increase in latency even at high SNRs (Kaplan-Neeman et al., 2006; Parbery-Clark et al., 2011; Papesh et al., 2015).

Thus, it can be stated that the ACC can give an idea about the speech perception in noise ability in hearing aid users & that hearing aid users need higher Signal to noise ratios for better detection of ACC response.

Acknowledgements

Special thanks to Dr Wafaa El-Kholy, Professor of Audiology and head of Audiology unit_ORL department_ Ain Shams University, for her expertise and knowledge that has been invaluable.

Thanks from heart to the children and their parents for participation in the practical part of that work.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interests

The authors declare that there is no conflict of interest.

References

Billings, CJ., Grush, L. and Maamor, N. (2017). Acoustic change complex in background noise: phoneme level and timing effects. Physiology Rep: 5 (20):e1346.

Billings, CJ., McMillan, GP., Penman, TM. & Gille, SM. (2013). Predicting Perception in Noise Using Cortical Auditory Evoked Potentials. Journal of the Association for Research in Otolaryngology: 14, 891-903.

Coez, A., Belin, P., Bizaguet, E., Ferrary, E., Zilbovicius, M. & Samson, Y. (2010). Hearing loss severity impaired processing of formant transition duration. Neuropsychologia; 48: 3057-3061.

El-kholy WA, Galal EM, Aly BMA (2020): Acoustic Change Complex (ACC) in Children with Selective Auditory Attention Deficit .Childhood studies, Published: Jan 2020.

El-kholy, WA., Hassan, DM., Shafik, NA. & Eltoukhy, YEK. (2020): Acoustic Change Complex (ACC) using Speech and Non-Speech Stimuli in Normal Hearing Children. QJM: An International Journal of Medicine, Volume 113, Issue Supplement_1, March 2020, hcaa047.008, Published: 05 May 2020.

Han, JH. and Dimitrijevic, A. (2020): Acoustic Change Responses to Amplitude Modulation in Cochlear Implant Users: Relationships to Speech Perception(2020) Front Neurosci; 14: 124.

Kaplan-Neeman R, Kishon-Rabin L, Henkin Y and Muchnik C (2006). Identification of syllables in noise: Electrophysiological and behavioral correlates. The Journal of the Acoustical Society of America: 120: 926–933.

Kim, JR., Ahn, SY., Jeong, SW., Kim, LS., Park, JS., Chung, SH. & Oh, MK. (2012). Cortical Auditory Evoked Potential in Aging: Effects of Stimulus Intensity and Noise. Otology & Neurotology. 33(7): 1105-1112.

Martin, BA. and Boothroyd, A. (1999): Cortical, auditory, event-related potentials in response to periodic and aperiodic stimuli with the same spectral envelope. Ear Hear; 20: 33–44.

McCullagh, J., Musiek, FE. and Shinn, JJB. (2012) Auditory Cortical Processing in Noise in Normal-Hearing Young Adults. Journal of Audiological Medicine. 10: 114-121.

Mehta, K., Marriage, J., Mahon, M. & Vickers, D. (2017): How useful did families find CAEP with demonstrating hearing aid benefit, understanding their child's hearing loss and the impact of the loss? Manuscript in preparation.

Papesh, MA., Billing, CJ. and Baltzella, LS. (2015). Background noise can enhance cortical auditory evoked potentials under certain conditions. Clinical Neurophysiology. 126: 1319-1330.

Parbery-Clark, A., Marmel, F., Bair, J. & Kraus, N. (2011). What subcortical-cortical relationships tell us about processing speech in noise. Eur J Neurosci. 33:549–557

Tawfik, S., Shalaby, S., El-Kholi, W., El-Sady, S., Hegazi, M.., Hassan, D. and Thabet, M. (2006). Development of an Arabic computer-based remediation program for children with central auditory processing disorders. Presented in "28th International Congress of Audiology" – Innsbruck, Austria.

Tomblin, JB., Harrison, M., Ambrose, SE., Walker, EA., Oleson, JJ. & Moeller MP (2015). Language outcomes in young children with mild to severe hearing loss. Ear Hear. 36: 76Se-91S.

Tremblay, KL., Billings, CJ., Friesen, LM. & Souza, PE. (2006): Neural representation of amplified speech sounds. Ear Hear. 27: 93–103.

Yarali, M. (2020). Varying effect of noise on sound onset and acoustic change evoked auditory cortical N1 responses evoked by a vowel-vowel stimulus. International journal of psychophysiology. 152: 36-43.

Zhang, VW., Ching, TYC. Van Dun, B., Bardy, F., Ibrahim, R., Wong, C., Rance, G., Chisari, D., Sharma, M. & Dillon, H. (2021). The relationship between the acoustic change complex and behavioural response of speech discrimination in infants and young children. Presented in 21st IERSAG ''International Evoked Response Audiometry Study Group'' free online paper session.