Deconvolution for flexible recording of transient evoked potentials

Valderrama JT[1,2,3,*], de la Torre A[1,2], Alvarez IM[1,2], Segura JC[1,2], Vargas JL[4]

[1] Department of Signal Theory, Telematics and Communications, University of Granada, Granada, Spain
[2] Research Centre for Information and Communications Technologies, University of Granada, Granada, Spain
[3] Department of Linguistics, Macquarie University, Sydney, Australia
[4] ENT Service, San Cecilio University Hospital, Granada, Spain
* Presenting author

Keywords: deconvolution, latency-dependent filtering, full-range auditory evoked potentials, compact representation.

Background: Traditionally, to enhance the signal-to-noise ratio of auditory evoked potentials (AEPs), electroencephalogram segments are averaged. However, this requires an inter-stimulus interval longer than the duration of the AEP to prevent contamination from neighbouring responses. On the other hand, *deconvolution* algorithms allow for the recording of transient overlapping AEPs. Here we present the fundamentals and the research potential of a deconvolution method based on matrix processing.

Methods: *Iterative Randomised Stimulation and Averaging* (IRSA) consists of an iterative process in which the AEP is estimated after suppressing the interference from adjacent responses [1]. A matrix-based formulation of this method [2] significantly reduced the high computational cost of its predecessor and demonstrated that the algorithm converges onto a least-squares (LS) deconvolution [3]. In addition, the matrix implementation of this method allowed for the representation of AEPs in a lower-dimension vector space compared to the *time* or *frequency* domains typically used for AEPs [4], and we showed that deconvolution in this reduced space is feasible and appropriate [5].

Results: Overcoming the maximum-rate limitation of the averaging method enabled the design of an experiment which was appropriate to characterise both short-term and long-term adaptation mechanisms for the first time in humans [6]. Further, our research showed that projecting the AEP onto a reduced vector space and projecting back onto the original time domain provided a latency-dependent filtering that facilitated a compact representation of AEPs from cochlea to cortex [4]. Performing deconvolution in the reduced space leads to an optimal least squares estimation of the AEP [5].

Conclusion: Deconvolution algorithms overcome the maximum stimulus presentation rate limitation imposed by averaging methods, thus providing greater flexibility in designing AEP experiments. Representing AEPs in domains different than time or frequency represents a new avenue for AEP research, with numerous potential applications. For instance, the latency-dependent filtering method enables a compact representation of AEPs from the entire auditory pathway—a natural representation that removes the traditional discontinuities between peripherical, middle and central AEPs. The methods have demonstrated their robustness through simulations, and supplementary materials such as toolboxes are available to facilitate their implementation.

References:

[1] Valderrama J, de la Torre A, Alvarez I, Segura JC, Thornton ARD (2014). Auditory brainstem and middle latency responses recorded at fast rates with randomized stimulation. Journal of the Acoustical Society of America 136, 3233-3248. https://doi.org/10.1121/1.4900832

[2] de la Torre A, Valderrama J, Segura JC, Alvarez I (2019). Matrix-based formulation of the iterative randomized stimulation and averaging method for recording evoked potentials. Journal of the Acoustical Society of America 146, 4545-4556. https://doi.org/10.1121/1.5139639

[3] Bardy F, van Dun B, Dillon H, Cowan R (2014). Least-squares (LS) deconvolution of a series of overlapping cortical auditory evoked potentials: A simulation and experimental study. Journal of Neural Engineering 11, 046016, http://doi.org/10.1088/1741-2560/11/4/046016

[4] de la Torre A, Valderrama J, Alvarez I, Segura JC (2020). Latency-dependent filtering and compact representation of the complete auditory pathway response. Journal of the Acoustical Society of America 60, 96-103. https://doi.org/10.1121/10.0001673.

[5] de la Torre A, Valderrama J, Segura JC, Alvarez I, Garcia-Miranda J (2022). Subspace-constrained deconvolution of auditory evoked potentials. Journal of the Acoustical Society of America 151, 3745-3757. https://doi.org/10.1121/10.0011423

[6] Valderrama J, de la Torre A, Alvarez I, Segura JC, Thornton ARD, Sainz M, Vargas JL (2014). A study of adaptation mechanisms base don ABR recorded at high stimulation rate. Clinical Neurophysiology 125, 805-813. https://doi.org/10.1016/j.clinph.2013.06.190

e-mail corresponding author: jvalderrama@ugr.es