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Editorial

Exploring the Neurodynamic Signals of the Deafened Brain: Factors Influencing Cochlear Implant Outcomes

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Deafness alters the neurodynamics of central processing within and across sensory modalities, thereby impacting real-world speech communication. Temporal processing (i.e., processing of acoustic objects that vary over time) constitutes an essential element for understanding speech. Distorted or damaged auditory temporal processing impairs speech-related activity, delaying development in children and increasing listening effort in adults with hearing loss. Even in normal-hearing adults, speech occurring in noisy conditions may result in temporal masking and masking of the target signal itself, requiring temporal segregation between the two for comprehension to be possible. This adversity is a consistent challenge in cochlear implant (CI) users, resulting in impaired speech-in-noise (SiN) perception due to the inherent spectral and temporal limitations of CIs.

Since SiN perception is not sufficiently estimated by the individual hearing threshold and varies among CI users, individual central auditory processing is suggested to be more closely associated with variability in SiN perception [1]. Han et al. [2] investigated the relationship between behavioral and electrophysiological measures of SiN perception. Using varied voice onset times, they observed that difficulties in SiN were revealed even in good performers, particularly in words with low familiarity. Moreover, N1/P2 cortical auditory evoked potential latencies increased with noise masking, and the electrophysiological component P2 (rather than N1) was suggested to better reflect SiN in CI users. They concluded that active learners have more benefits from CI, as evidenced by shortened P2 latencies. We may not preclude the possibility that this finding is affected by age, since age differences were not systematically controlled, but the meaningful contribution of this study lies in its objective quantification of cortical auditory activity in response to temporal features, helping gauge the patient's current status and providing guidance for any adjustments or need for alternate interventions.

Recently, factors beyond central auditory processing were reported to influence CI outcomes. When auditory input is decreased and/or degraded, auditory cortical areas may be repurposed by other intact modalities, such as the visual and somatosensory modalities. This process, referred to as cross-modal neuroplasticity, may contribute to the outcomes of CIs. In congenitally and profoundly deaf adults, Scott et al. [3] observed reliably increased responses to visual stimulation in Heschl's gyrus regions, the site of the primary auditory cortex, unlike matched hearing adults, using functional magnetic resonance imaging. More recently, earlier and larger cortical visual and somatosensory evoked potentials and the corresponding activation of auditory cortical areas by visual [4] and somatosensory [5] stimuli were observed in pediatric CI users compared to age-matched controls, indicative of cross-modal reorganization. These cross-modal changes were negatively correlated with SiN perception, in that children who showed more cross-modal plasticity also had more difficulty with SiN, suggesting that cross-modal reorganization is an important factor influencing CI outcomes. This was confirmed by a recent case study demonstrating that a highly plastic auditory cortex and consequent reversal of cross-modal reorganization after CI were associated with good outcomes in a single-sided deaf child, demonstrating the clinical feasibility of these techniques [6].

Using newer imaging methods such as functional near-infrared spectroscopy, Anderson et al. [7] observed increased visual activation in response to sound in poor CI performers, suggesting that the degree of preoperational visual activation may function as a predictive factor of CI outcomes. Thus, while re-organization during deafness appears to limit speech perception outcomes with a CI, a recent study showed a positive relationship between cross-modal activation and audiovisual integration strength for CI users, suggesting that the associated benefits in face recognition and lip-reading may be useful in real-world communication [8].

Various neurodynamic cues in the deafened brain are being investigated in terms of CI outcome measures, with potential predictive roles and the possibility to serve as a guide to future rehabilitation. Since advances in CI technology have already enabled phonetic-level segregation, future efforts should focus on aural rehabilitation tailored towards understanding and utilizing multi-sensory cortical processing to optimize CI outcomes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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