AUDITORY EVENT-RELATED POTENTIALS: A POSSIBLE OBJECTIVE TOOL FOR EVALUATING AUDITORY COGNITIVE PROCESSING IN OLDER ADULTS WITH COCHLEAR IMPLANTS

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Abstract

A wealth of research shows that aging adversely affects the morphology and physiology of the peripheral and central auditory system, resulting in a decline in auditory function. Moreover, age-related cognitive deficits in attention, working memory, and speed of information processing have been reported, augmenting the challenges involved in auditory rehabilitation of older adults.

With the growing number of older adults receiving cochlear implants (CIs) there is general consensus that substantial benefits can be gained. Nonetheless, variability in speech perception performance is high, and the relative contribution and interactions among peripheral, central auditory, and cognitive factors have not been fully delineated.

A possible objective means for assessing the benefits derived from CIs in older adults involves electrophysiological measures. In particular, auditory event-related potentials (AERPs), which allow evaluation of the time-course of cortical information processing from early perceptual to later cognitive, post-perceptual stages, could prove advantageous.

In the current report our experience with AERPs elicited by perceptual and higher order cognitive tasks in normal hearing listeners and in CI recipients is reported, and their implications for the evaluation of older adults with CIs is discussed. By varying task complexity and degree of cognitive load, AERPs can expose processing difficulties of older adults with a CI and gauge the contribution of bottom-up versus top-down processing. The suggested comprehensive, hierarchical AERP evaluation may contribute to the better understanding of the neural manifestations of age-related auditory/cognitive decline and its interaction with CIs. It may also lead to the development of CI strategies and rehabilitation procedures tailored specifically to this unique group.

Background

A wealth of literature shows that aging adversely affects auditory system morphology and physiology [1]. Age-related changes result in decline in auditory function that include: decreased hearing sensitivity, especially in the high frequencies; decreased temporal and frequency resolution; decline in speech perception in non-optimal listening conditions; and reduced binaural processing [e.g. 2,3].

Deterioration of auditory function is accompanied by cognitive decline manifested by impairments in working memory, attention, and a reduced ability to inhibit processing of irrelevant information; there is also a general 'slowing down' of information processing [for review see 4].

Auditory rehabilitation of the older hearing-impaired adult is therefore a challenge. Nonetheless, with the growing number of older adults receiving cochlear implants (CIs), there is general consensus that substantial benefits can be gained. It is also agreed, however, that there is high variability in speech perception performance both in quiet and in noise, and the relative contribution and interactions among peripheral, central auditory, and cognitive factors are not fully understood. Behavioral speech perception studies show controversial results, with some suggesting similar performance of young and older adults [e.g. 5], and others indicating significantly poorer performance in older adults [e.g. 6]. It should be taken into account, however, that clinically-used speech perception tests are limited as they do not reflect cognitive aspects of speech understanding which affect the amount of attention, effort, and memory resources expended during communication. Moreover, they provide the 'end product' or 'outcome' of auditory processing but do not follow the sequence of events that lead to that outcome.

An objective means for assessing the benefits derived from CIs in older adults are electrophysiological measures. In particular, auditory event-related potentials (AERPs), which allow evaluation of the time-course of cortical information processing from early perceptual to later cognitive, post-perceptual stages, may prove advantageous [7]. The purpose of the current short review is to elucidate the potential use of AERPs for evaluating auditory/cognitive processing in older adults with CIs. By varying task complexity and degree of cognitive load, AERPs may expose processing difficulties of older adults with CIs and gauge the contribution of bottom-up *vs.* top-down processing.

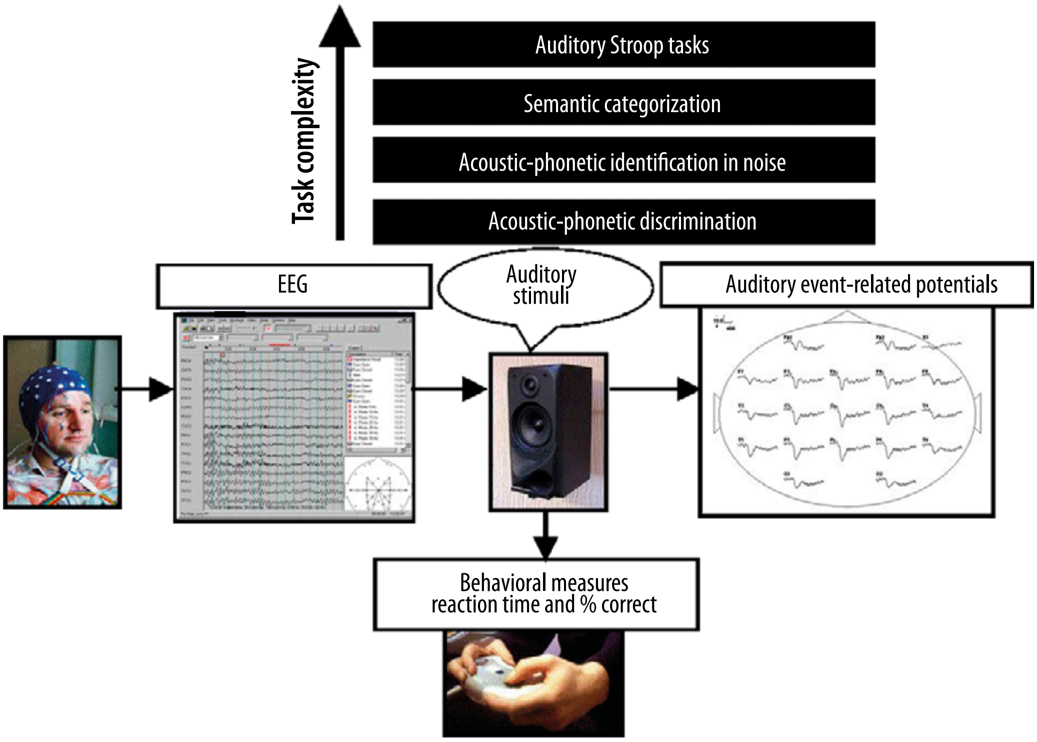

Figure 1. A schematic illustration of the recording of auditory event-related potentials to tasks of increasing complexity.

Methods

In a series of studies we showed that valuable information regarding auditory processing can be gained by means of AERPs from healthy and clinical populations [8–11], and from CI recipients in particular [12–15]. In these studies we recorded the brain electrical activity from multiple electrodes by means of a Brain Performance Measurement (BPM) System (Orgil™) while subjects performed auditory tasks of increasing difficulty (for technical details see Henkin et al. [14]). The timing and strength of auditory processing was manifested by AERP's latencies and amplitudes, respectively, and the relationship with behavioral measures (e.g. performance accuracy and reaction time) was assessed.

Results and Discussion

In a study designed to evaluate acoustic phonetic *discrimination* in post-lingual adult CI recipients, oddball tasks that included pairs of stimuli that differed by one phonetic feature were constructed [14]. We asked how increasing acoustic phonetic difficulty – from an easy 'vowel place' task (/ki/ *vs.* /ku/) to a difficult 'place of articulation' task (/ka/ *vs.* /ta/) – affects the P3 potential. Results in CI recipients indicated that, compared to NH controls, there was prolonged processing time and reduced synchrony, as reflected by longer P3 latency and reduced amplitudes. Furthermore, P3 was sensitive to acoustic phonetic difficulty in a hierarchical manner and differences between CI and NH subjects were more pronounced in the more difficult 'vowel height' task and place of articulation task.

Increasing task complexity in a group of normal hearing listeners, by using an acoustic phonetic *identification* task in noise, confirmed the advantage of AERPs for comparing bottom-up, perceptual processes *vs.* top-down cognitive processes [11]. In this study, subjects were required to identify the syllables /da/ and /ga/ presented in quiet and in signal-to-noise ratios (SNRs) ranging from +15 to –6 dB. Results indicated that N1 latency increased as SNR decreased from the most favorable SNR listening condition of +15 dB. In contrast, P3 latency was not altered in the favorable SNRs, and was prolonged only at SNRs equal to or less than 0 dB. The changes in N1, which is known to reflect the initial processing of the physical characteristics of the stimulus, reflect difficulty in bottom-up processing. Top-down processing left the higher order cognitive P3 unchanged in the favorable SNR; however, with increasing uncertainty, top-down processing could not compensate and indeed performance dramatically decreased.

Another means for increasing task complexity is by enhancing linguistic demand. For example, AERPs that were recorded during a semantic *categorization* task in which subjects were required to respond to stimuli from a targeted semantic category (names) and to ignore a non-target category (body parts) differentiated between healthy children and those with idiopathic generalized epilepsy who are prone to cognitive deficits [8,9]. In contrast, AERPs to tonal and easy acoustic phonetic discrimination tasks were comparable.

A task that is especially suitable for testing age-related decline in inhibitory processes and its effect on auditory/cognitive efficiency is the 'Stroop task'. In an auditory version of the task that we recently constructed [10], listeners were required to classify word meaning or speaker's gender while ignoring the irrelevant (congruent or incongruent) speaker's gender or word meaning, respectively. A significant auditory Stroop effect was evident and manifested in prolonged reaction time and reduced performance accuracy to incongruent *vs.* congruent stimuli, as expected. Interestingly, the timing of neural events (latencies of N1, P2, N2, and N4) to congruent and incongruent stimuli did not differ, suggesting that auditory conflict processing was post-perceptual and located at response selection and execution stages. Nonetheless, reduced N1 amplitude to incongruent stimuli indicated a conflict processing signature at the initial stages of processing.

Taken together, the described hierarchical set of auditory tasks –characterized by increasing auditory/cognitive demand from simple acoustic phonetic discrimination to high-load cognitive Stroop tasks (summarized in Figure 1) – may prove advantageous for the evaluation of older adults with CIs. Such data may contribute to the better understanding of the neural manifestations of age-related auditory/cognitive decline and its interaction with CIs. Furthermore, it may lead to the development of CI device strategies and rehabilitation procedures tailored specifically to this unique group of patients.

References:

1. Gordon-Salant S, Frisina RD: Introduction and overview. In: Gordon-Salant S, Frisina RD, Popper AN, Fay RR (eds.), The Aging Auditory System, Springer Handbook of Auditory Research, 2010; 34: 1–18
2. Fitzgibbons PJ, Gordon-Salant S: Behavioral studies with aging humans: hearing sensitivity and psychoacoustics. In: Gordon-Salant S, Frisina RD, Popper AN, Fay RR (eds.), The Aging Auditory System, Springer Handbook of Auditory Research, 2010; 34: 111–34
3. Pichora-Fuller MK, Souza PE: Effects of aging on auditory processing of speech. Int J Audiol, 2003; 42(Suppl.2): S11–16
4. Pichora-Fuller MK, Singh G: Effects of age on auditory and cognitive processing: implications for hearing aid fitting and audiologic rehabilitation. Trends Amplif, 2006; 10: 29–59
5. Budenz CL, Cosetti MK, Coelho DH et al: The effects of cochlear implantation on speech perception in older adults. J Am Geriatr Soc, 2011; 59(3): 446–53
6. Friedland DR, Runge-Samuelson C, Baig H, Jensen J: Case-control analysis of cochlear implant performance in elderly patients. Arch Otolaryngol Head Neck Surg, 2010; 136(5): 432–38
7. Martin BA, Tremblay KL, Stapells D: Principles and applications of cortical auditory evoked potentials. In: Burkard RF, Don M, Eggermont JJ (eds.), Auditory Evoked Potentials: Basic principles and clinical applications. Baltimore: Lippincott Williams & Wilkins, 2007; 482–507
8. Henkin Y, Kishon-Rabin L, Gadoth N, Pratt H: Auditory event related potential during phonetic and semantic processing in children. Audiol Neurotol, 2002; 7: 228–39
9. Henkin Y, Kishon Rabin L, Pratt H et al: Linguistic processing in idiopathic generalized epilepsy: an auditory event related potential study. Epilepsia, 2003; 44: 1207–17
10. Henkin Y, Yaar-Soffer Y, Gilat S, Muchnik C: Auditory conflict processing: behavioral and electrophysiological manifestations of the Stroop effect. JAAA, 2010; 21: 474–86
11. Kaplan-Neeman R, Kishon-Rabin L, Henkin Y, Muchnik C: Identification of syllables in noise: electrophysiological and behavioral correlates. JASA, 2006; 120: 926–33
12. Henkin Y, Kishon-Rabin L, Tetin-Schneider S et al: Low resolution electromagnetic tomography (LORETA) in children with cochlear implants: a preliminary report. Int J Audiol, 2004; 43: 48–51
13. Henkin Y, Kileny PR, Hildesheimer M, Kishon-Rabin L: Phonetic processing in children with cochlear implants: an auditory event-related potentials study. Ear Hear, 2008; 29: 239–49
14. Henkin Y, Tetin-Schneider S, Hildesheimer M, Kishon Rabin L: Cortical neural activity underlying speech perception in post-lingual adult cochlear implant recipients. Audiol Neurotol, 2009; 14: 39–53
15. Henkin Y, Givon L, Yaar-Soffer Y, Hildesheimer M: Cortical binaural interaction during speech processing in children with bilateral cochlear implant. Cochlear Implants Inter, 2011; 12: S61–65