Emerging Neurophysiological Methods for Assessing Relevant Hearing Functions

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Audiology Australia Online Conference
24—25 October 2024

UNIVERSIDAD DE GRANADA

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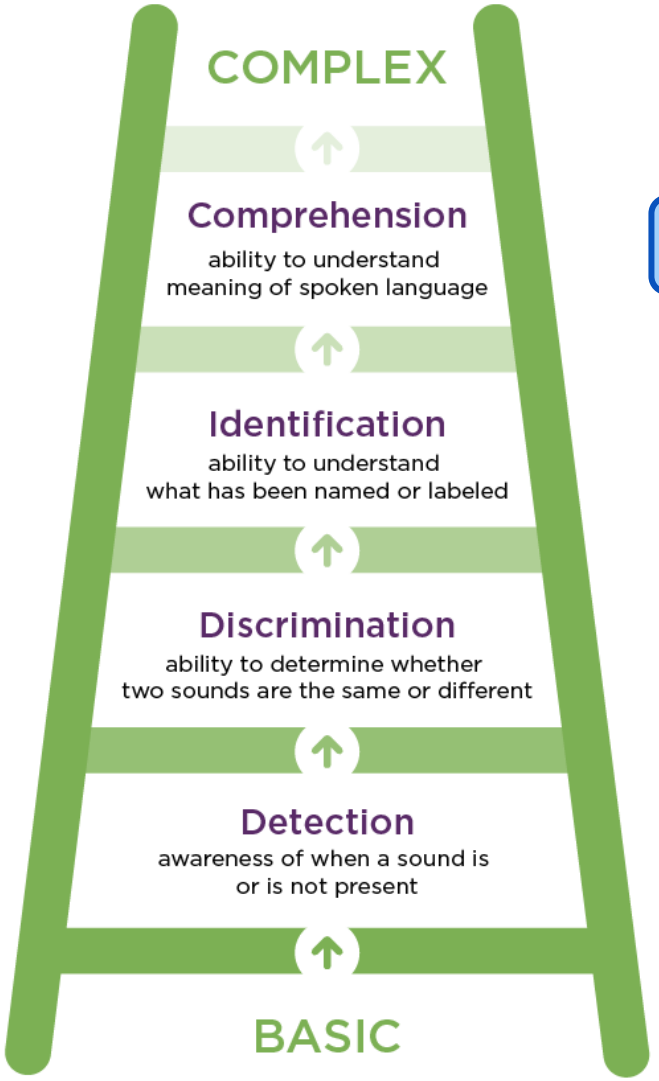
Structure. *The Erber's auditory hierarchy*



Cortical response to natural speech

N400

P300

Acoustic Change Complex (ACC)

ABR

ASSR

MLR

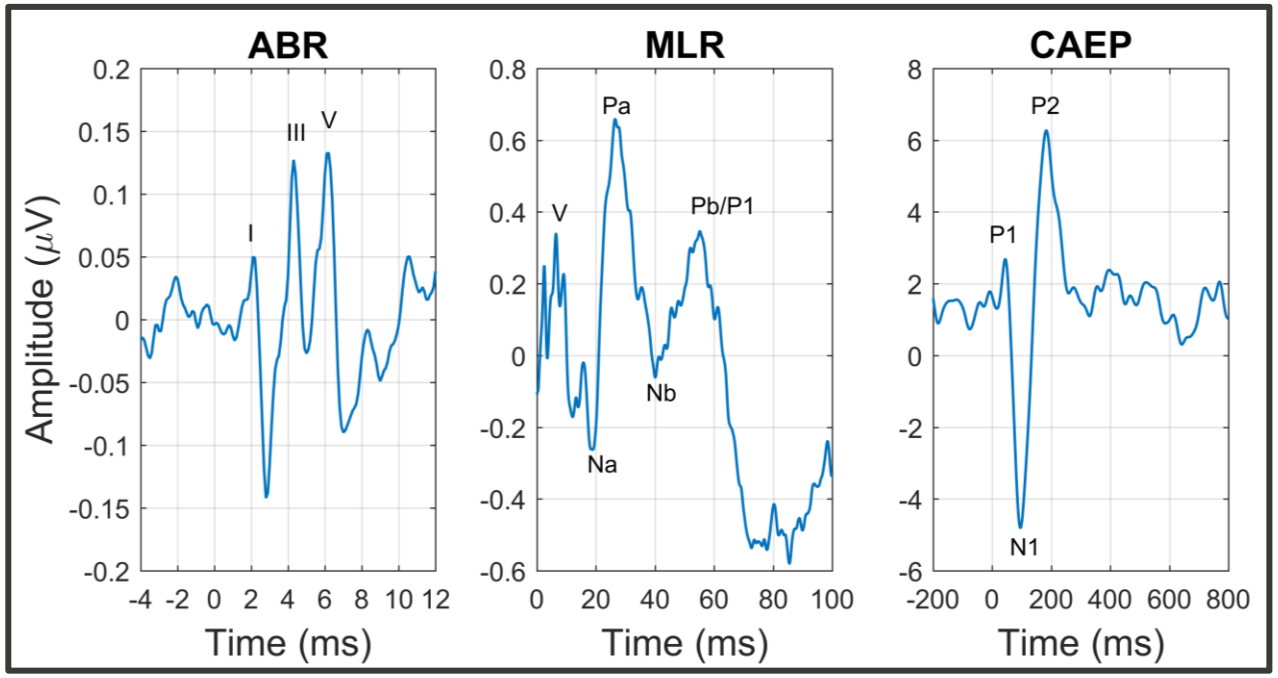
CAEP

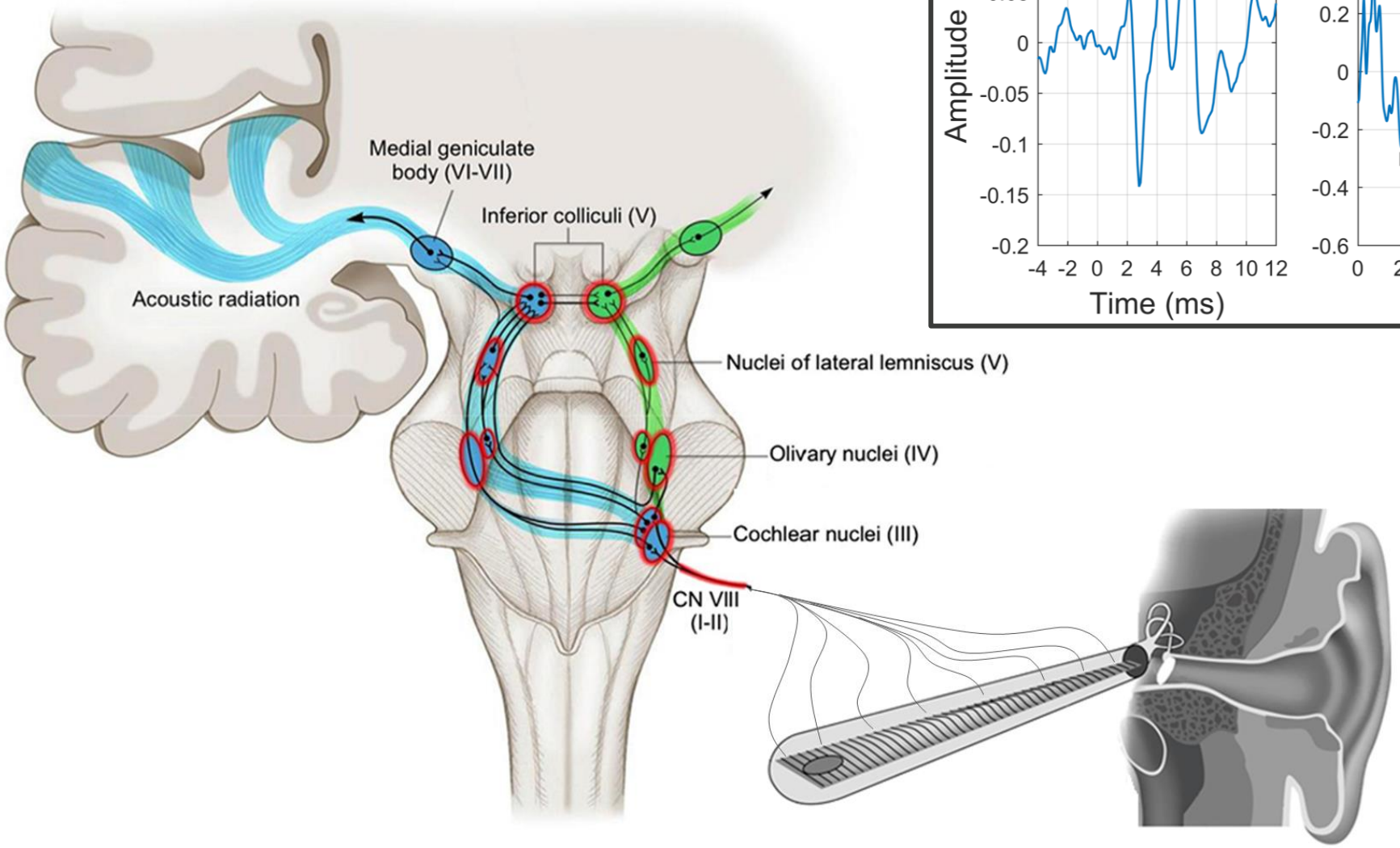
Full-range AEPs

Standard AEPs

- ✓ *ABR*
- ✓ *MLR*
- ✓ *CAEP*
- ✓ *ASSR*

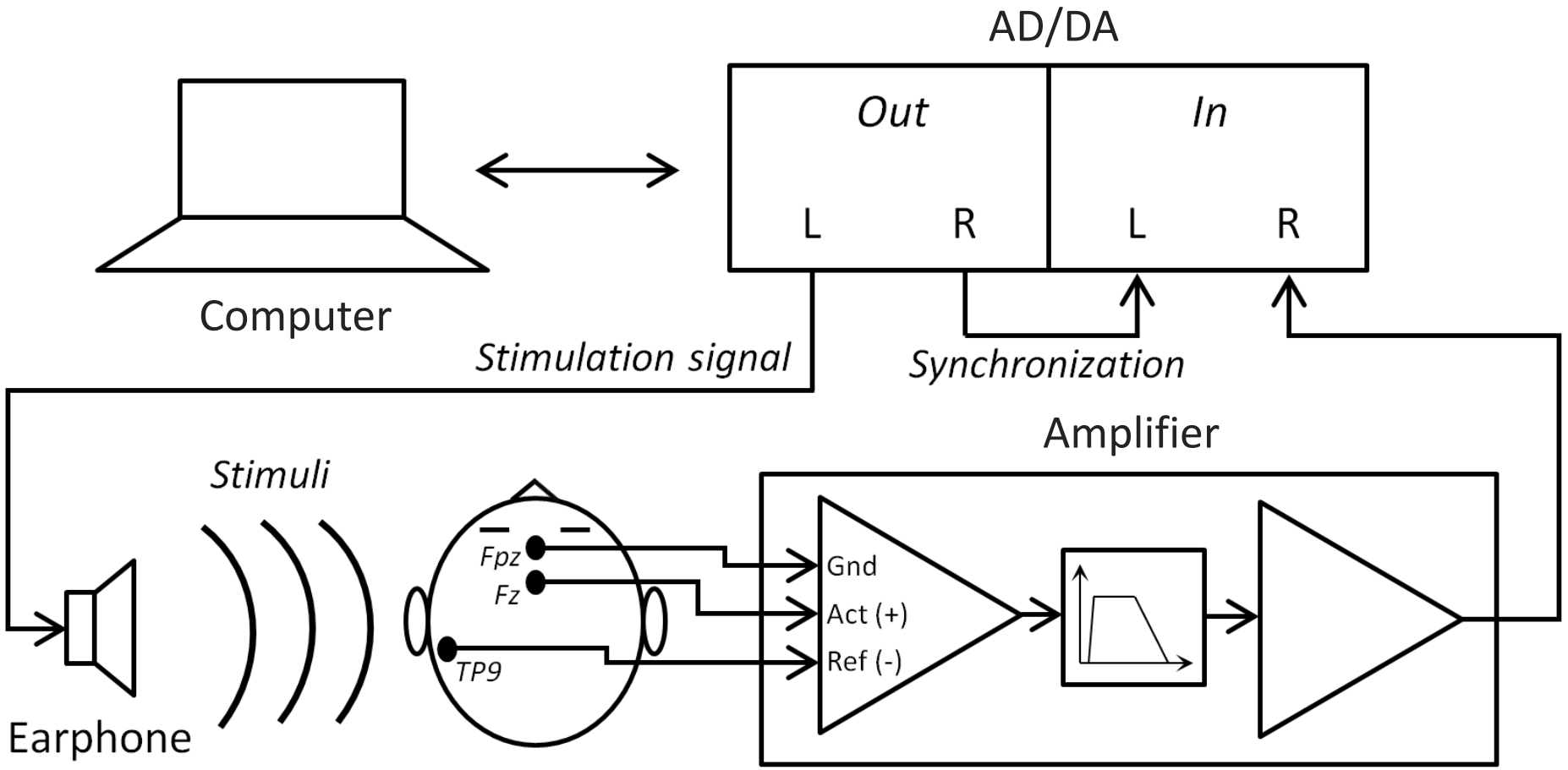
Standard AEPs





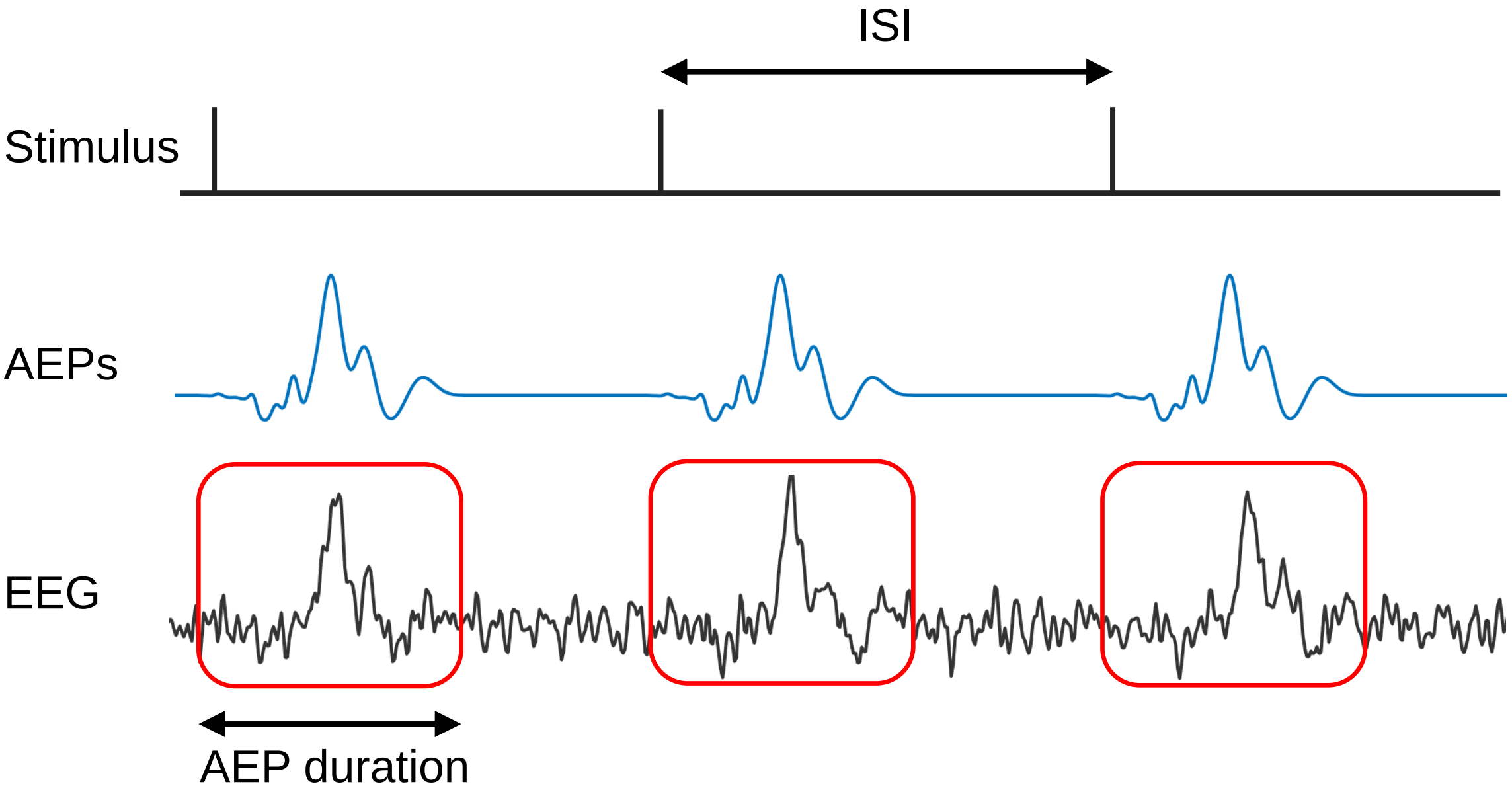
Recording process

Recording process. *Hardware* elements

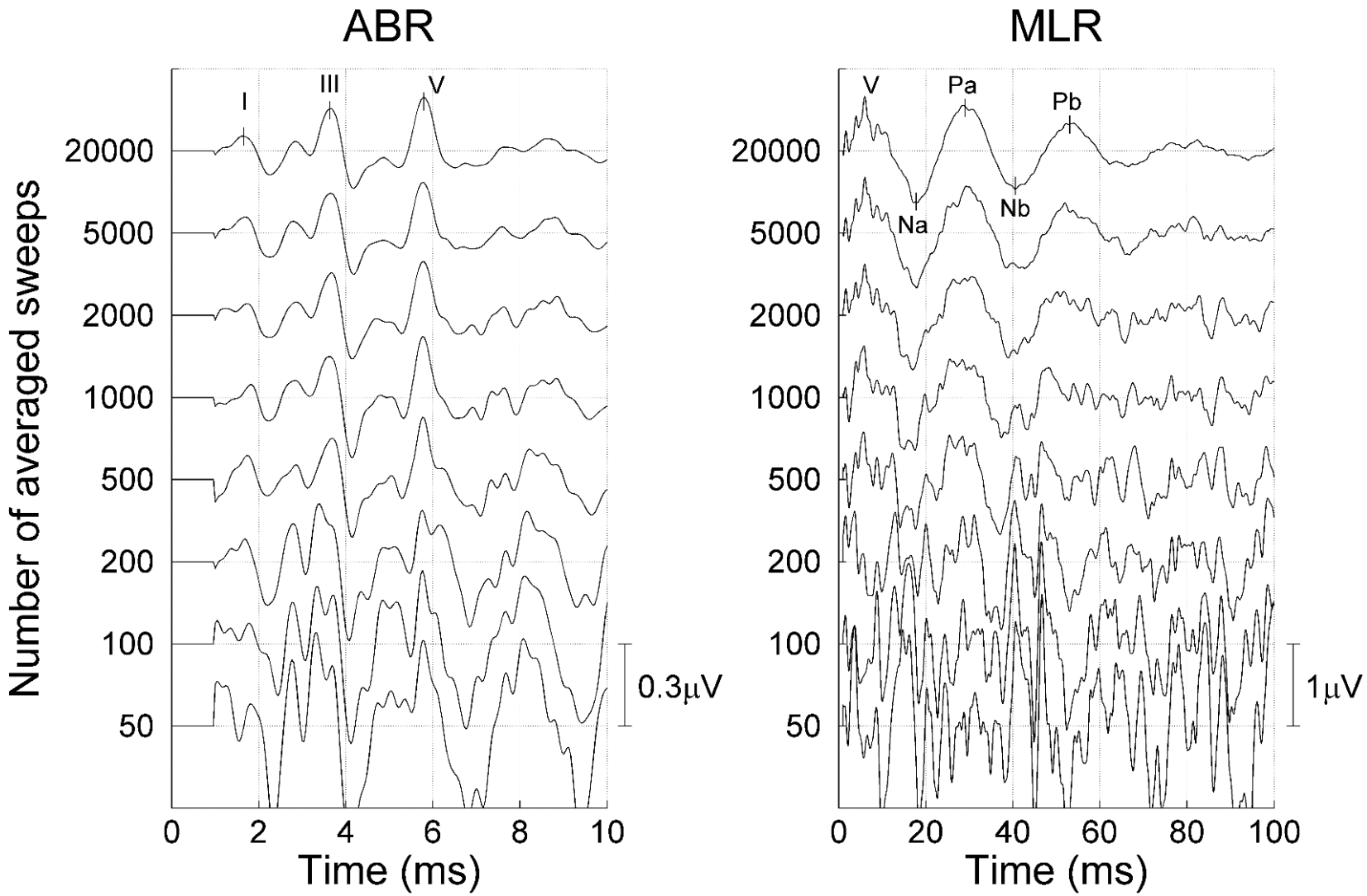


Valderrama et al. (2014), Biomedical Engineering

Recording process. *Software* processing

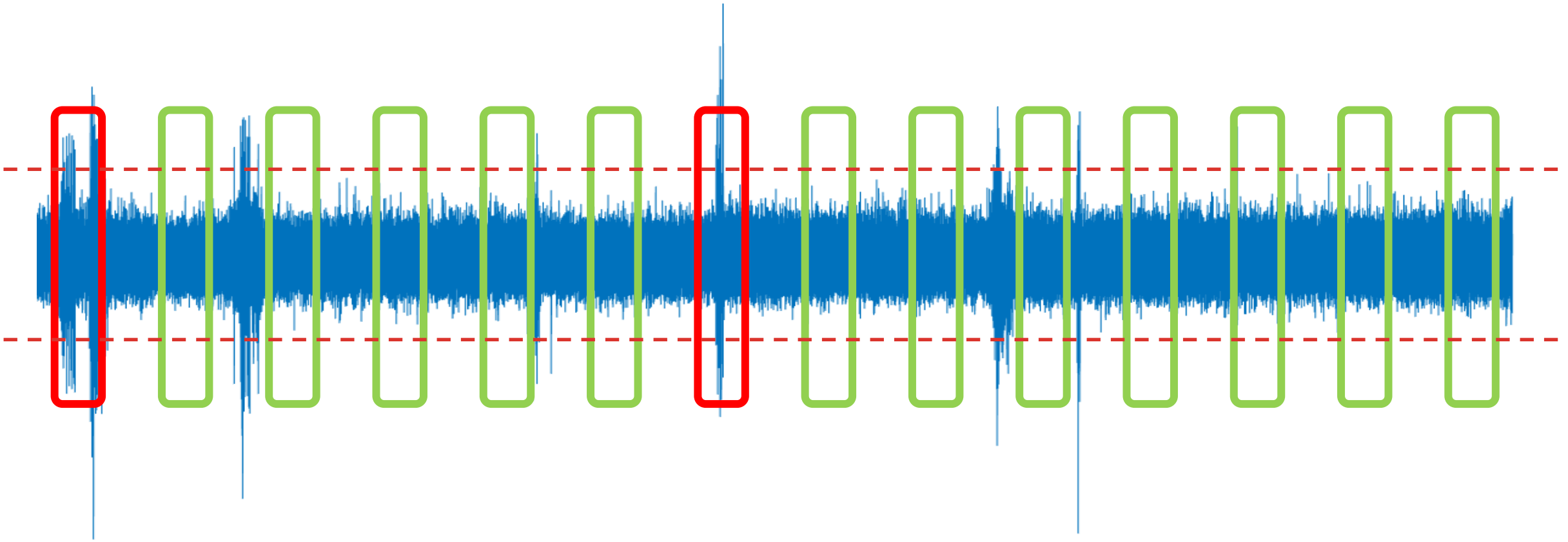


A compromise between Quality and Time



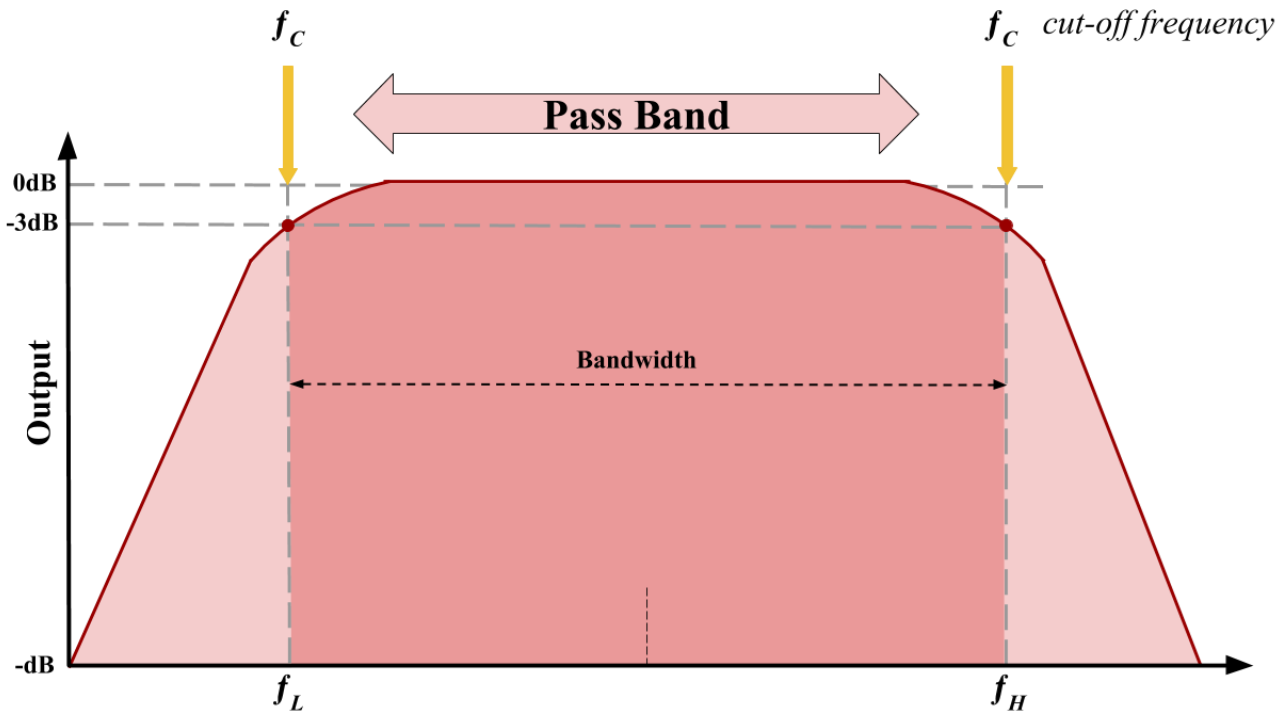
Valderrama et al. (2014), Biomedical Engineering

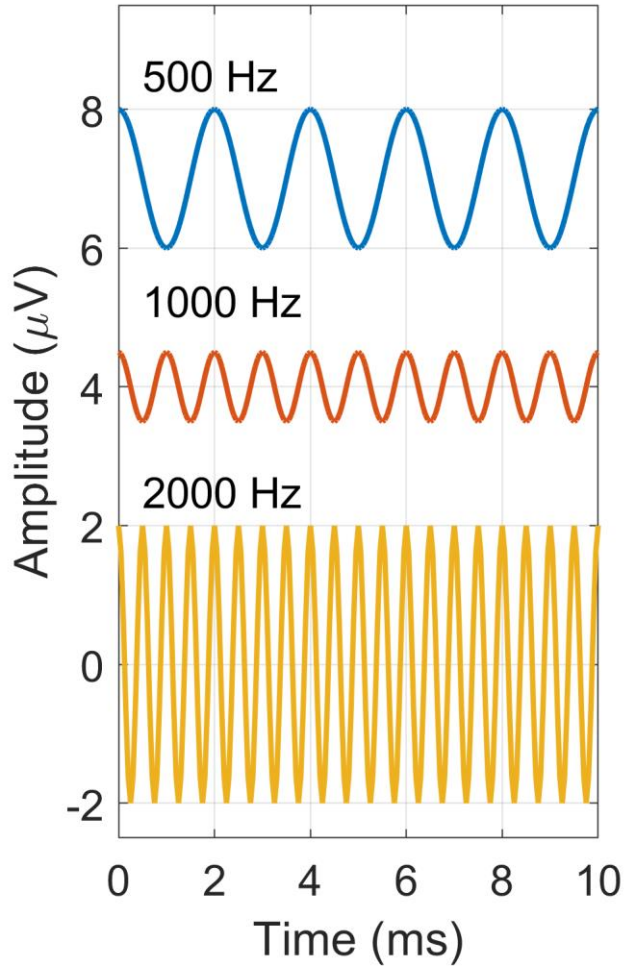
Strategies to improve quality. *Artifact rejection*



Artifact rejection prevents contaminated epochs to be included in the average

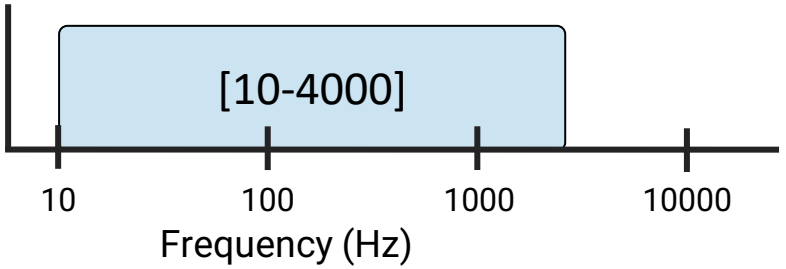
Strategies to improve quality. *Filtering*

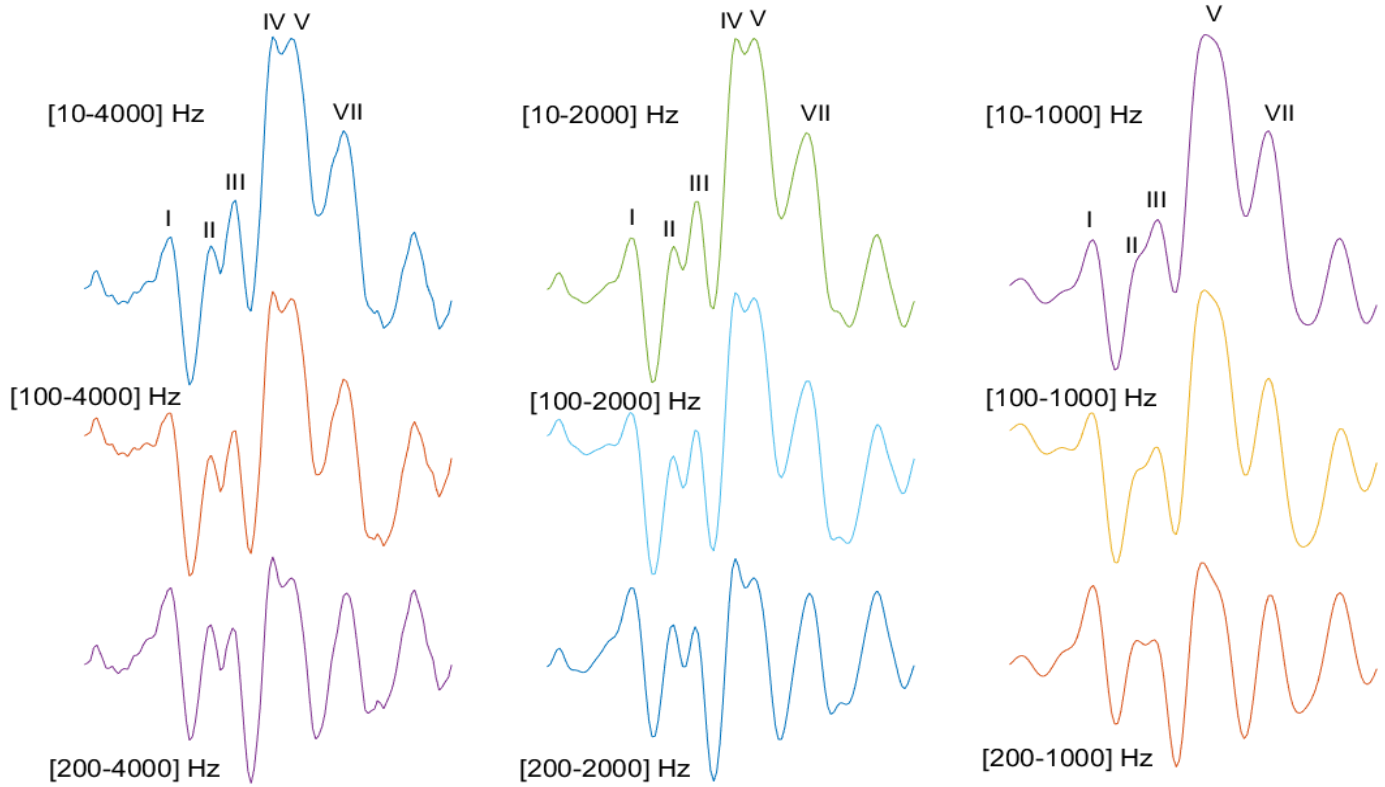




<u>Filtering reduces noise</u> by attenuating frequency components outside the signal of interest (our AEPs)

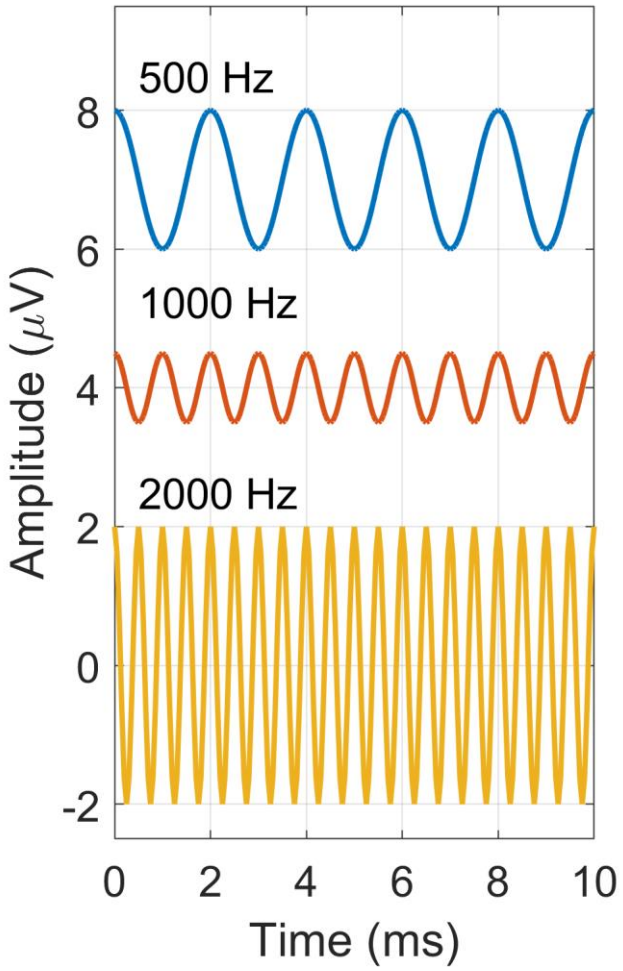
Strategies to improve quality. *Filtering*

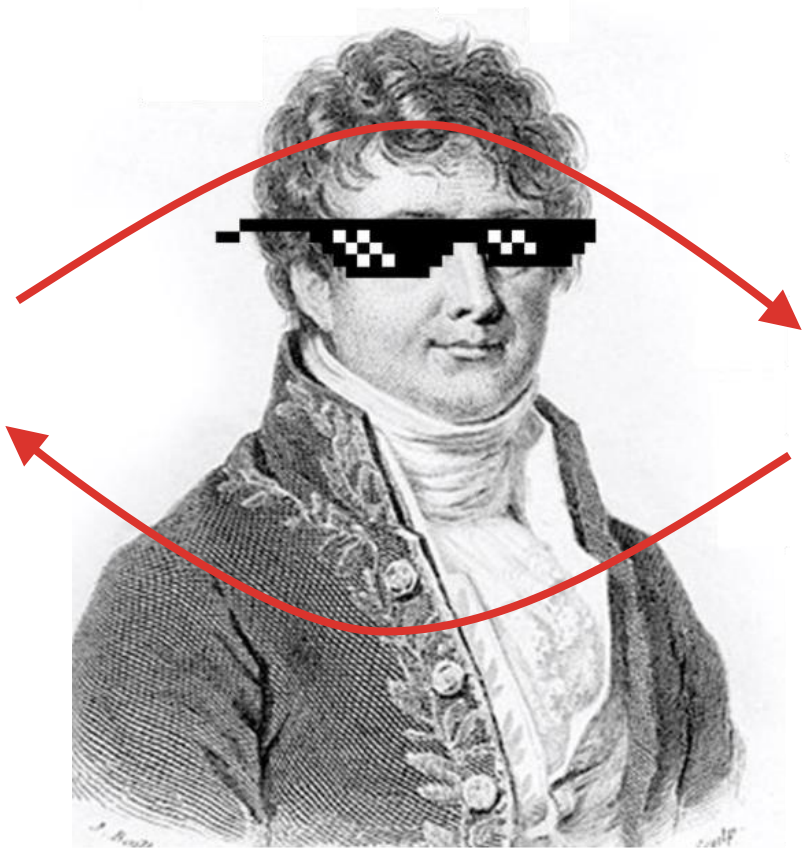




Time vs Frequency analysis

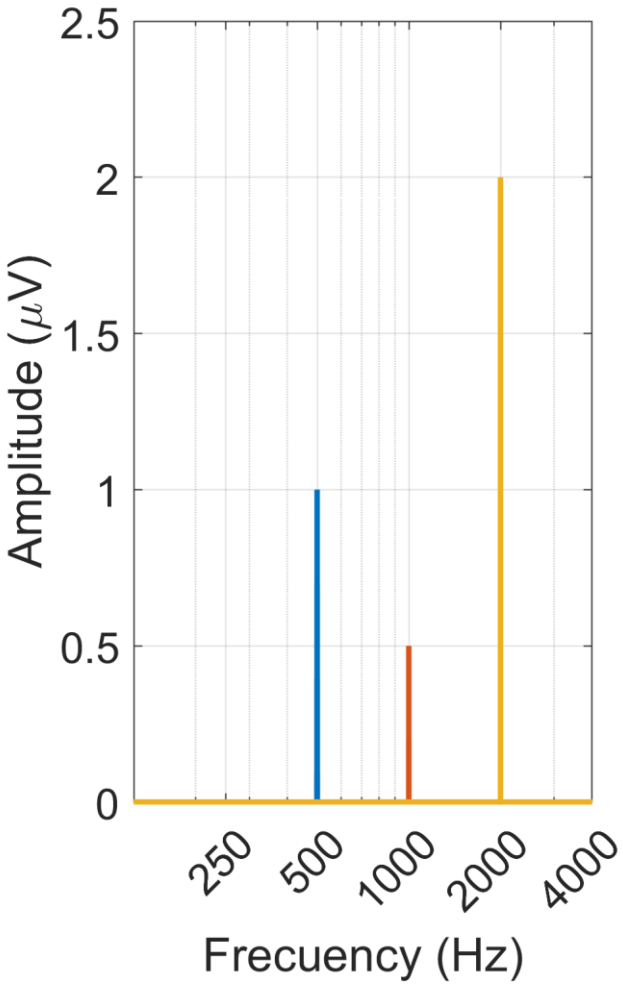
Time domain



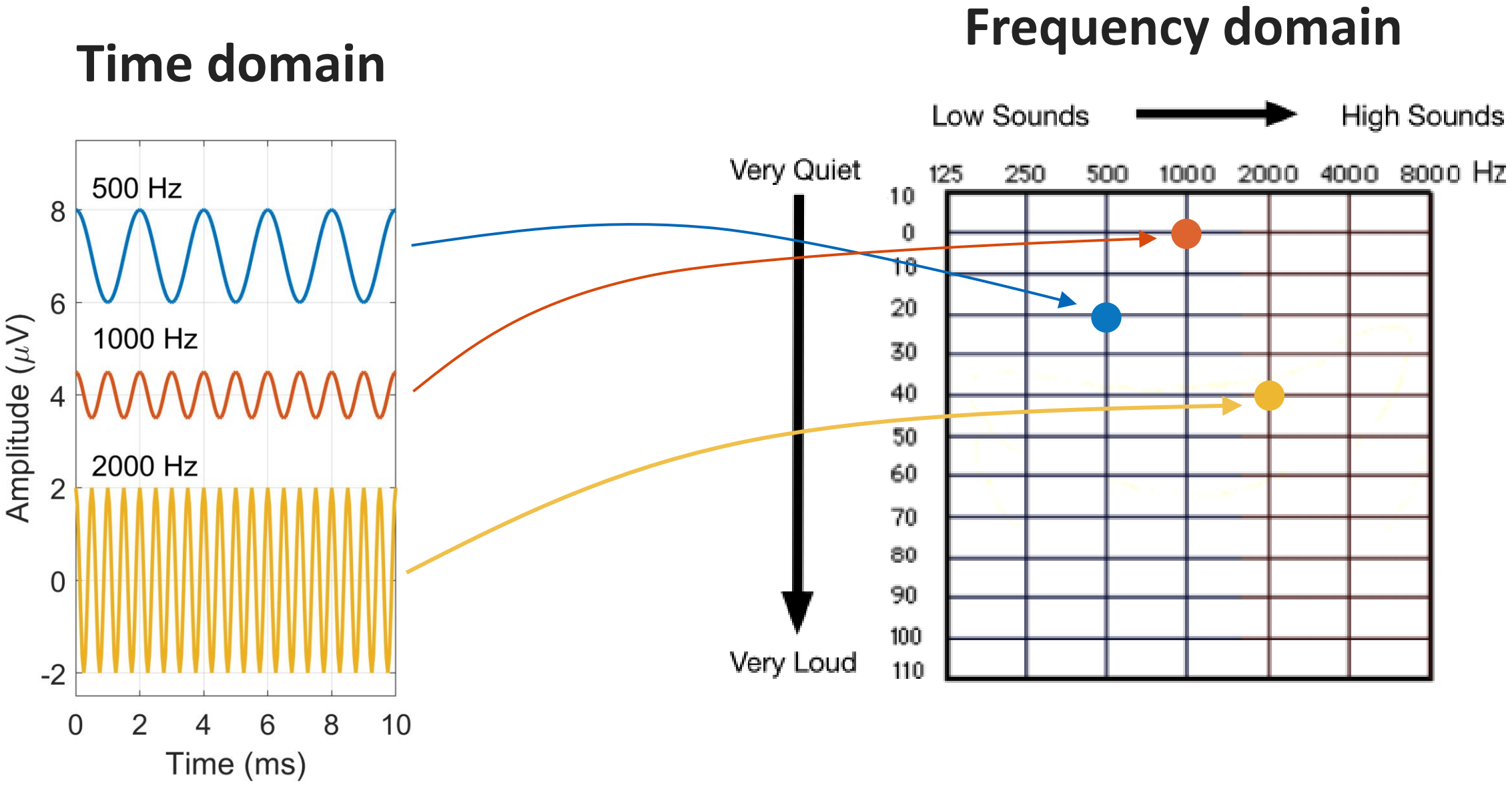


Fourier Transform

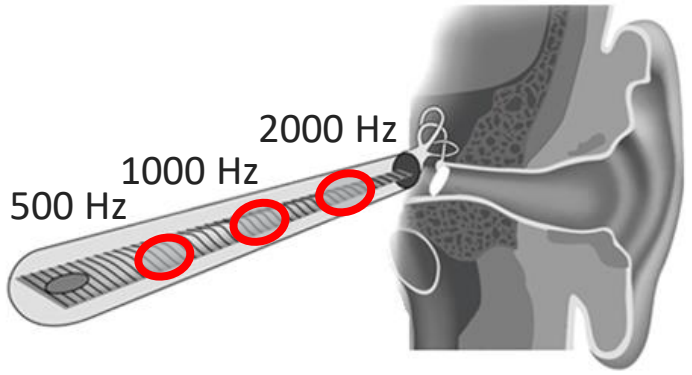
Frequency domain

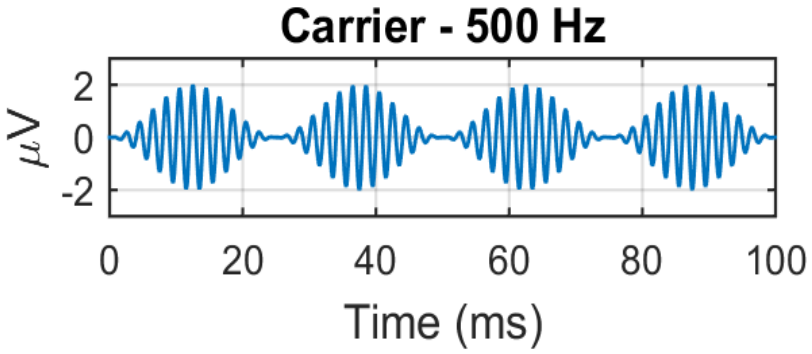


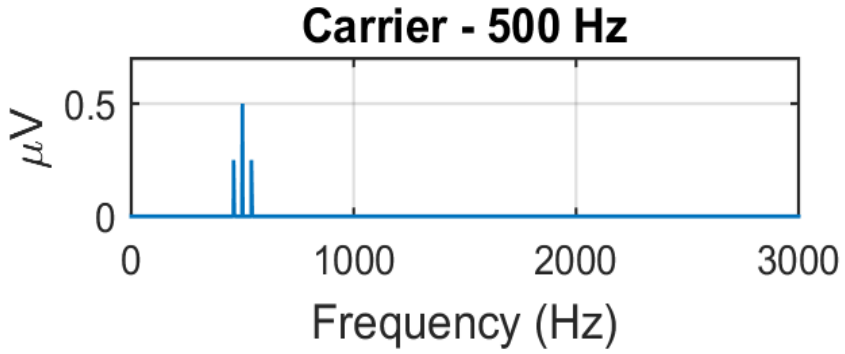
The Fourier Transform in the clinic

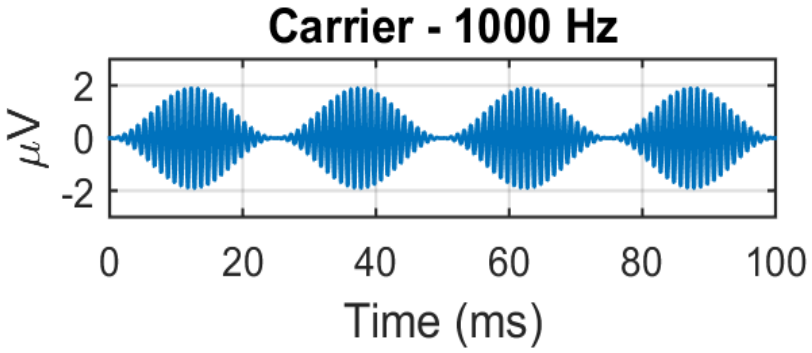


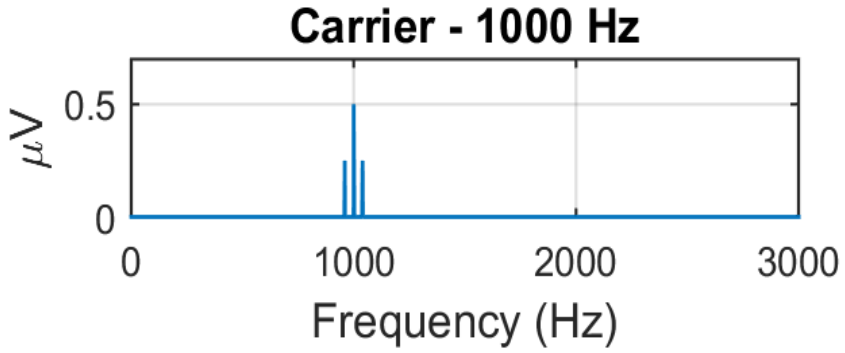
40 Hz ASSR. *Stimuli*

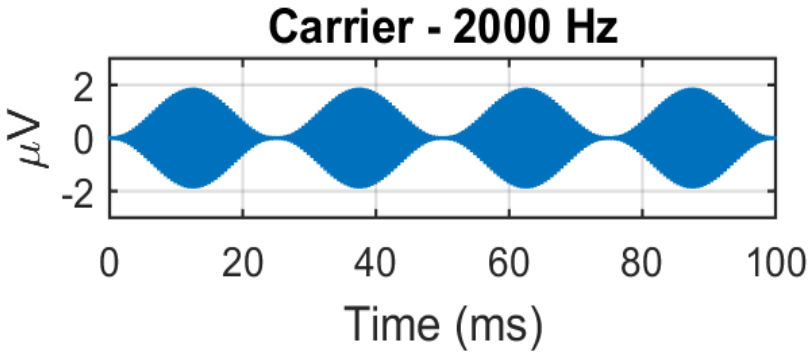


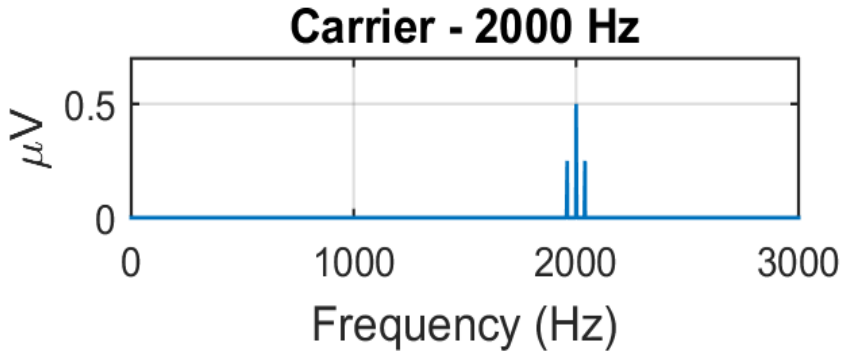






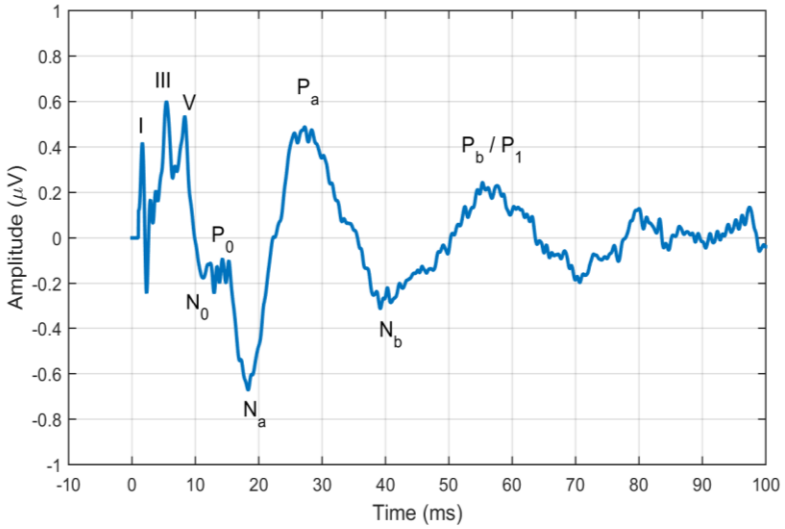


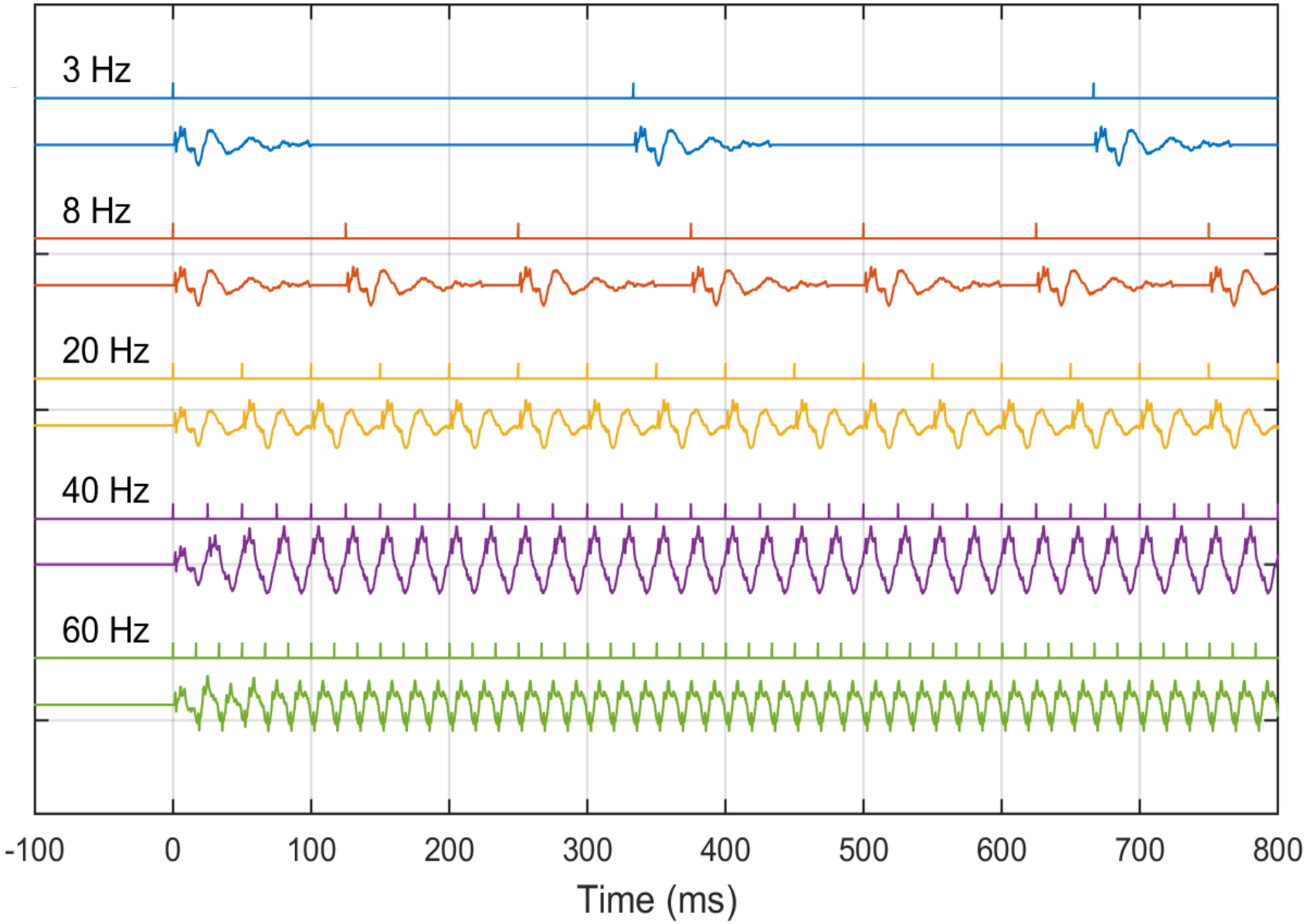




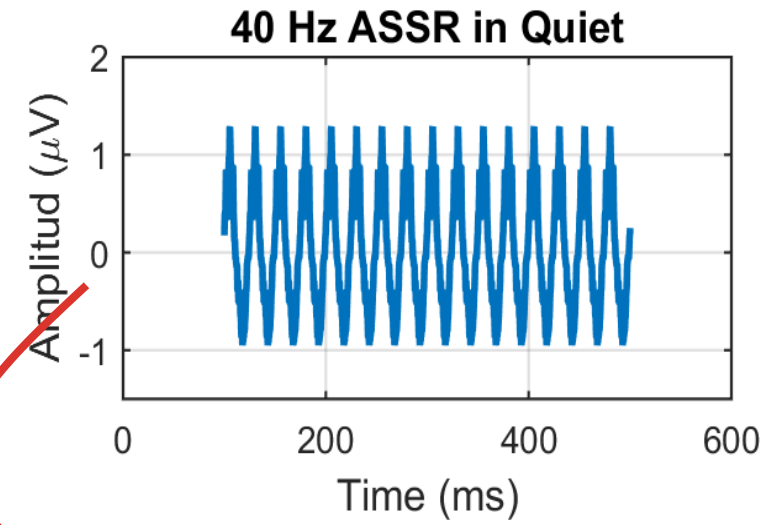
Why 40 Hz?

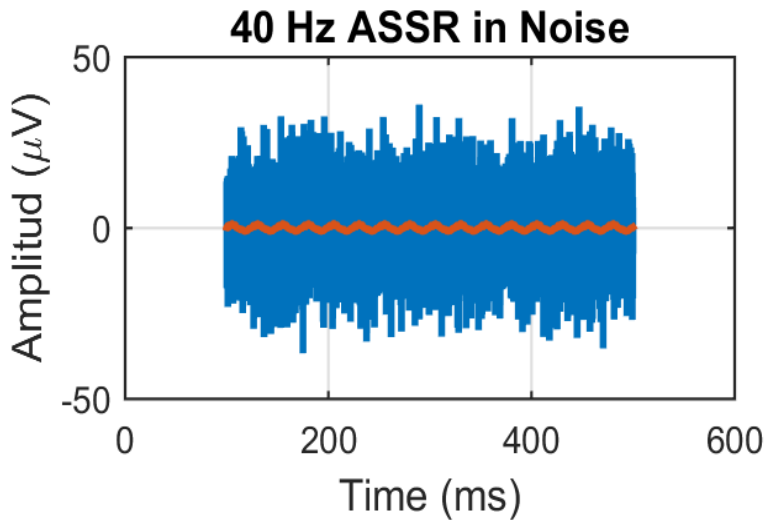
Middle Latency Response (MLR)

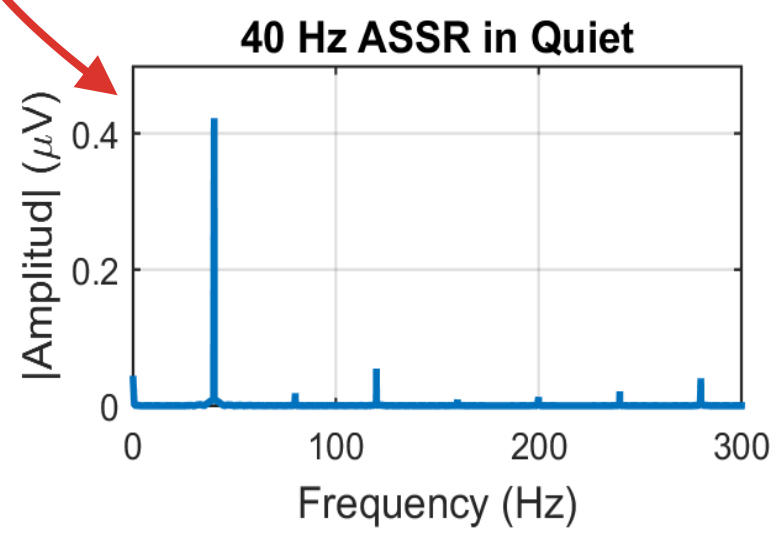


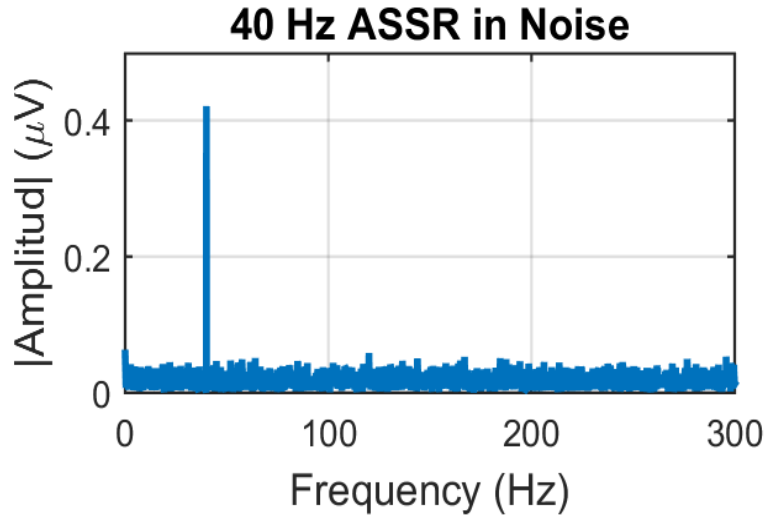


40 Hz ASSR. *Response analysis*

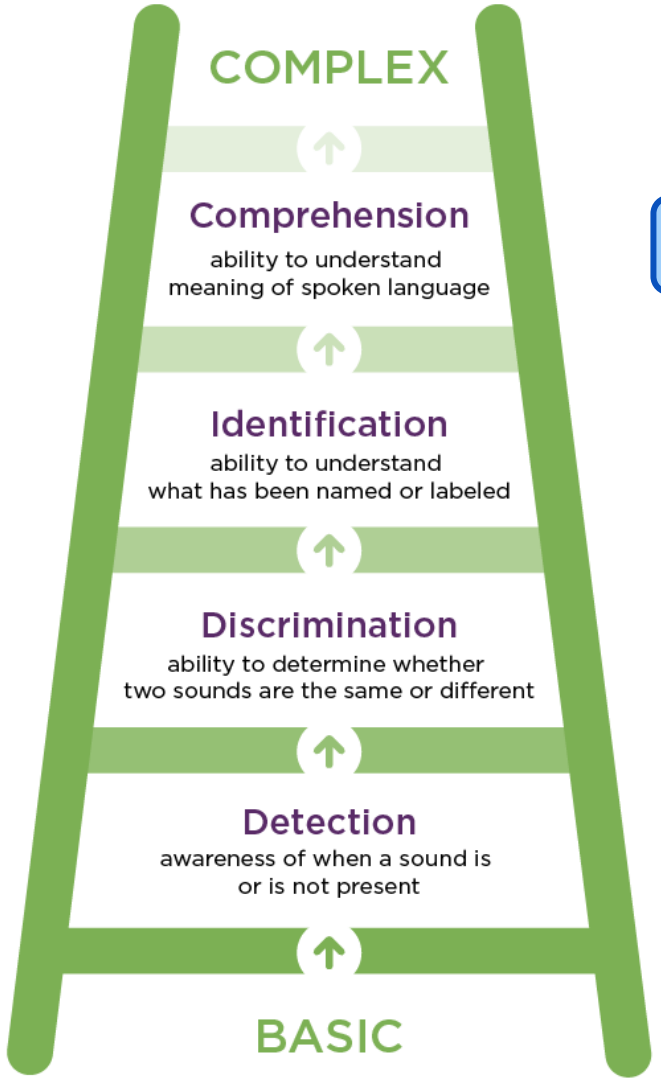








The Erber's auditory hierarchy



Cortical response to natural speech

N400

P300

Acoustic Change Complex (ACC)

ABR

ASSR

MLR

CAEP

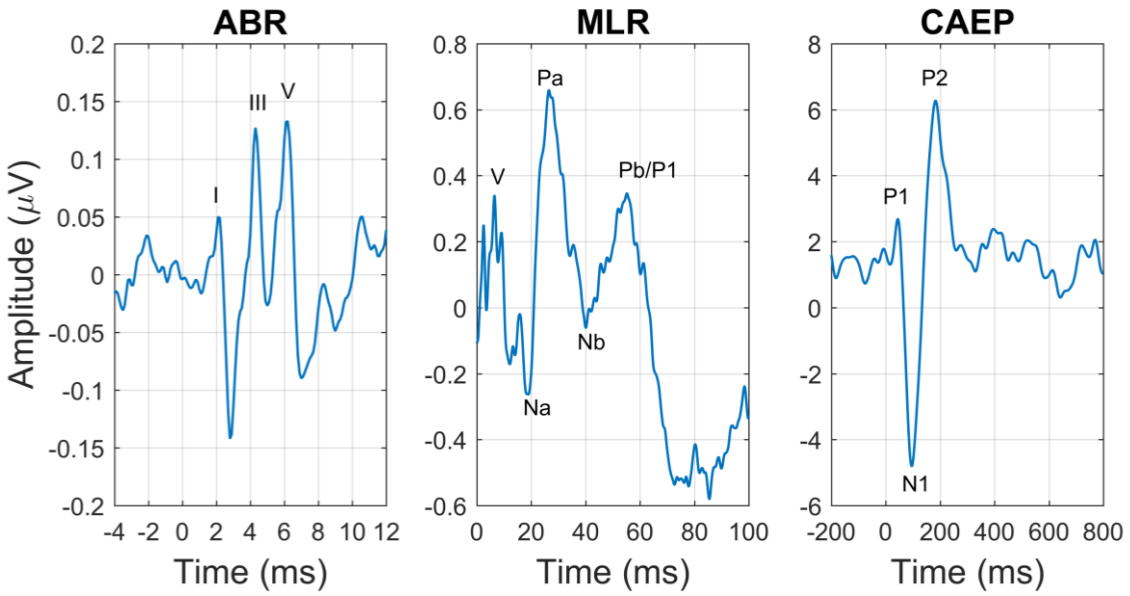
Full-range AEPs

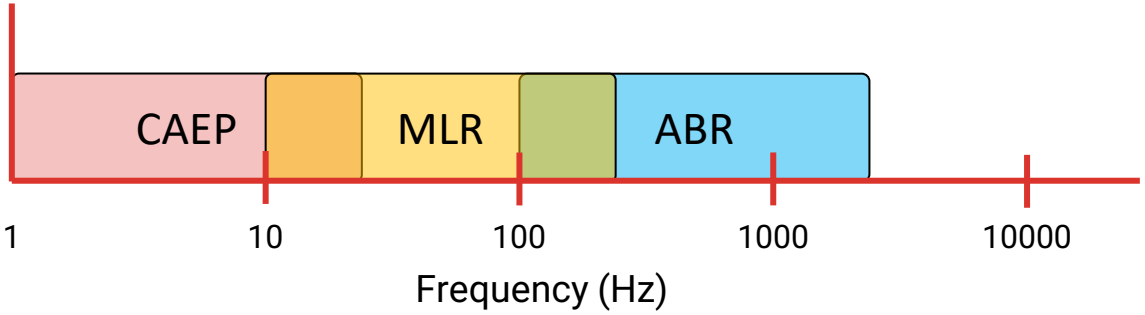
Detection

- ✓ *Full-range AEPs*

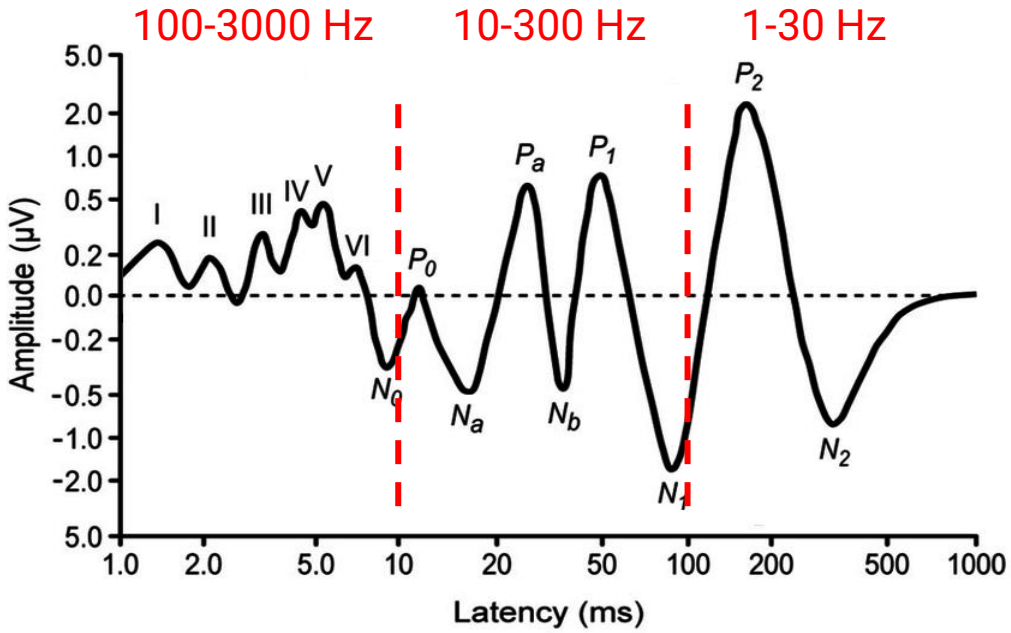
Conventional vs Desired AEPs

Conventional AEPs





Desired AEPs



Latency-dependent filtering

JASA ARTICLE

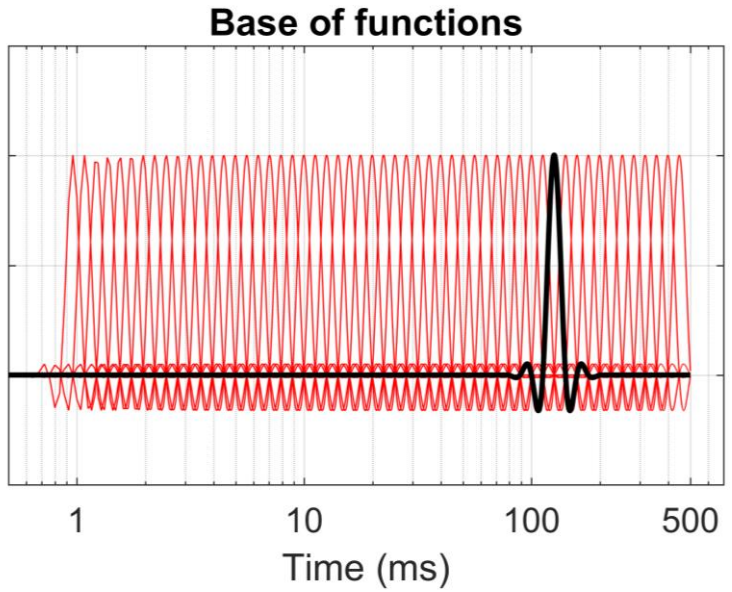
Latency-dependent filtering and compact representation of the complete auditory pathway response

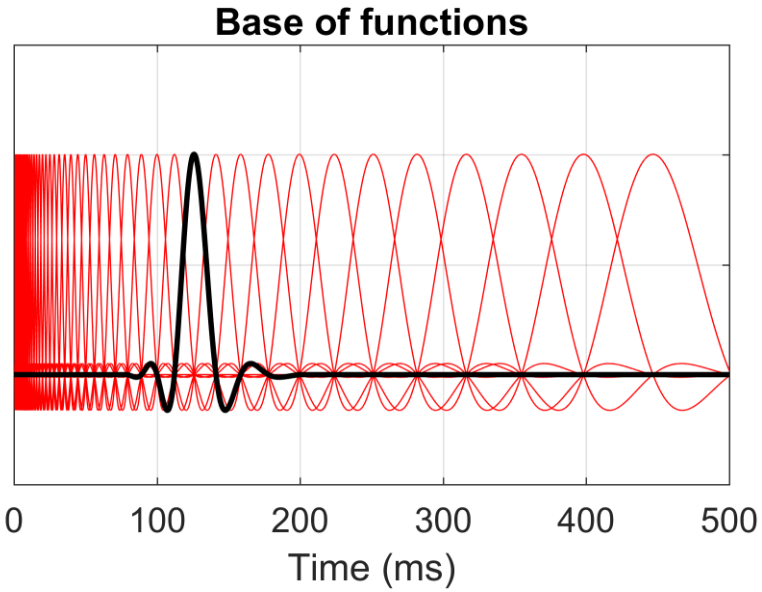
Angel de la Torre,[1,a)] Joaquin T. Valderrama,[2,b)] Jose C. Segura,[1,c)] and Isaac M. Alvarez[1,d)]
[1]*Department of Signal Theory, Telematics, and Communications, University of Granada, Granada, Spain*
[2]*National Acoustic Laboratories, Sydney, Australia*

ABSTRACT:
Auditory evoked potentials (AEPs) include the auditory brainstem response (ABR), middle latency response (MLR), and cortical auditory evoked potentials (CAEPs), each one covering a specific latency range and frequency band. For this reason, ABR, MLR, and CAEP are usually recorded separately using different protocols. This article proposes a procedure providing a latency-dependent filtering and down-sampling of the AEP responses. This way, each AEP component is appropriately filtered, according to its latency, and the complete auditory pathway response is conveniently represented (with the minimum number of samples, i.e., without unnecessary redundancies). The compact representation of the complete response facilitates a comprehensive analysis of the evoked potentials (keeping the natural continuity related to the neural activity transmission along the auditory pathway), which provides a new perspective in the design and analysis of AEP experiments. Additionally, the proposed compact representation reduces the storage or transmission requirements when large databases are manipulated for clinical or research purposes. The analysis of the AEP responses shows that a compact representation with 40 samples/decade (around 120 samples) is enough for accurately representing the response of the complete auditory pathway and provides appropriate latency-dependent filtering. MATLAB/Octave code implementing the proposed procedure is included in the supplementary materials. https://doi.org/10.1121/10.0001673

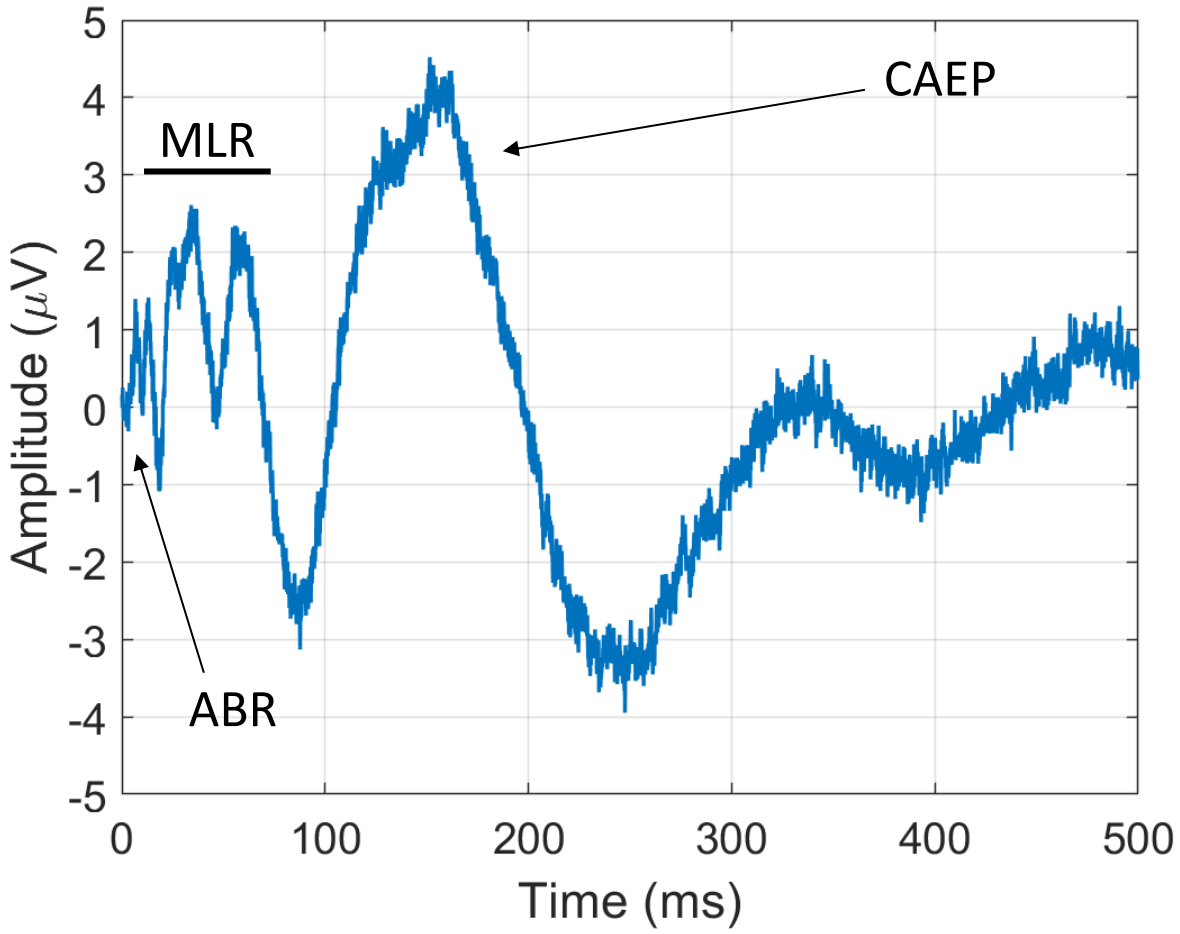
(Received 29 December 2019; revised 6 July 2020; accepted 14 July 2020; published online 4 August 2020)

[Editor: Sarah Verhulst] Pages: 599–613





Full-range AEP example



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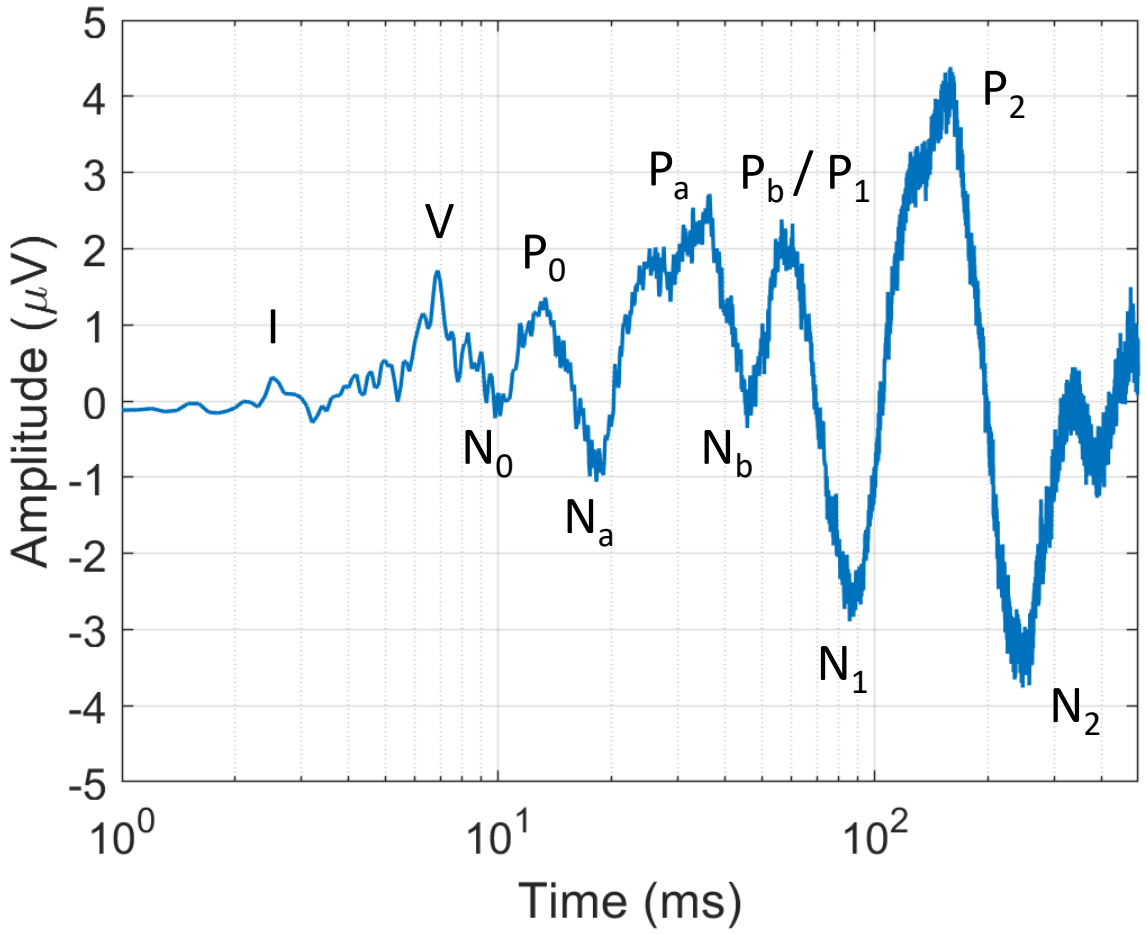
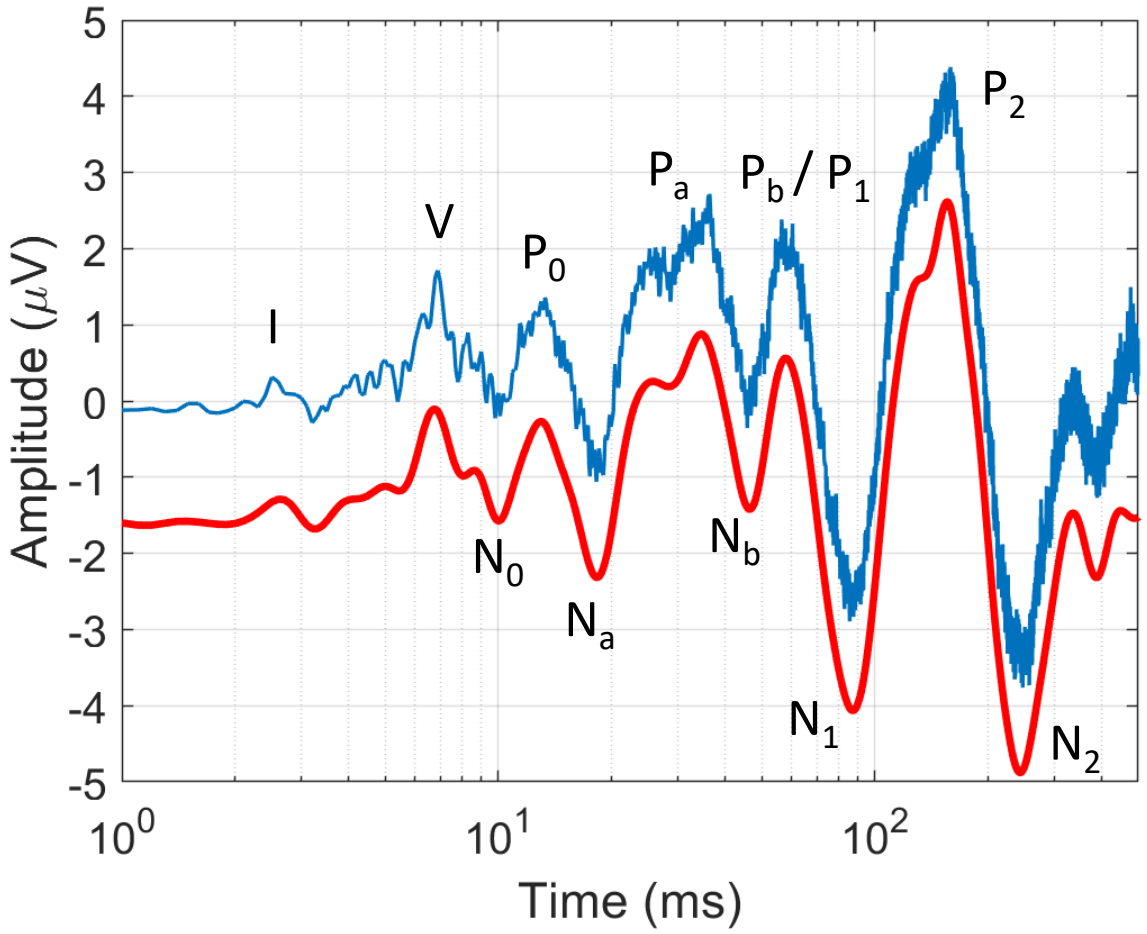
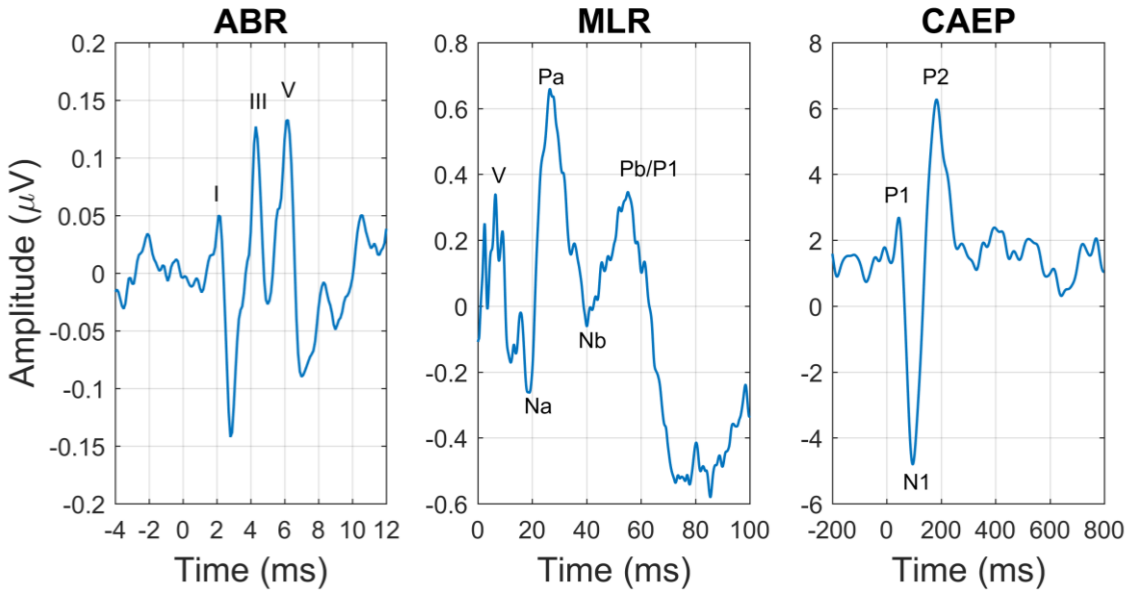


Full-range AEP example

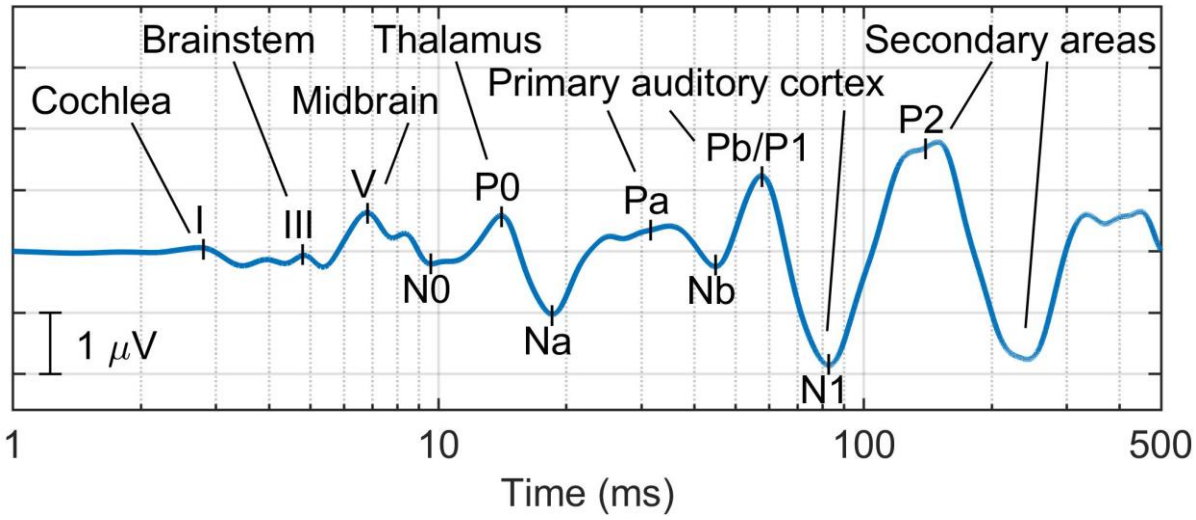


Full-range vs Conventional AEPs

Conventional AEPs



Full-range AEP

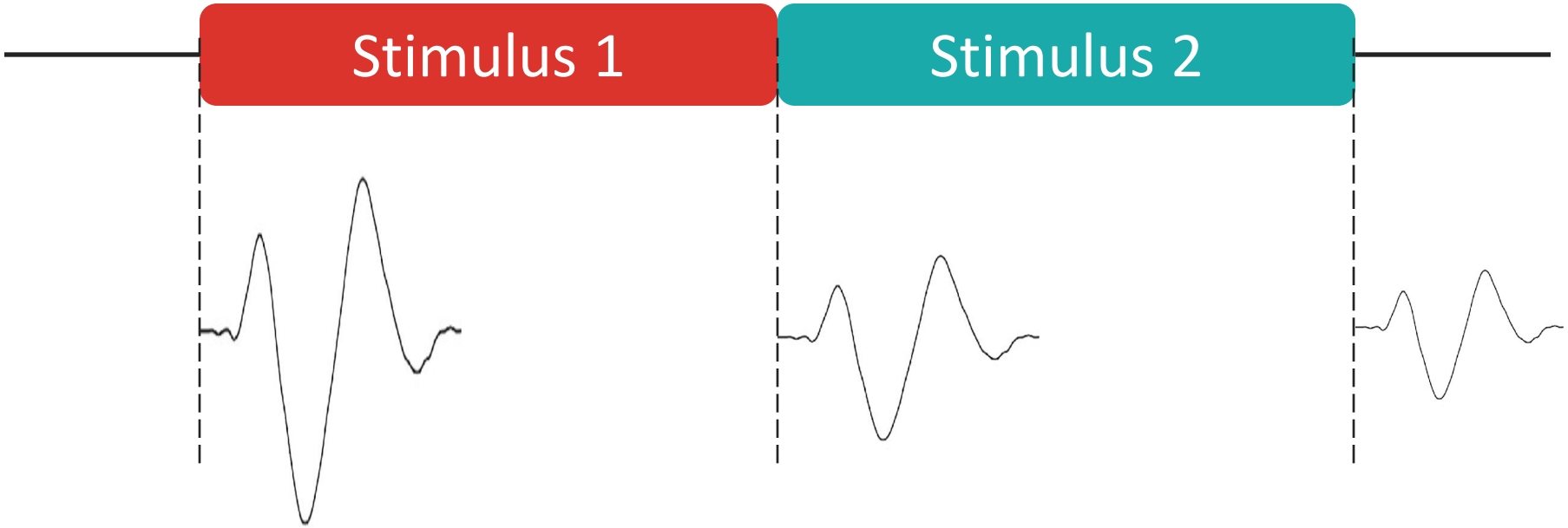


Valderrama et al. (2022), Frontiers in Neuroscience

Discrimination

- ✓ ***Acoustic Change Complex (ACC)***
  - ***Localisation***
  - ***Binaural hearing***

Acoustic Change Complex (ACC)



Onset CAEP

Detection

ACC

DISCRIMINATION

Offset CAEP

Detection

ACC applications. *Localisation*

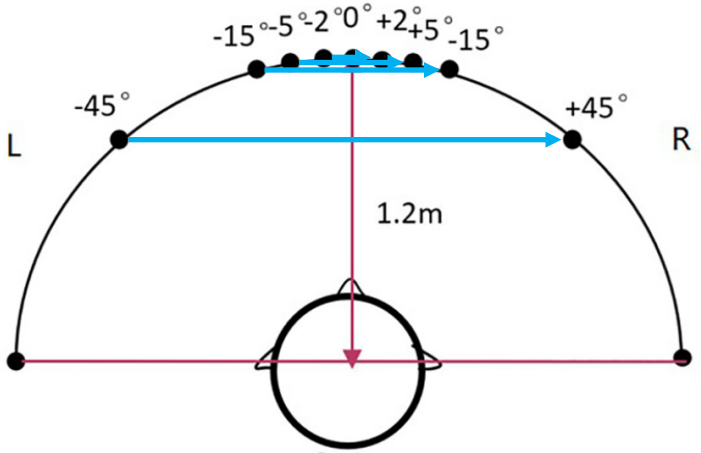
frontiers | Frontiers in Neuroscience

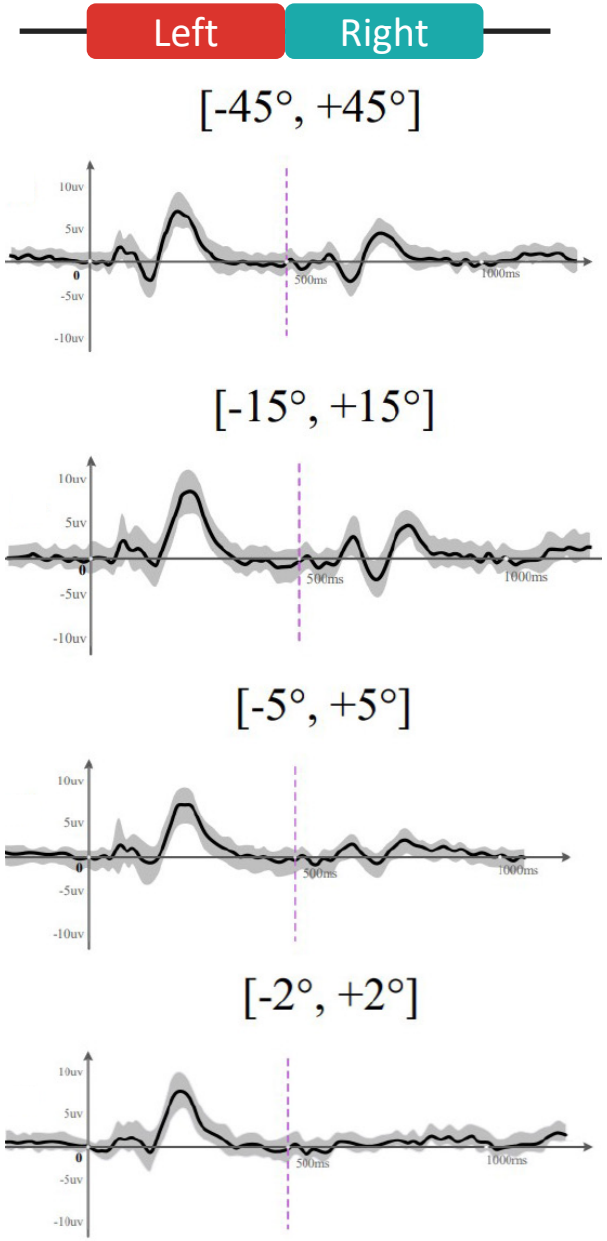
ORIGINAL RESEARCH
published: 06 June 2022
doi: 10.3389/fnins.2022.908989

Acoustic Change Complex Evoked by Horizontal Sound Location Change in Young Adults With Normal Hearing

Zhi-Tong Fan[1†], Zi-Hui Zhao[1†], Mridula Sharma[2], Joaquin T. Valderrama[2,3], Qian-Jie Fu[4], Jia-Xing Liu[1], Xin Fu[1], Huan Li[1], Xue-Lei Zhao[1], Xin-Yu Guo[1], Luo-Yi Fu[1], Ning-Yu Wang[1] and Juan Zhang[1]*

[1] Department of Otolaryngology Head and Neck Surgery, Beijing Chaoyang Hospital, Capital Medical University, Beijing, China, [2] Department of Linguistics, Faculty of Human Sciences, Macquarie University, Sydney, NSW, Australia, [3] National Acoustic Laboratories, Sydney, NSW, Australia, [4] Department of Head and Neck Surgery, David Geffen School of Medicine, University of California, Los Angeles, Los Angeles, CA, United States





ACC applications. *Binaural hearing sensitivity*

JARO 17: 591–607 (2016)
DOI: 10.1007/s10162-016-0584-6

JARO
Journal of the Association for Research in Otolaryngology

Research Article

Neural Representation of Interaural Time Differences in Humans—an Objective Measure that Matches Behavioural Performance

Jaime A. Undurraga,[1,2] Nick R. Haywood,[1,2] Torsten Marquardt,[2] and David McAlpine[1,2]

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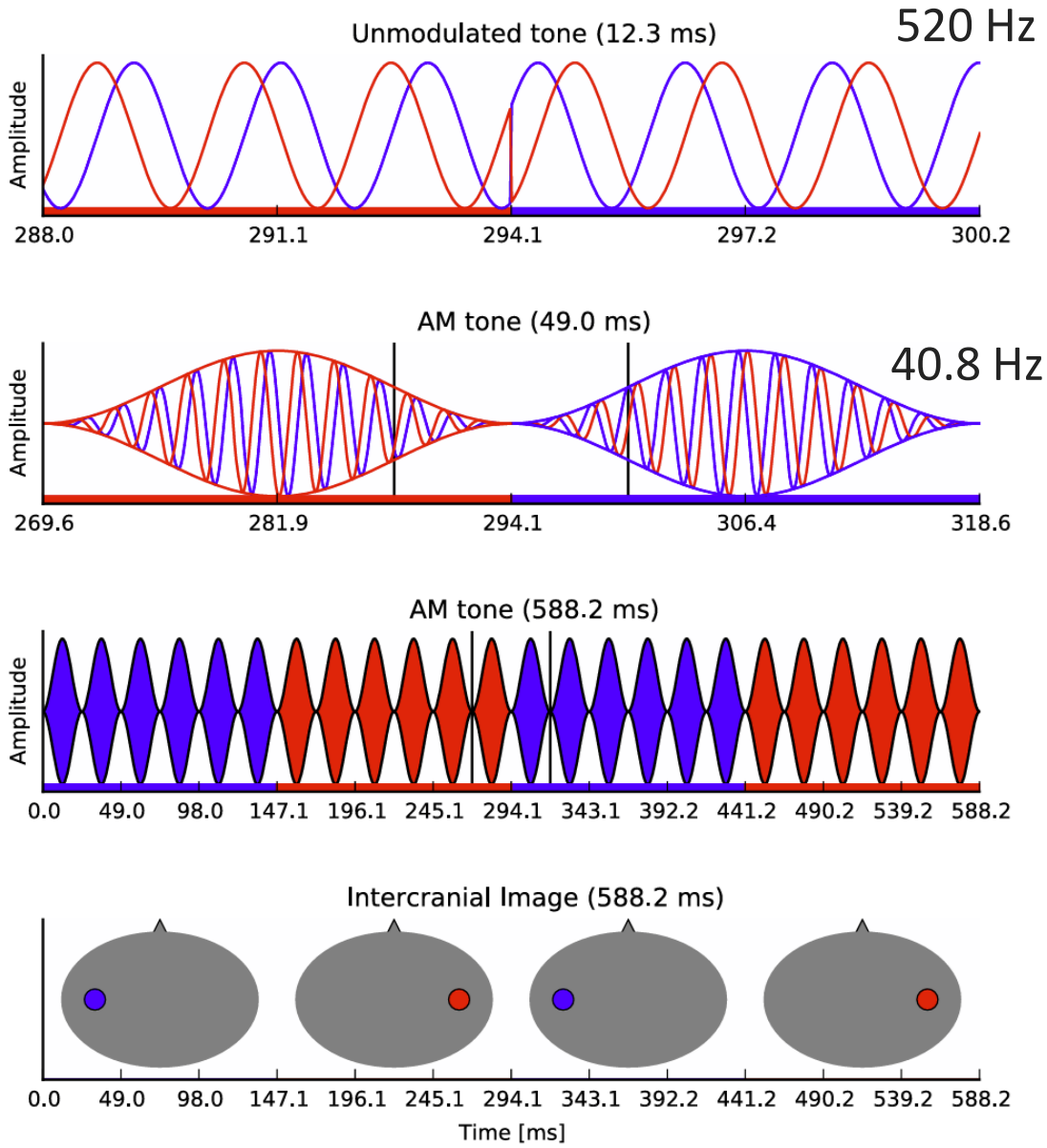
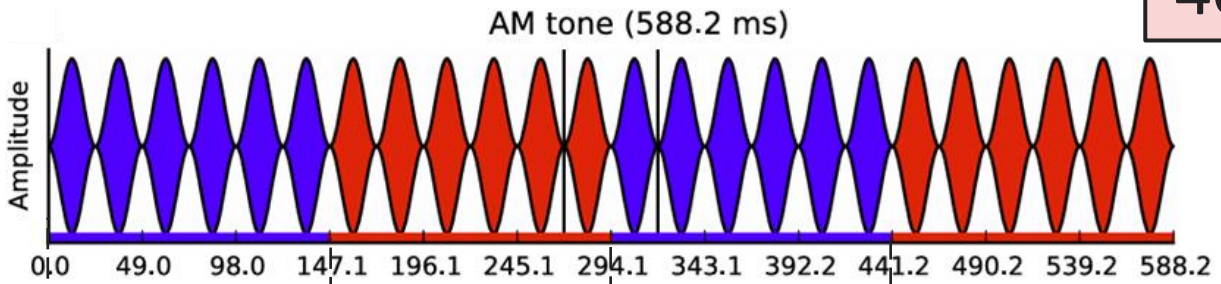
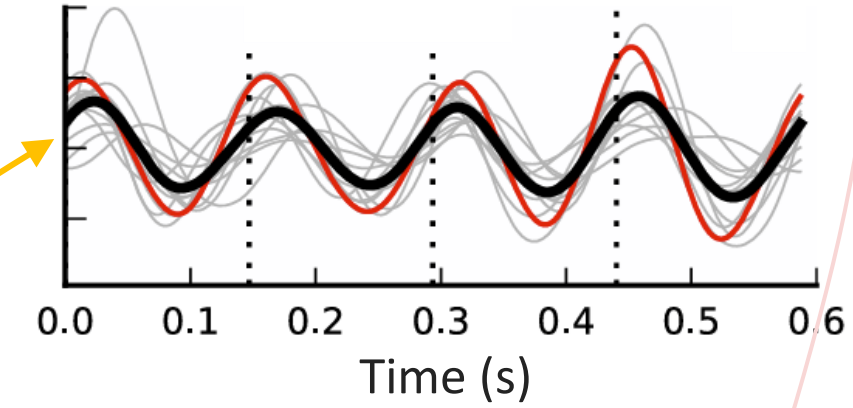
Received: 25 May 2016; Accepted: 15 August 2016; Online publication: 14 September 2016

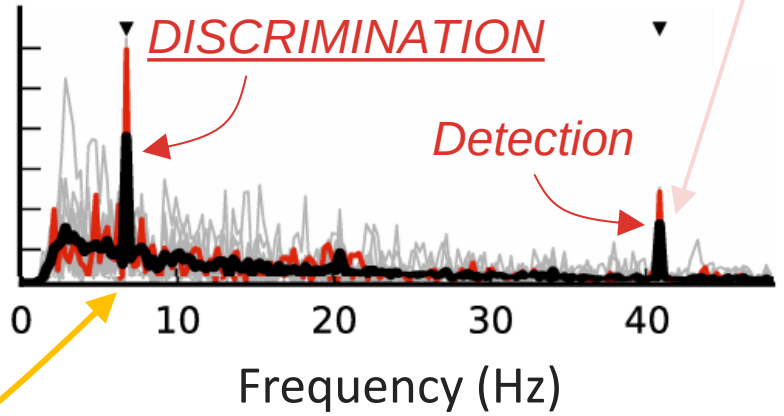


ACC applications. *Binaural hearing sensitivity*

40.8 stim/sec





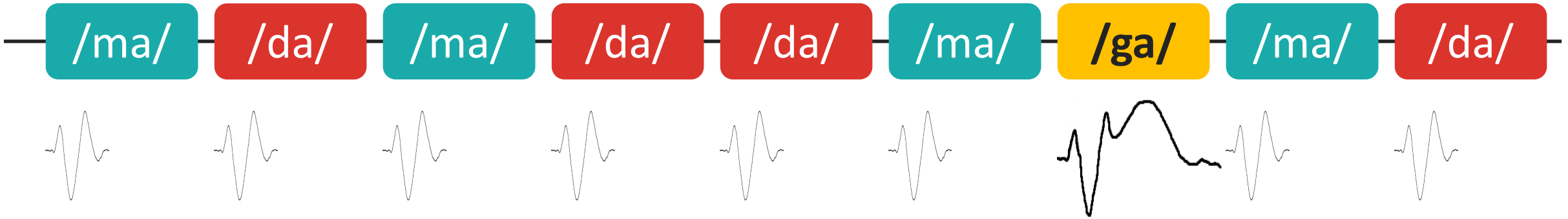


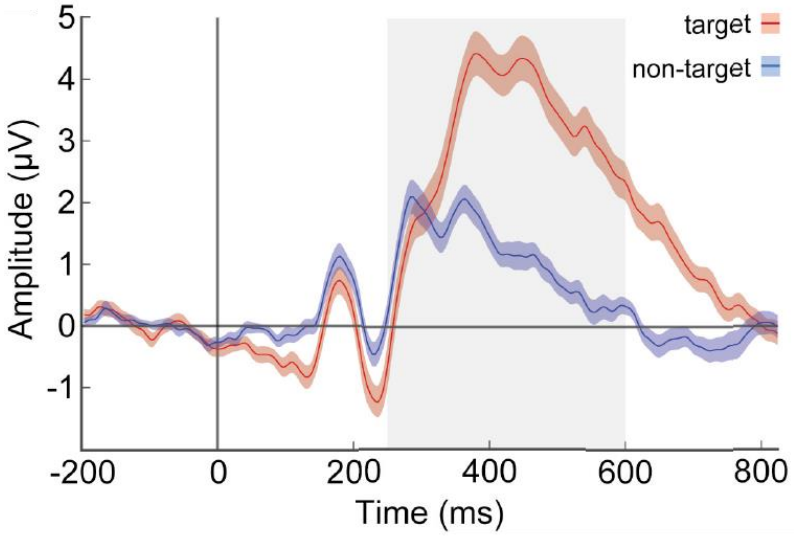
6.8 changes/second

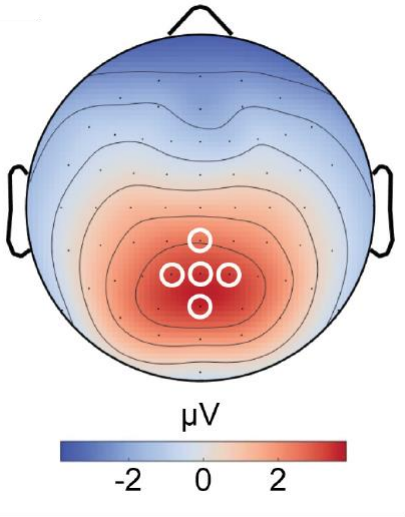
Identification

- ✓ *P300*

Identification. *P300*







Comprehension

- ✓ *N400*

Comprehension. *N400*

INTERNATIONAL JOURNAL OF AUDIOLOGY
2021, VOL. 60, NO. 2, 96–103
https://doi.org/10.1080/14992027.2020.1798518

ORIGINAL ARTICLE

Design and evaluation of the effectiveness of a corpus of congruent and incongruent English sentences for the study of event related potentials

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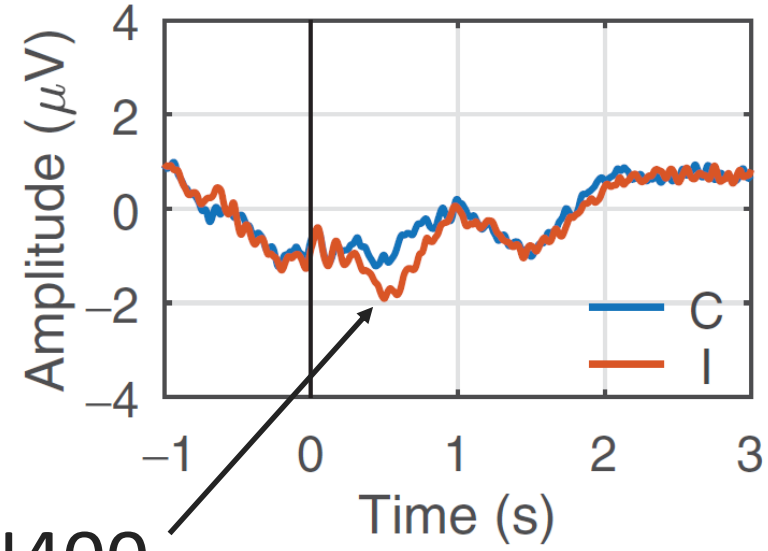
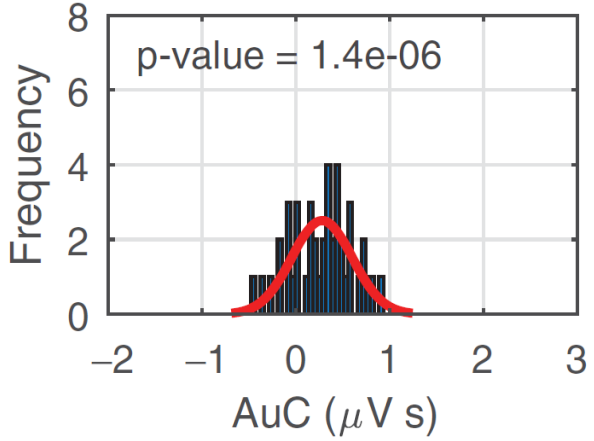
ABSTRACT

Objective: To design and evaluate the effectiveness of a stimulus material in eliciting the N400 event related potential (ERP).
Design: A set of 700 semantically congruent and incongruent sentences was developed in accordance with current linguistic norms, and validated with an electroencephalography (EEG) study, in which the influence of age and gender on the N400 ERP magnitude was analysed.
Study sample: Forty-five normal-hearing subjects (19–57 years, 21 females) participated in the EEG study.
Results: The stimulus material used in the EEG study elicited a robust N400 ERP, with a morphology consistent with the literature. Results also showed no statistically significant effect of age or gender on the N400 magnitude.
Conclusions: The material presented in this paper constitutes the largest complete stimulus set suitable for both auditory and text-based N400 experiments. This material may help facilitate the efficient implementation of future N400 ERP studies, as well as promote standardisation and consistency across studies.

ARTICLE HISTORY
Received 6 January 2020
Revised 18 May 2020
Accepted 12 July 2020

KEYWORDS
N400; speech perception; language-related ERPs; semantic violation





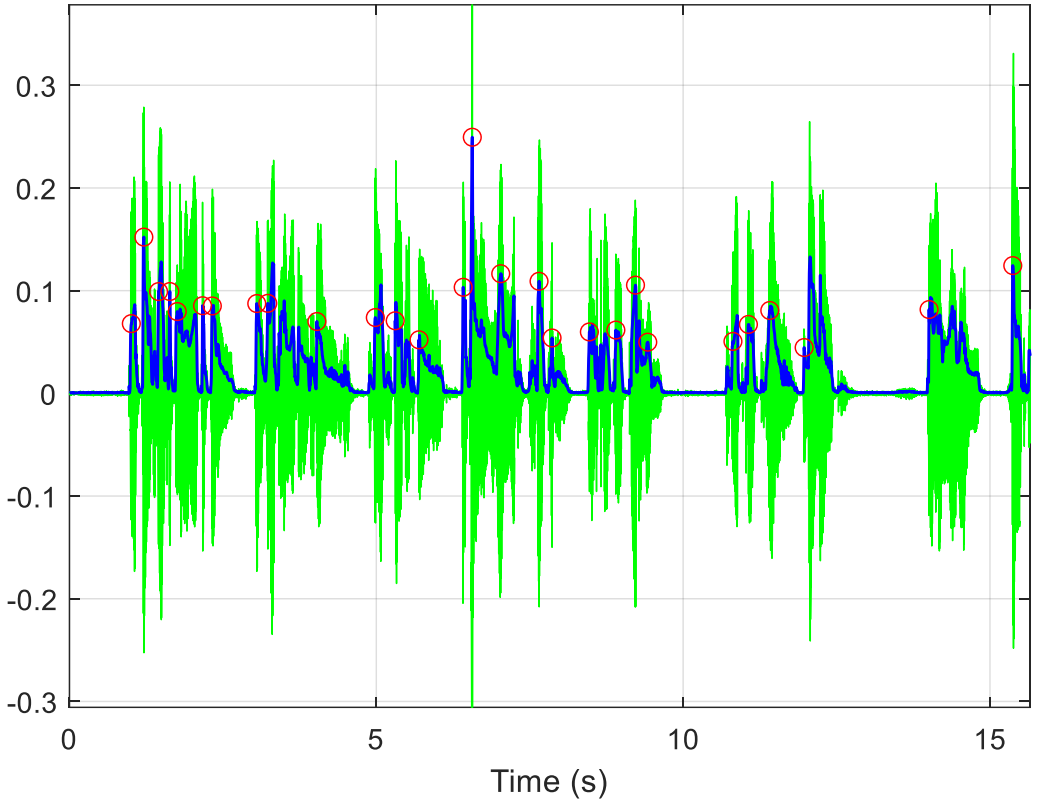
- Congruent: The driver puts the **petrol** in the car.
- Incongruent: The mother breaks the **petrol** on the shelf.

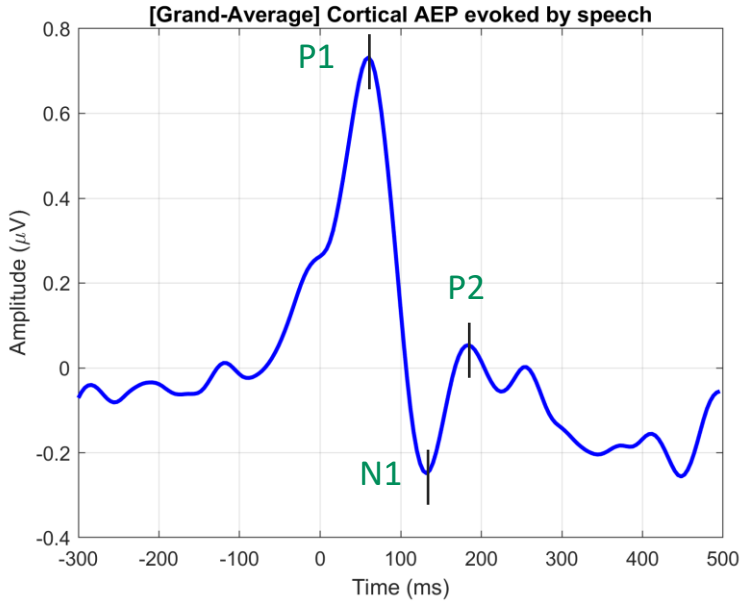
Speech processing

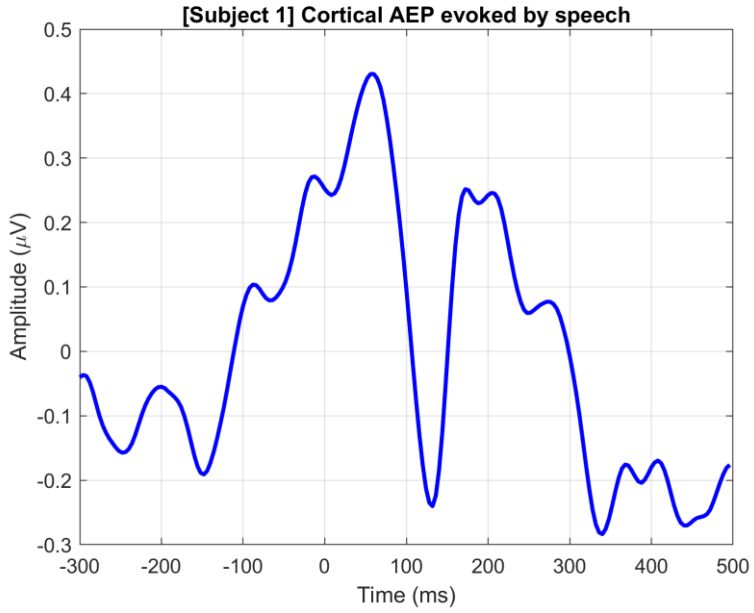
- ✓ *Cortical response to natural speech*
- ✓ *Selective attention*

Speech processing. *CAEP to natural speech (in Quiet)*

Audiobook 1

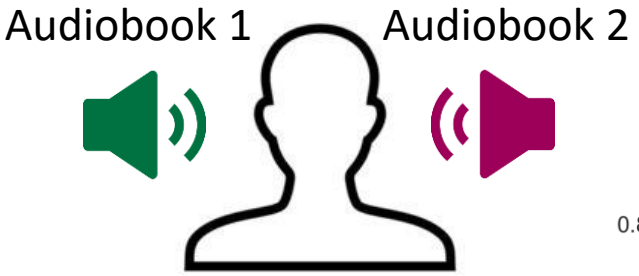


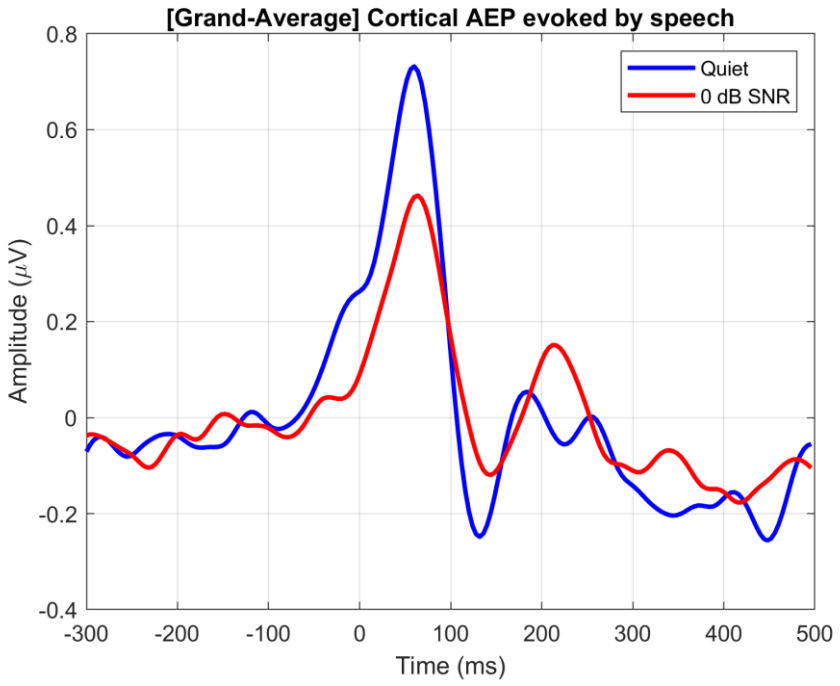


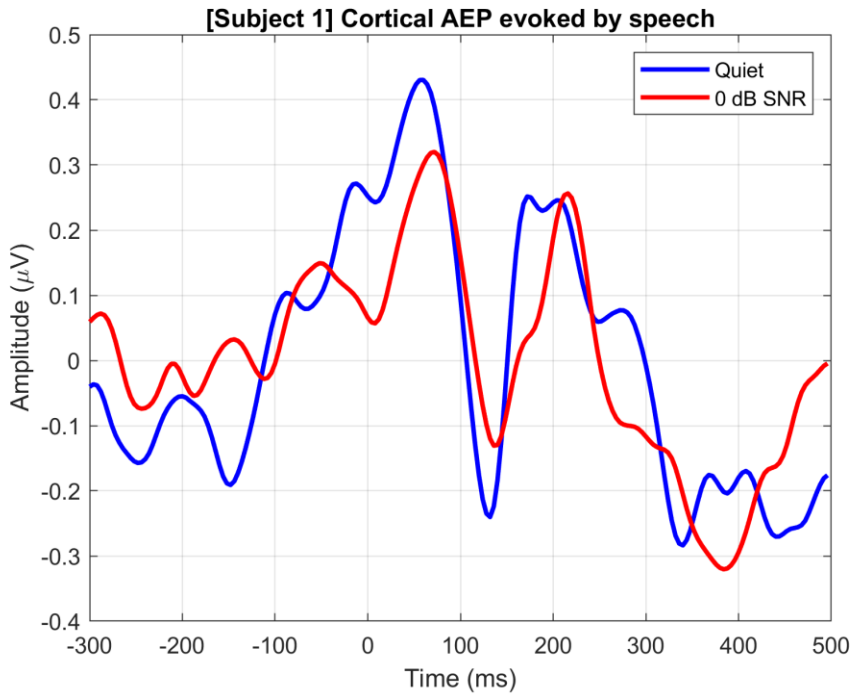


Results showed that it is feasible to obtain the cortical response to speech with this methodology, and that this response can also be obtained at individual level (not only at group level).

Speech processing. *CAEP to natural speech (in Noise)*

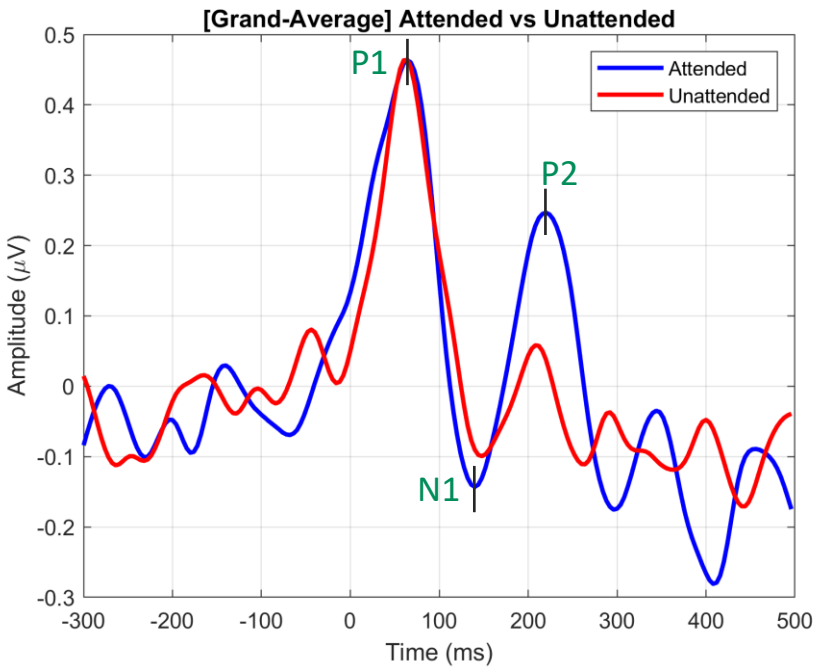


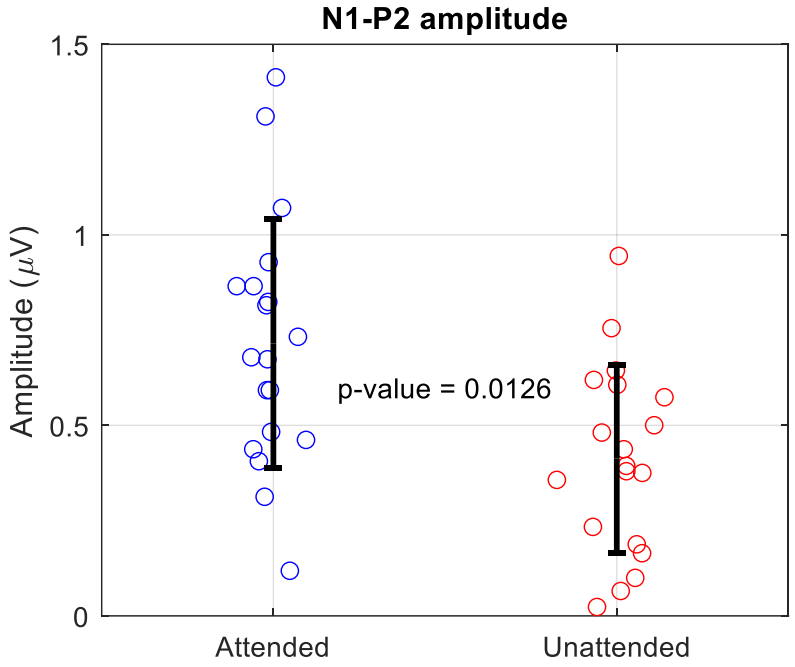




Results demonstrated that it is feasible to record a cortical response to speech at 0 dB SNR.

Speech processing. *Selective attention*





These results suggest that

- P1-N1 amplitude → *Detection*
- N1-P2 amplitude → *Comprehension*

Relevant finding: The N1-P2 amplitude of the cortical response evoked by natural speech has potential to become an objective biomarker of selective attention.

Take-home & Acknowledgements

- EEG has significant potential for assessing relevant hearing functions.
- Standard auditory evoked potentials, such as ABRs, MLRs, CAEPs and ASSR, offer objective biomarkers of a person's ability to **DETECT** sounds.
- There exist other EEG biomarkers that assess higher hearing functions, including **SOUND DISCRIMINATION** (ACC), **SOUND IDENTIFICATION** (P300), and even **LANGUAGE COMPREHENSION** (N400).
- Research using natural stimuli, like continuous speech, aims to develop new biomarkers sensitive to **LINGUISTIC AND COGNITIVE PROCESSES**.

SLIDES

RYC2022-037875-I

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