The transient response to interaural time differences

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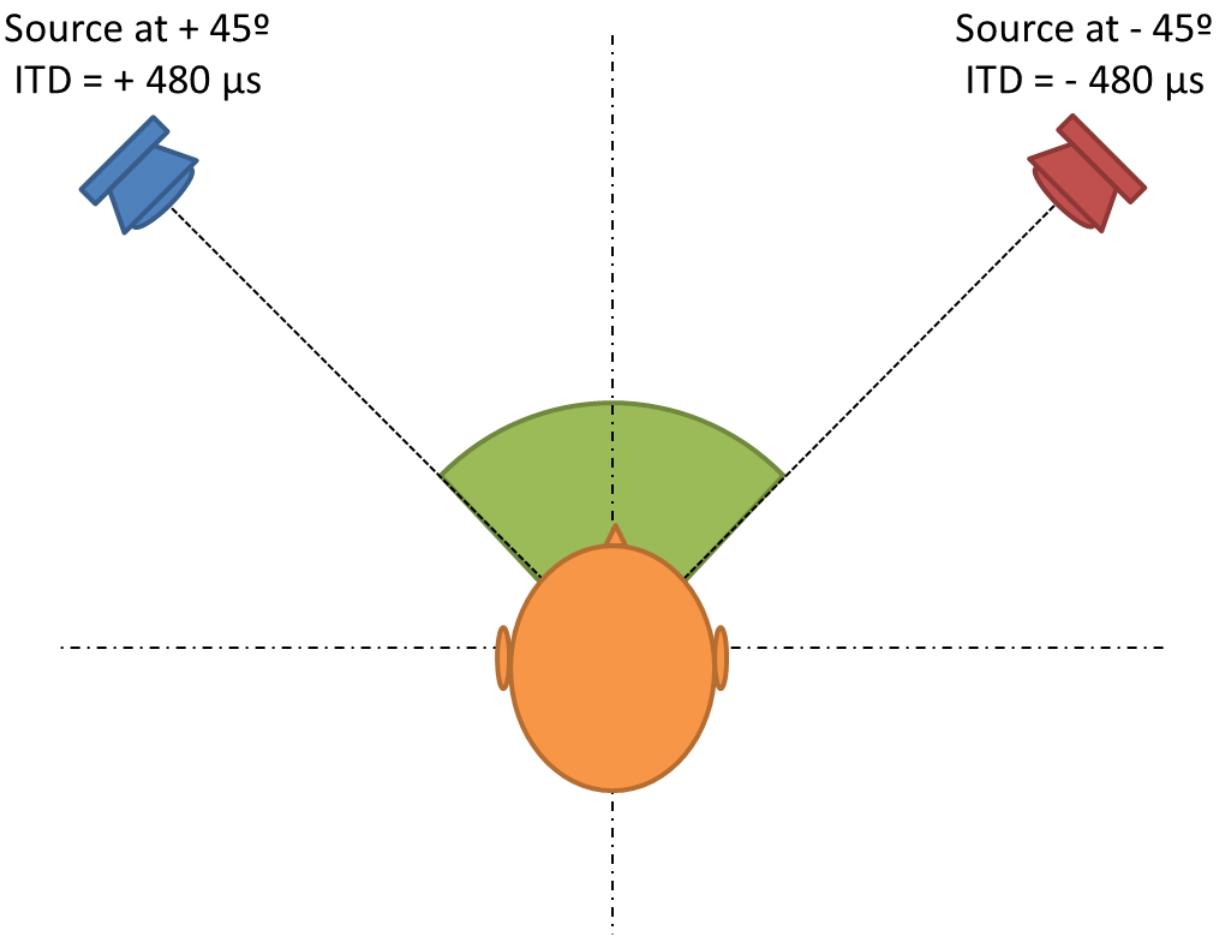
Motivation

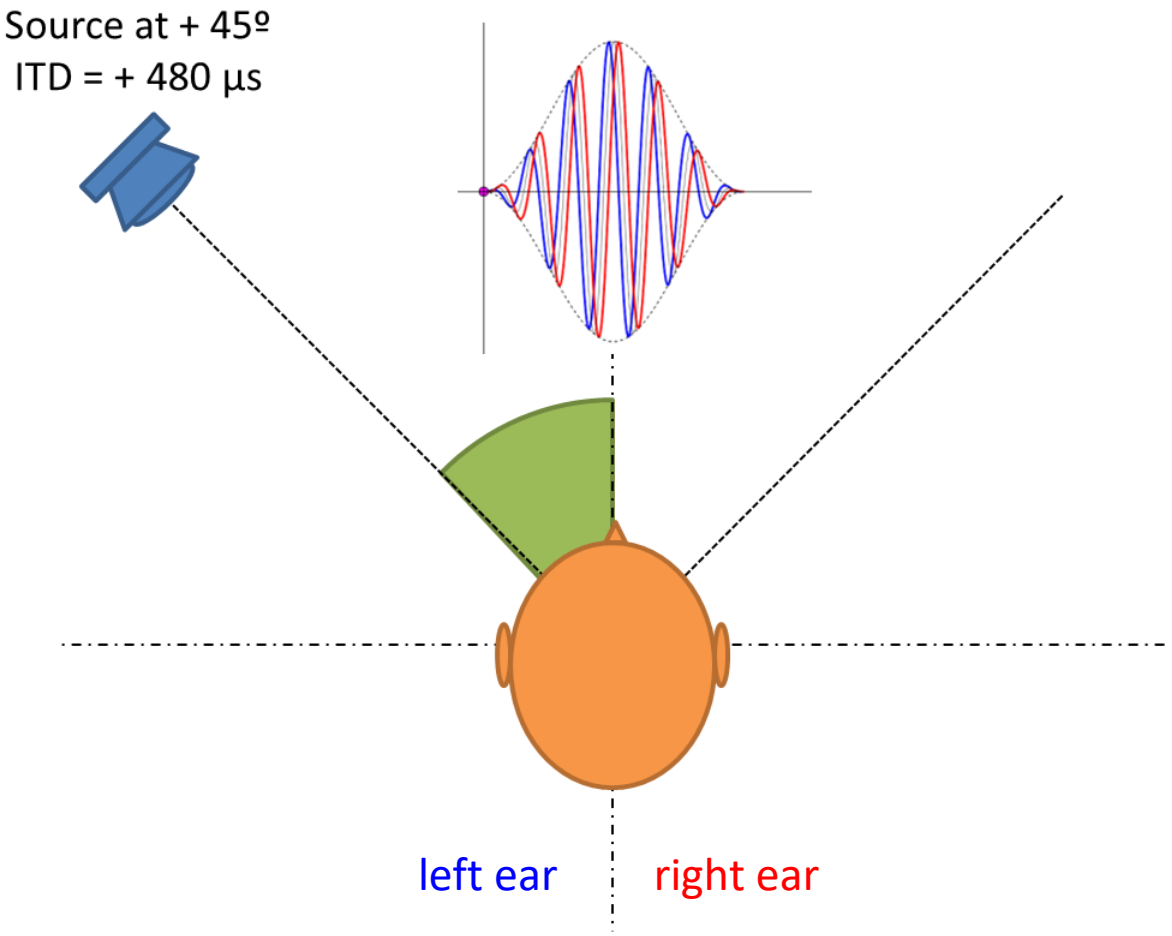
- Binaural hearing is important for:
  - Hearing perception
  - Hearing quality
  - Speech understanding in noise
- Steady state response to binaural hearing
  - Undurraga et al. J. Assoc Res Otolaryngol, 2016, 17: 591-607
- In this work: transient response associated with binaural hearing

Stimulation



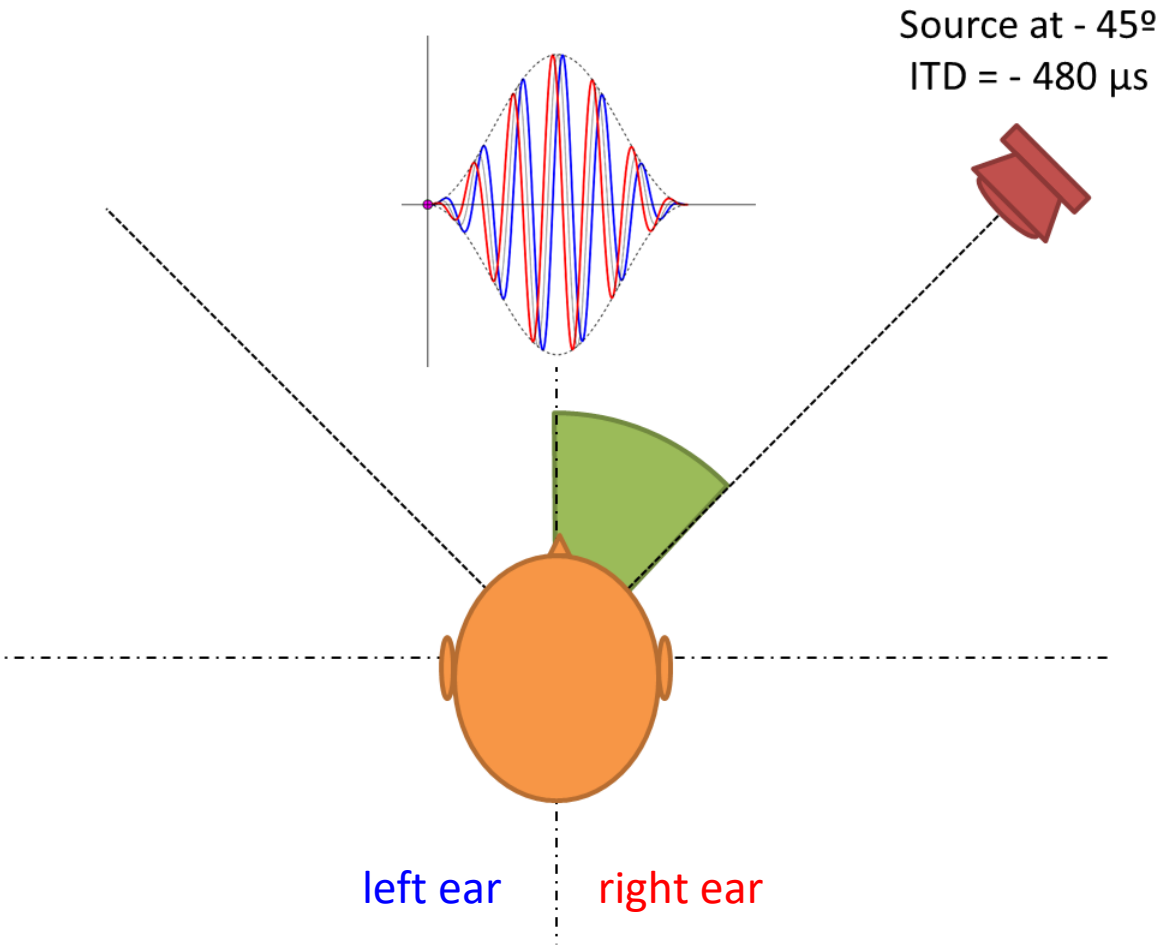
Stimulation

Sound source at the left side
(wave arrives earlier to the left ear)

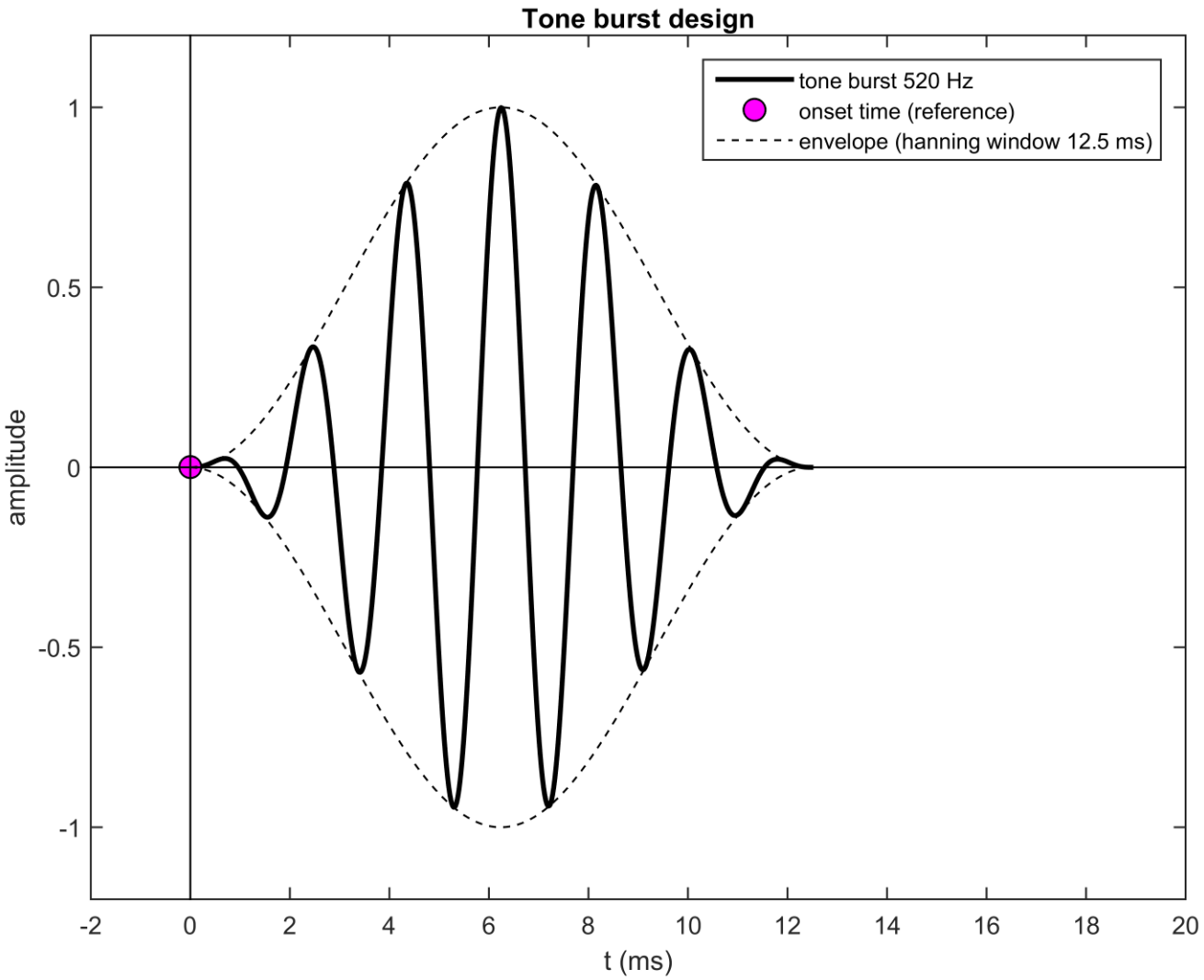


Stimulation

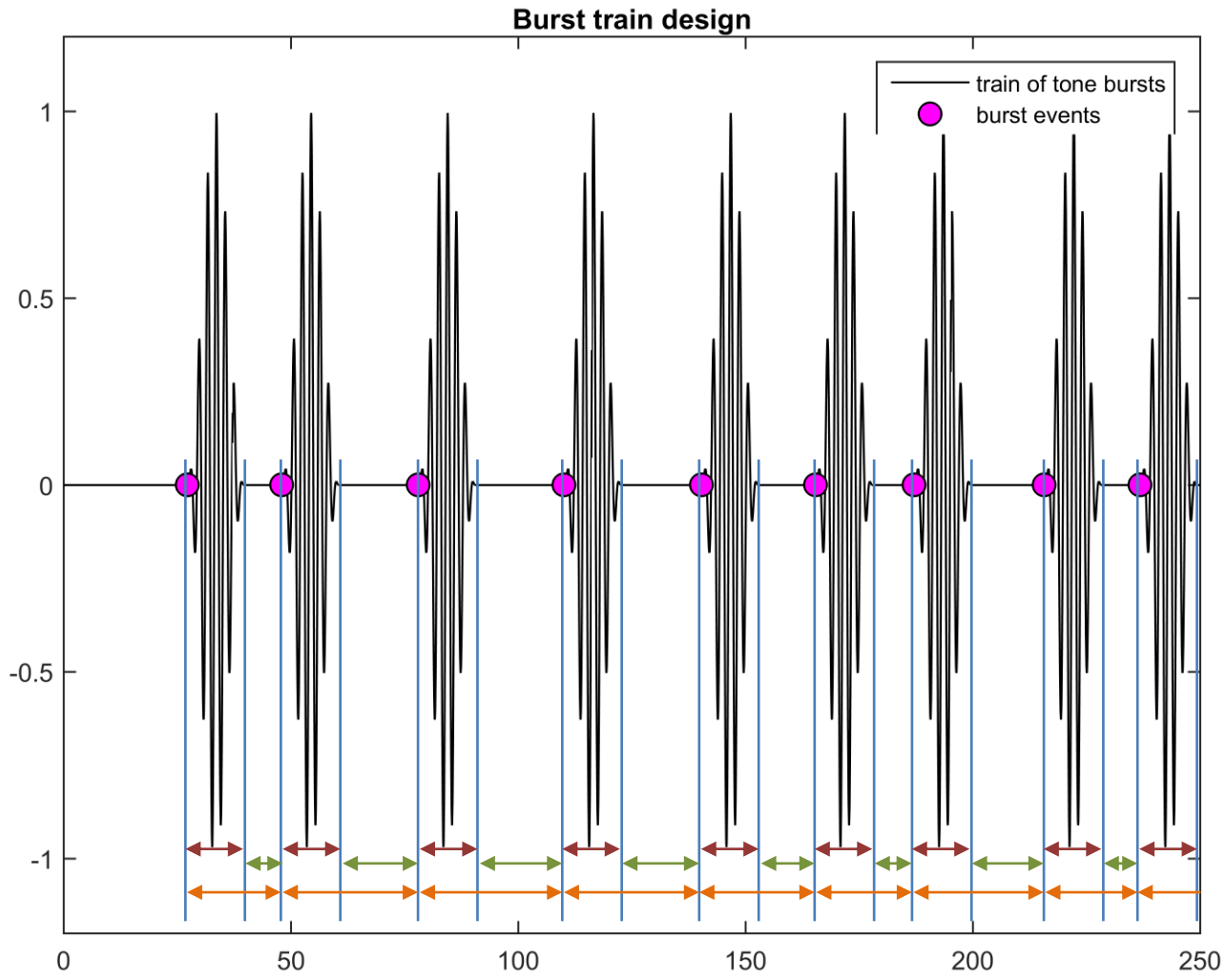
Sound source at the right side
(wave arrives earlier to the right ear)



Stimulus design: tone burst



Stimulus design: train of tone bursts



Burst duration
- 12.5 ms

Inter-Stimulus-Interval
- Range: 5 – 20 ms
- Average: 12.5 ms

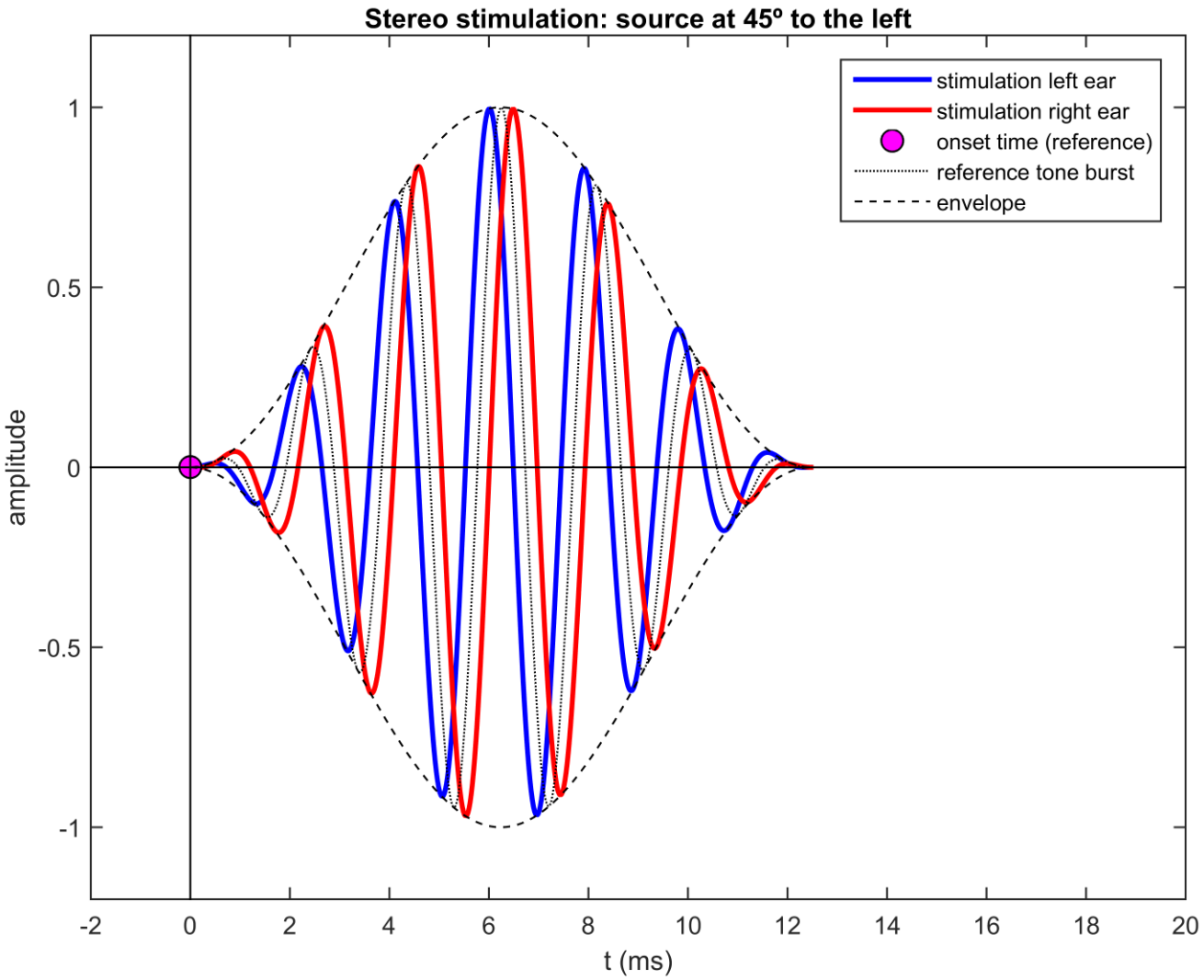
Onset time interval
- Range: 17.5 – 32.5 ms
- Average: 25 ms

Average stimulation period:
- 25 ms

Average stimulation rate:
- 40 Hz

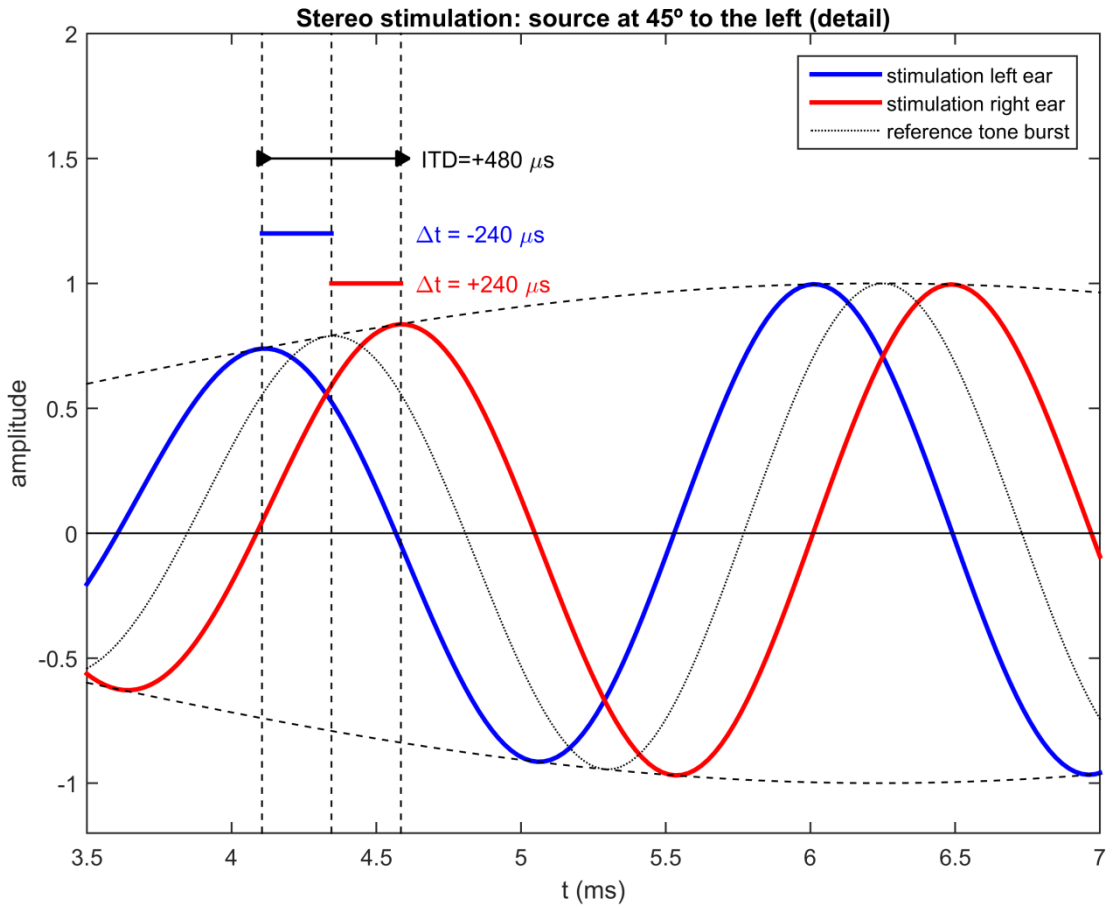
Stimulus design: stereo burst

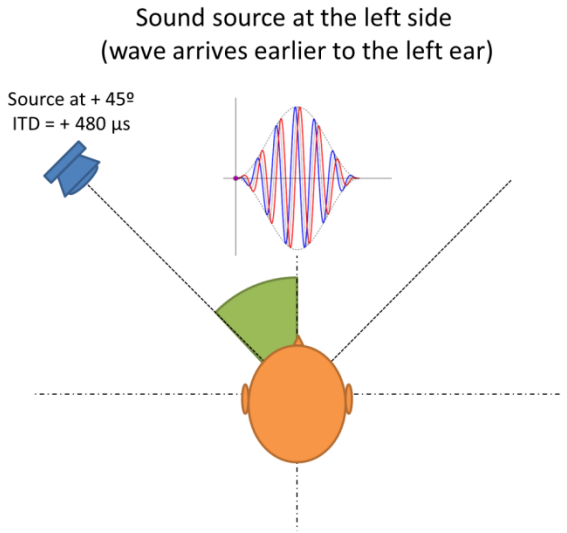
(source at the left side)



Stimulus design: stereo burst

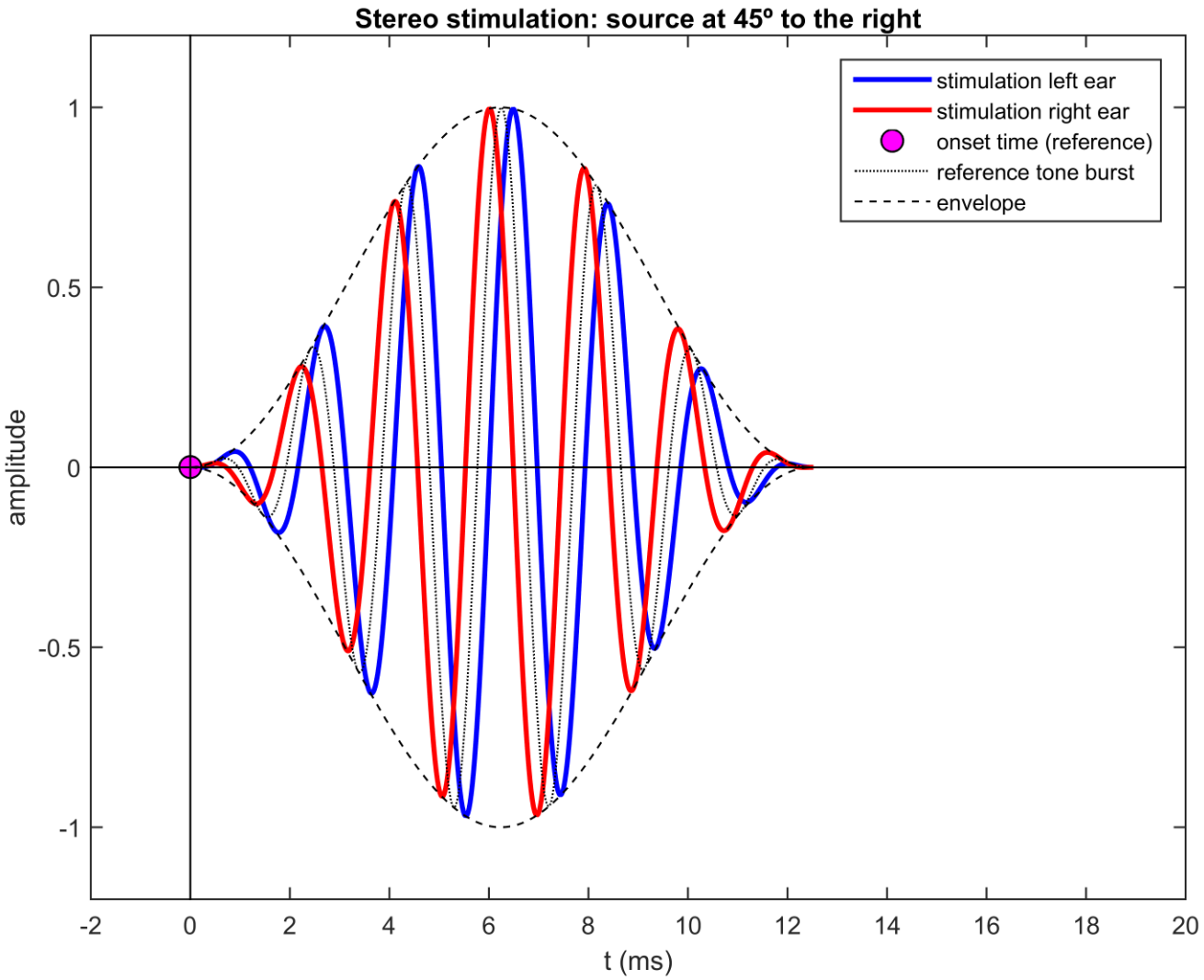
(source at the left side)





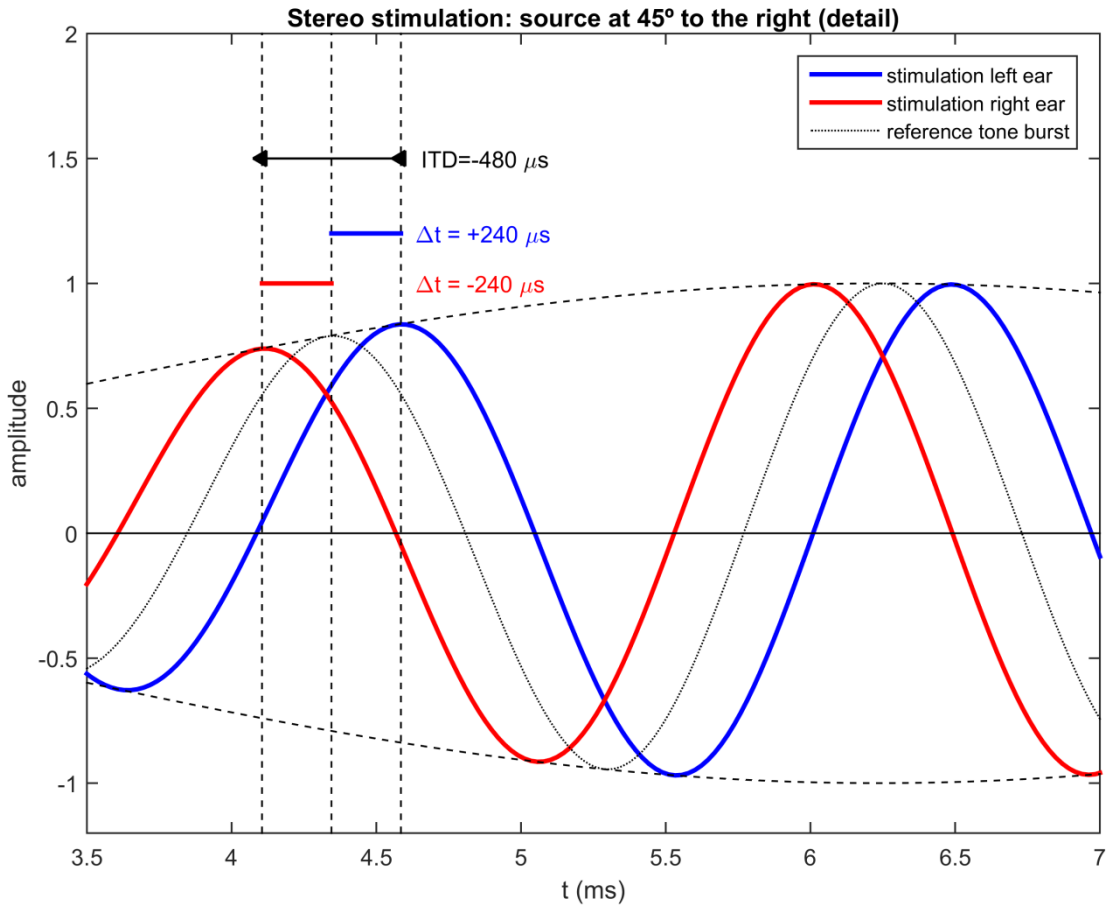
Stimulus design: stereo burst

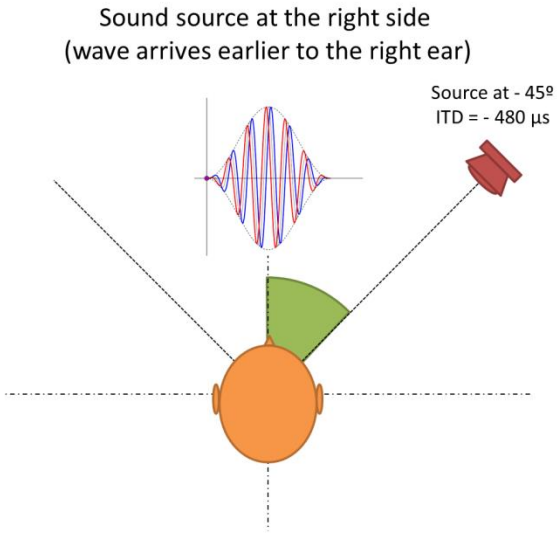
(source at the right side)



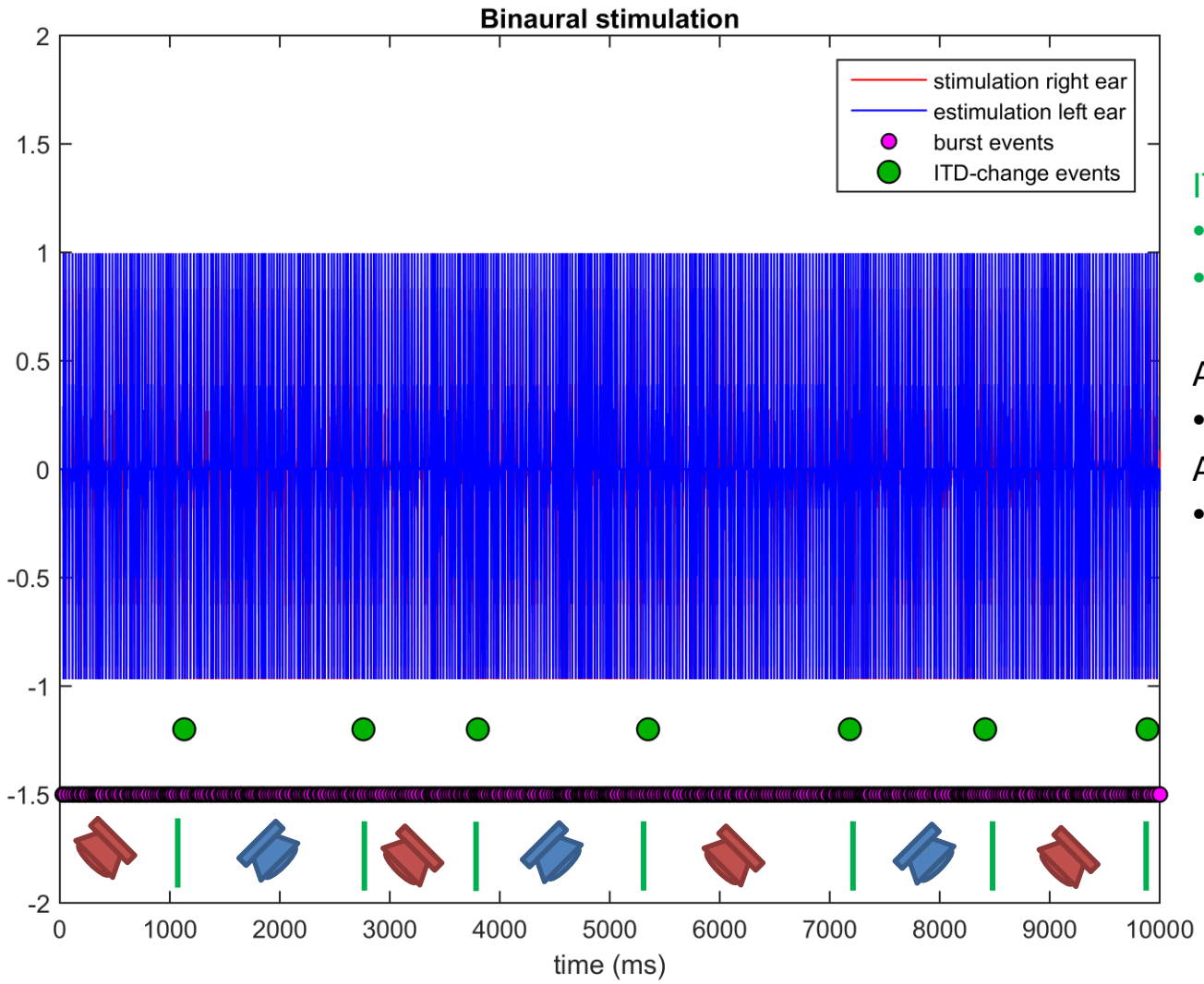
Stimulus design: stereo burst

(source at the right side)





Stimulus design



ITD change interval

- Range: 1.0 – 2.0 s
- Average: 1.5 s

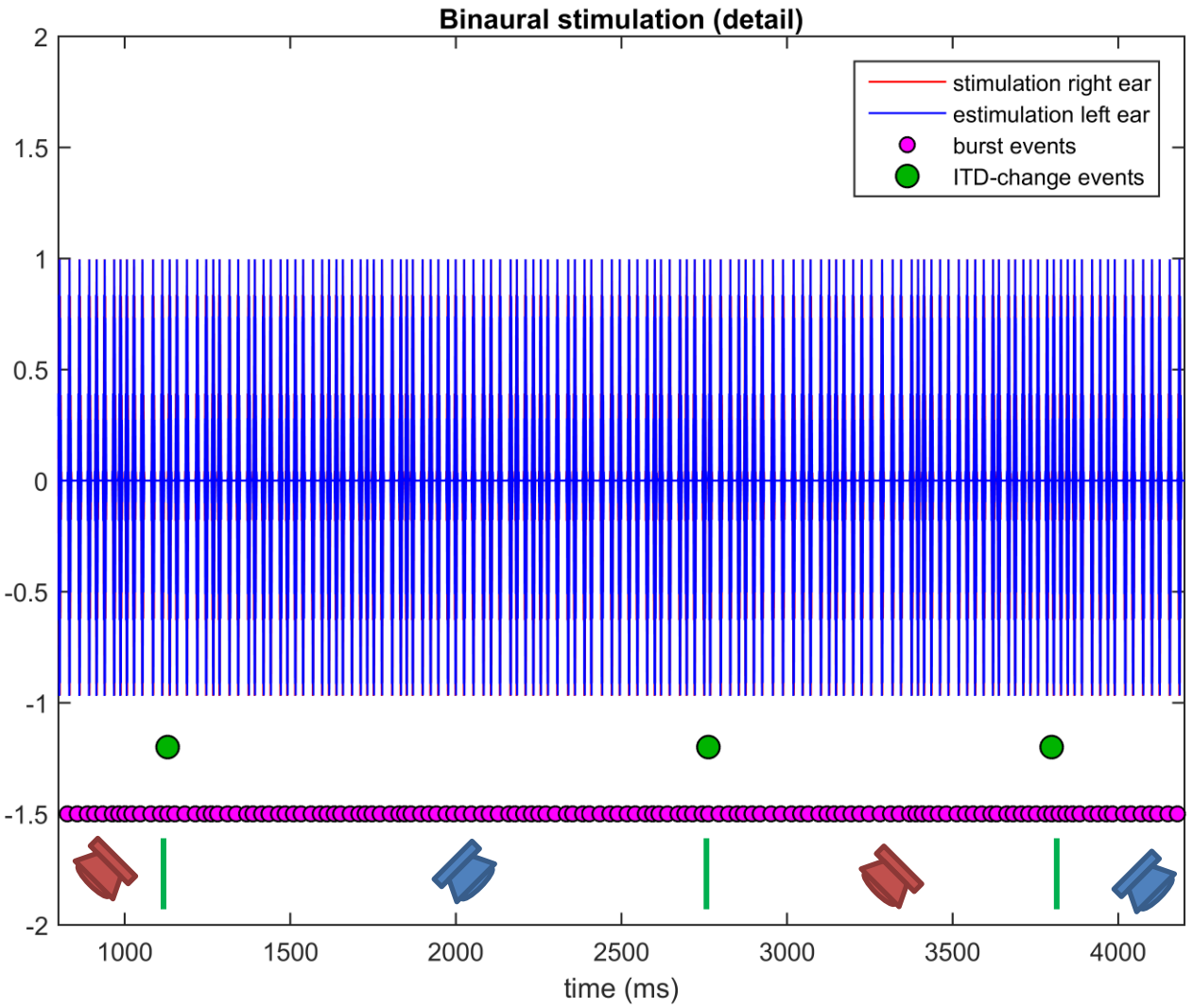
Average ITD change period:

- 1.5 s

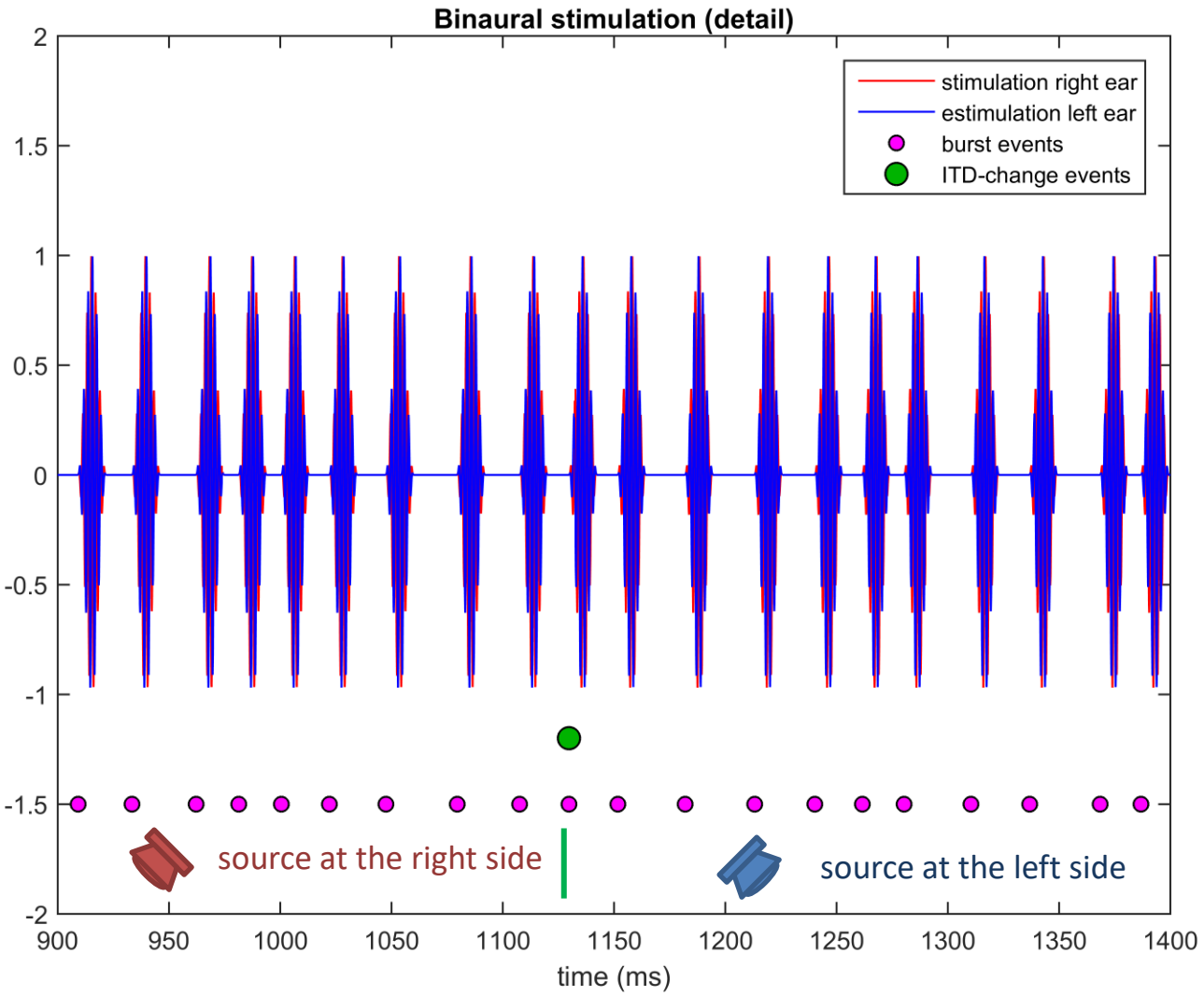
Average ITD change rate:

- 0.667 Hz

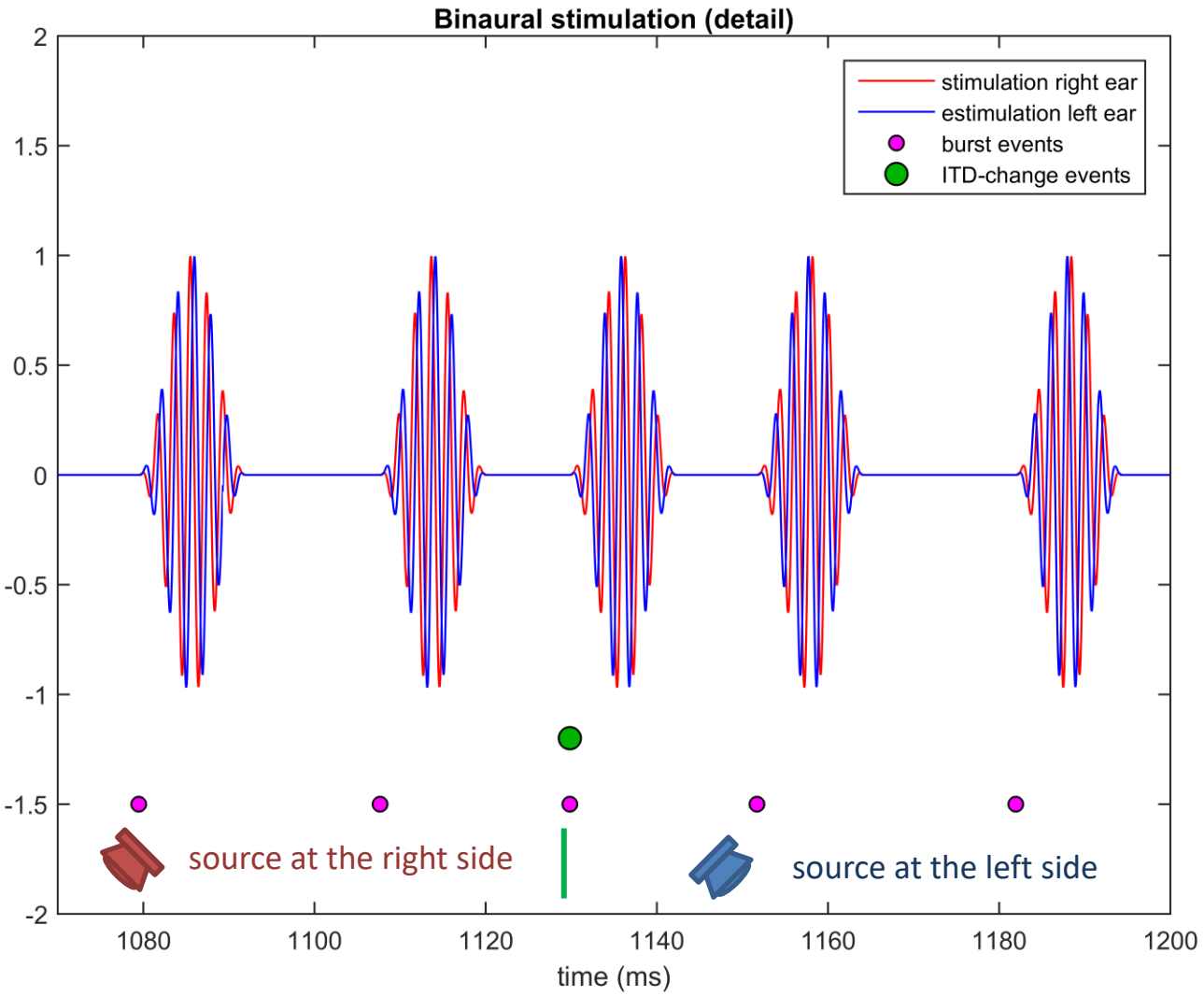
Stimulus design



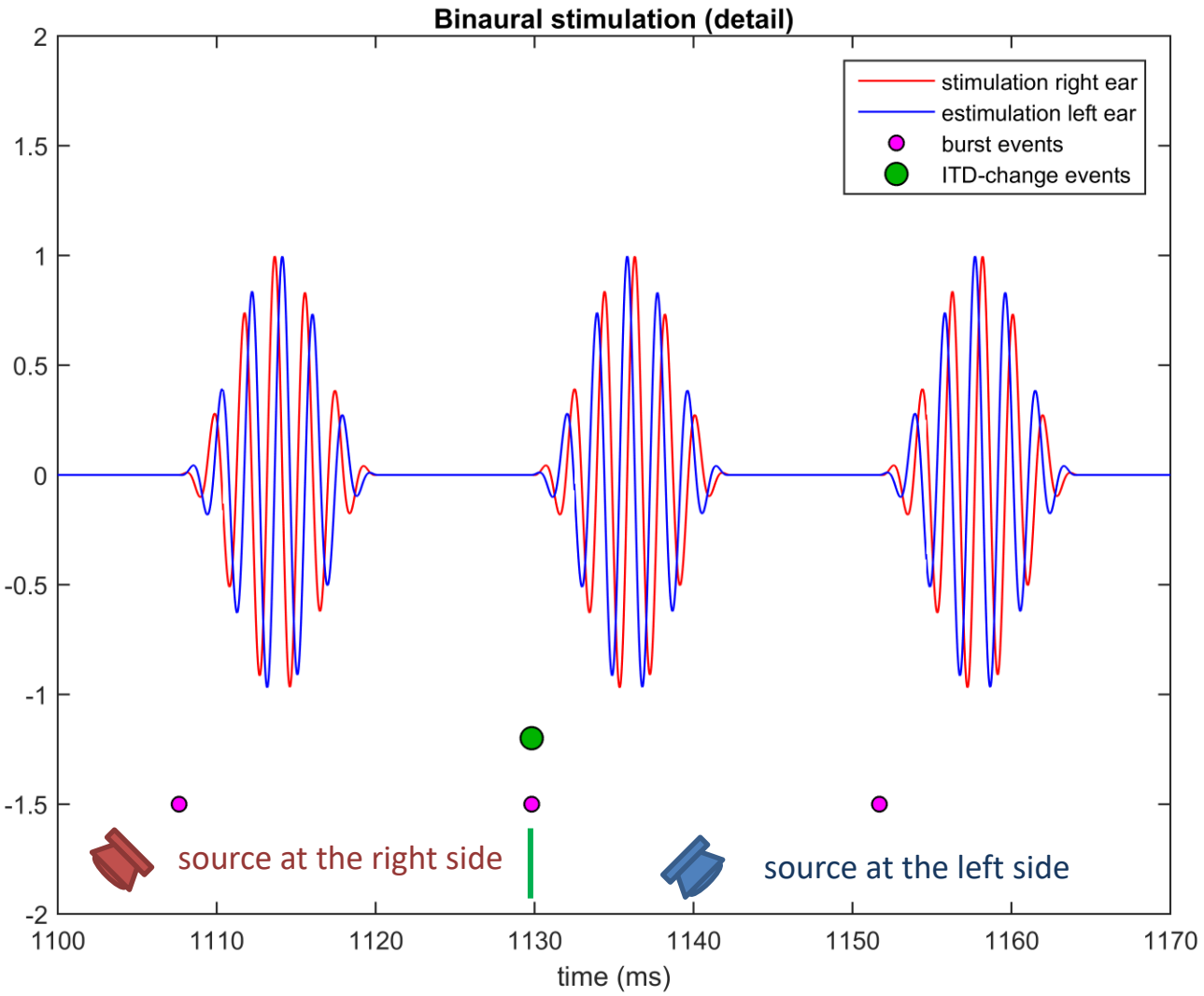
Stimulus design



Stimulus design



Stimulus design

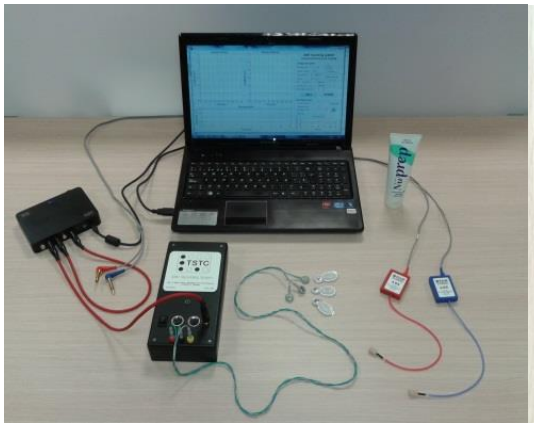


Methods (1)

- 8 Subjects (4 female, 4 male, [25-49] years)
- Stimulation:
  - Tone bursts of 525 Hz, 12.5 ms Hanning window
  - Repetition of burst:
    - Average period: 25 ms (17.5 – 32.5 ms)
    - Average rate: 40 Hz
  - Source location emulated with ITD
  - ITD changing between -480 µs and +480 µs
    - Source either at right (-480 µs) or at left (+480 µs)
    - Location changes with average period 1.5 s (1.0 – 2.0 s)
- Stimulation and EEG recording controlled with a laptop using MatLab

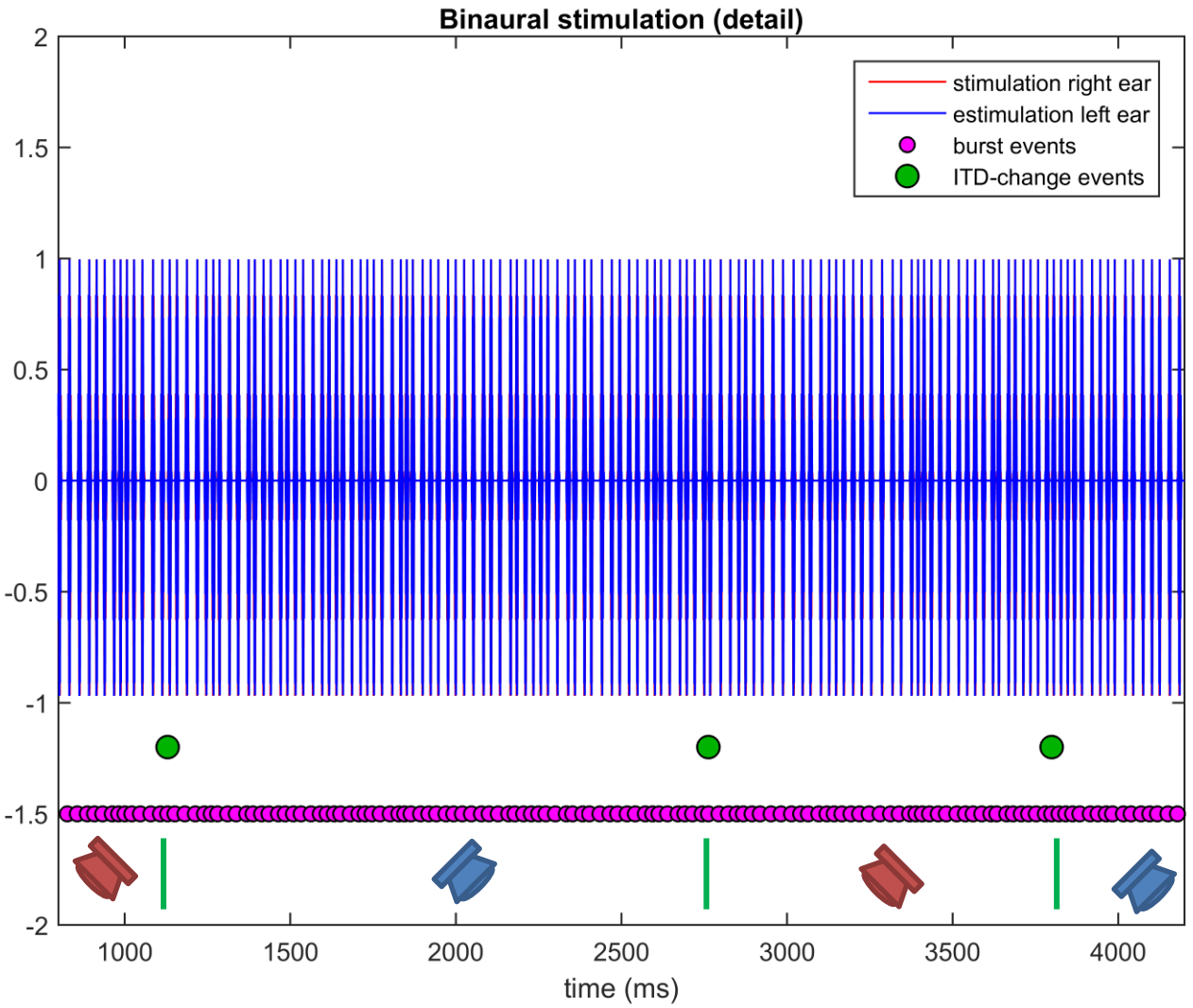
Methods (2)

- Responses:
  - for ITD = ± 480 μs (ITD conditions) and
  - for ITD = 0 μs (control)
- Stereo stimulation with ER-3A insert earphones
- Recordings of 25 minutes for ITD and 25 minutes for control. Stimulation presented at 50 dB.
- EEG recorded with an evoked potential amplifier in the band 1 Hz – 3.5 kHz



Valderrama et al. «A flexible and inexpensive high performance auditory evoked response recording system…» Biomedizinische Technik, 2014 Oct; 59(5):447-59. DOI: 10.1515/bmt-2014-0034.

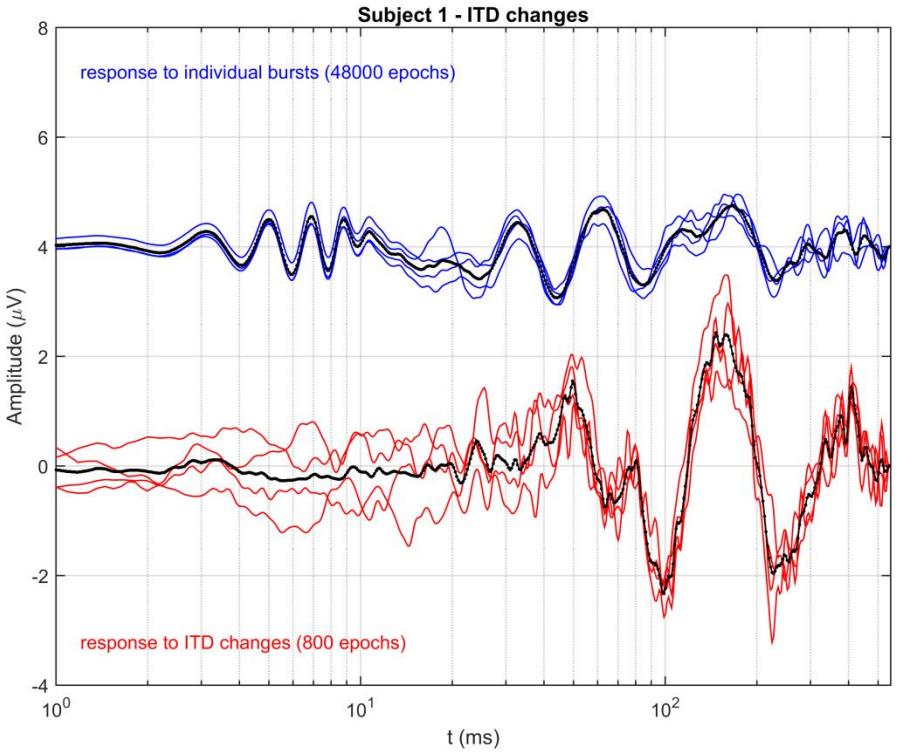
Deconvolution of EEG

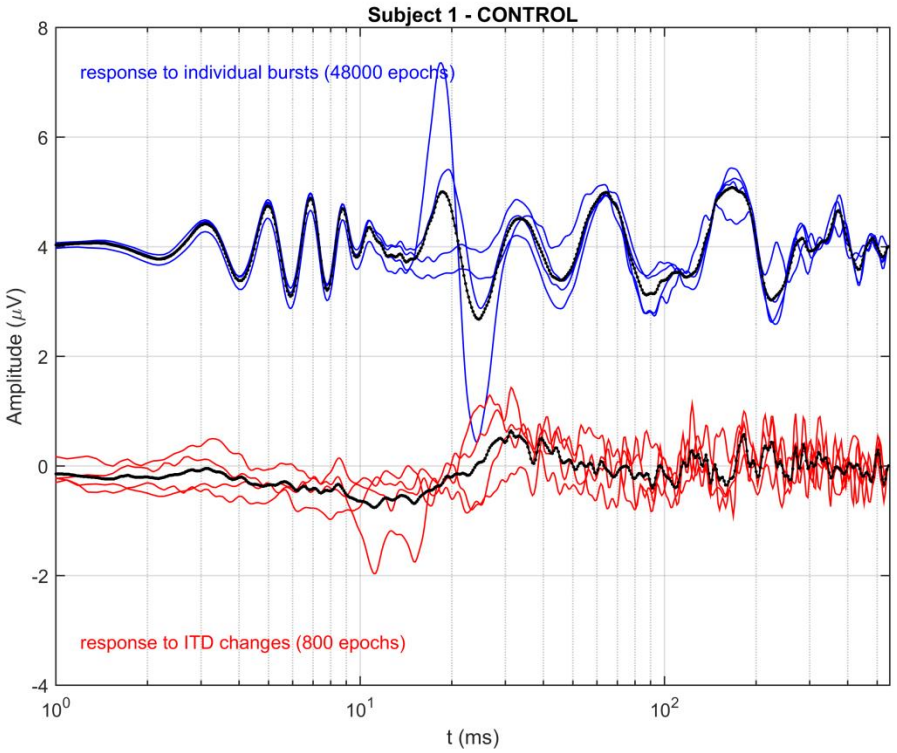


Methods (3)

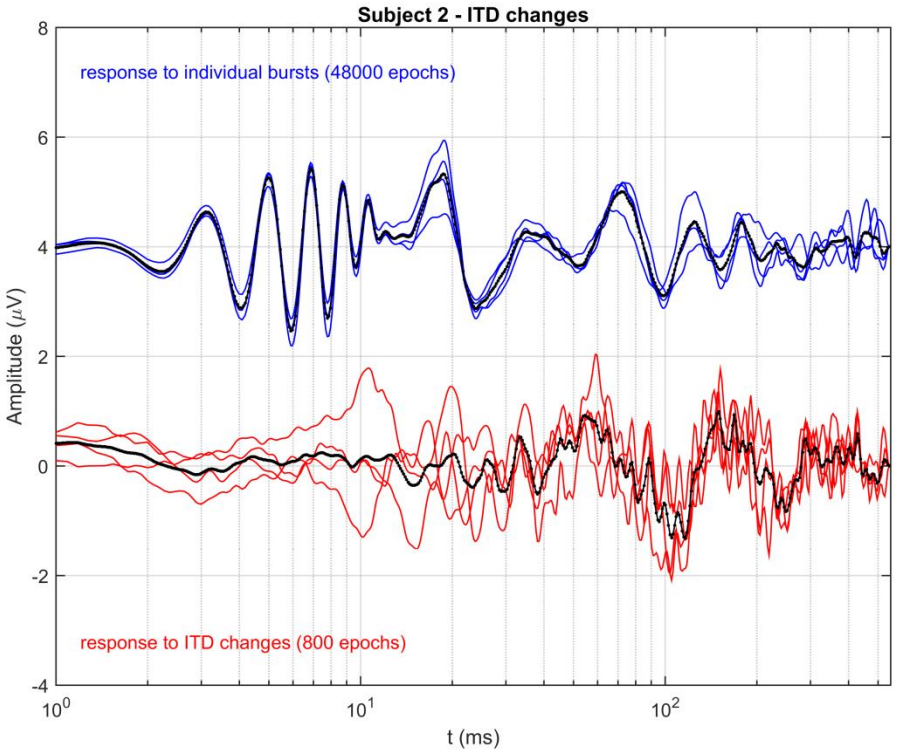
- Deconvolution provides two responses:
  - Response to tone burst
  - Response to ITD change
- Deconvolution with Matrix-IRSA
  - A. de la Torre et al., JASA 146(6), 2019, 4545-4556
- Latency dependent filtering (80 samples/dec)
  - A. de la Torre et al., JASA 148(2), 2020, 599-613
- Latency in logarithmic scale

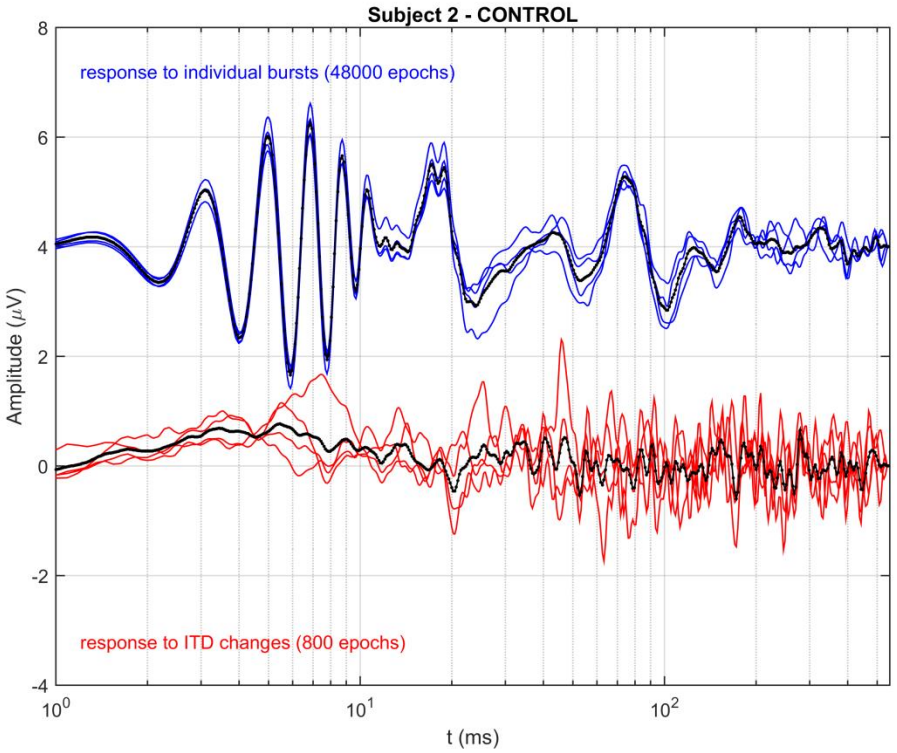
Results: subject 1



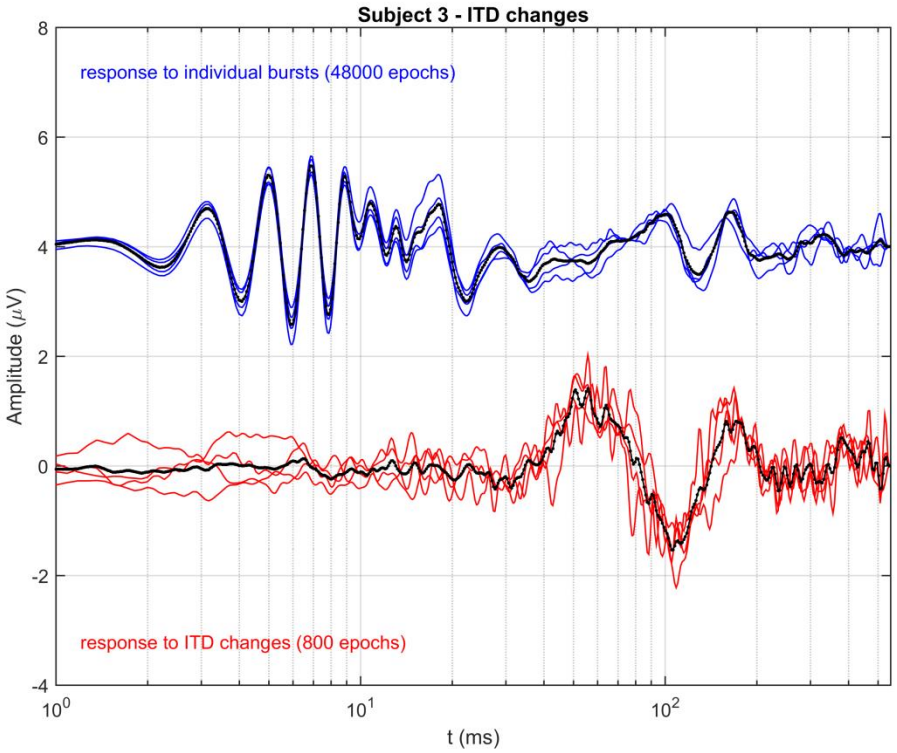


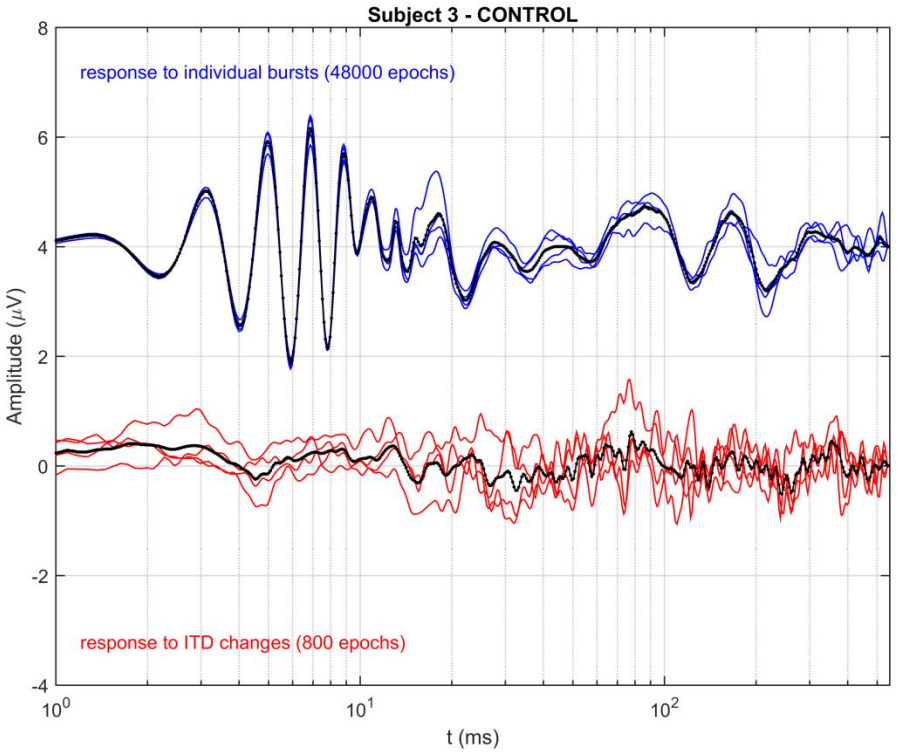
Results: subject 2



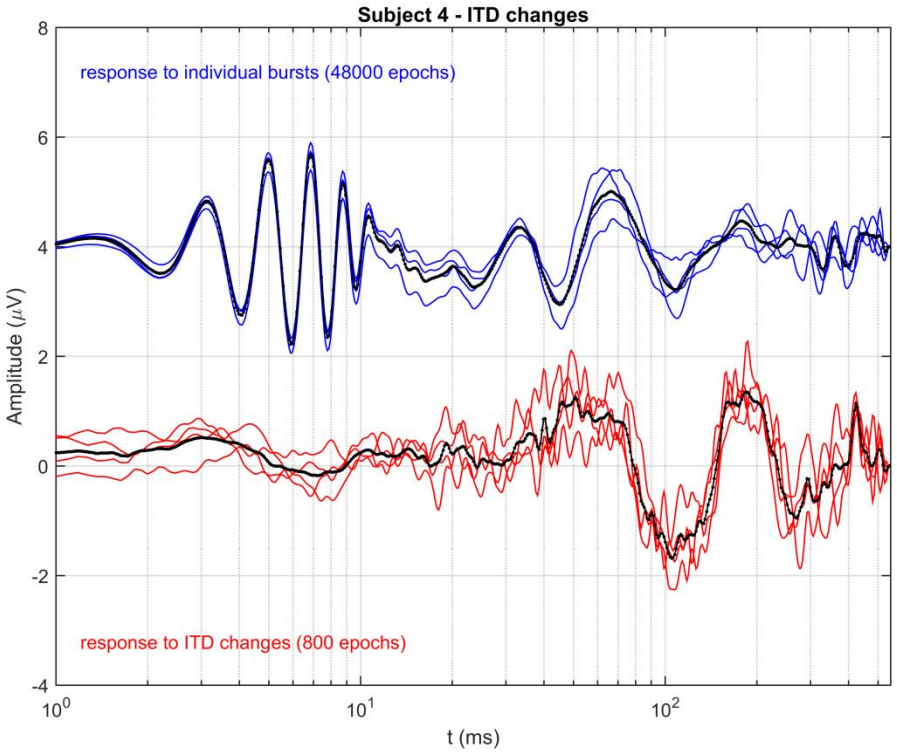


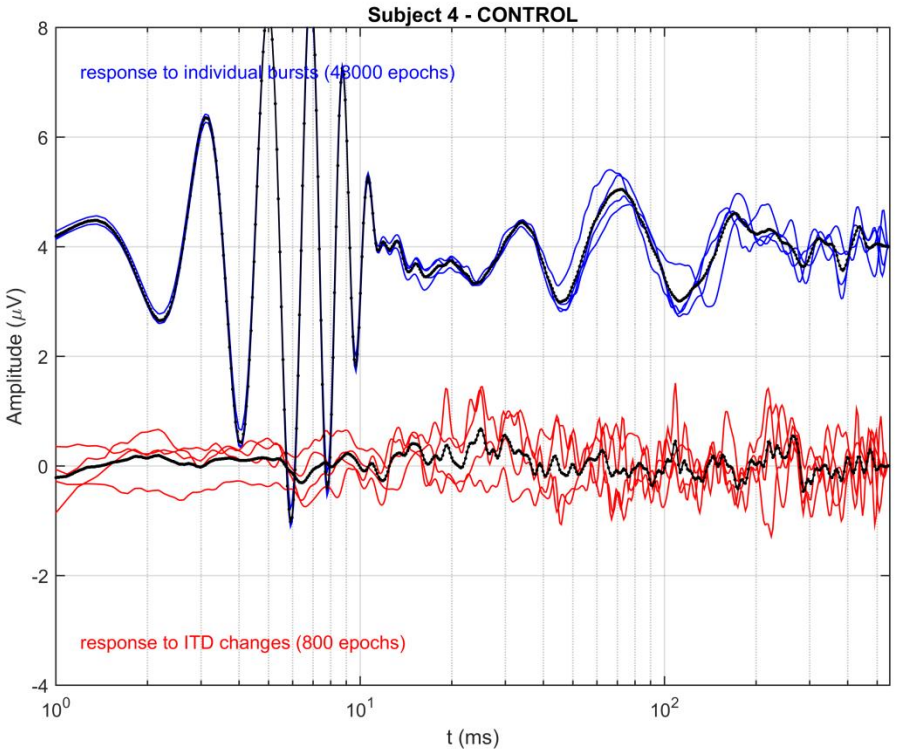
Results: subject 3



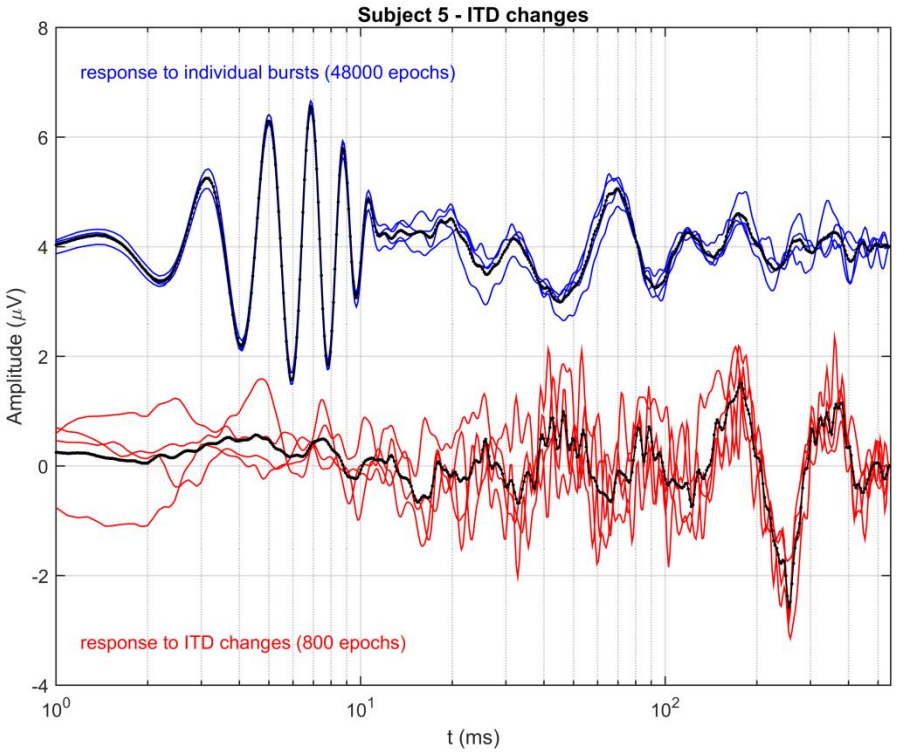


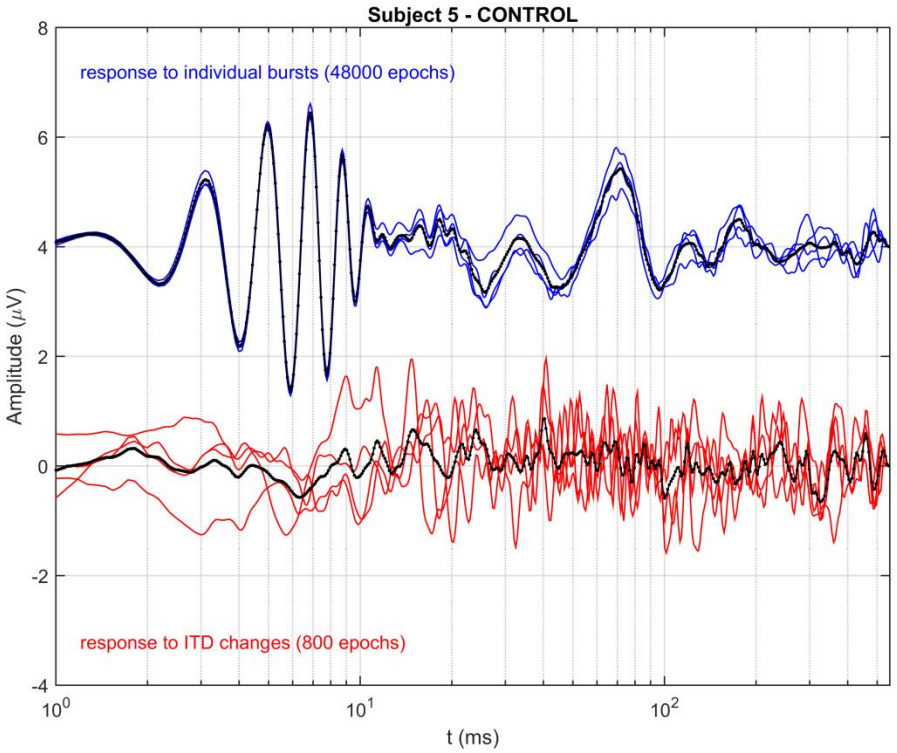
Results: subject 4



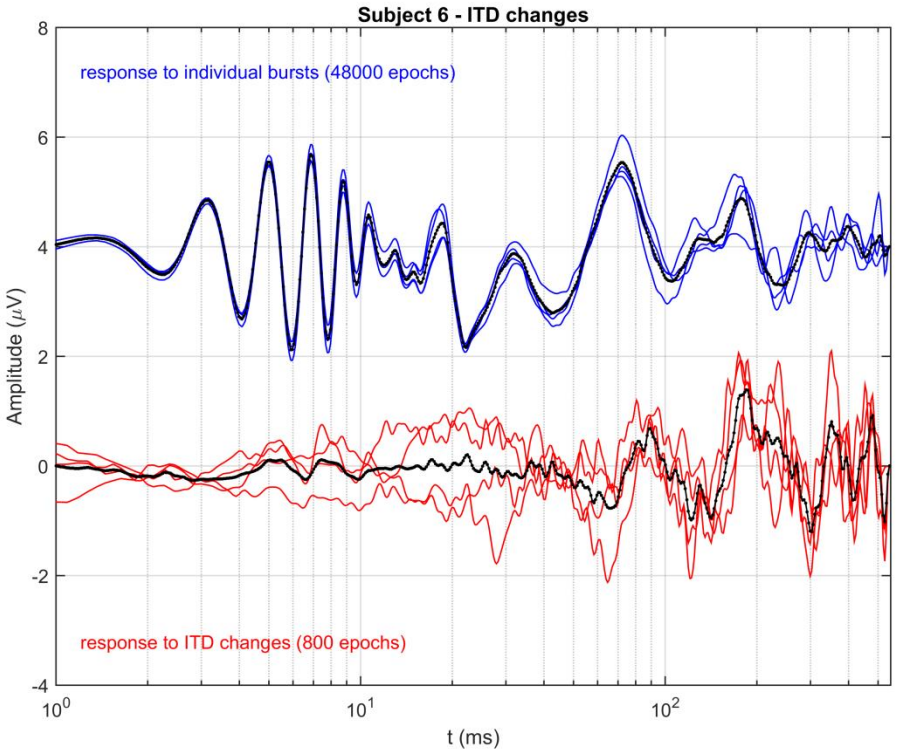


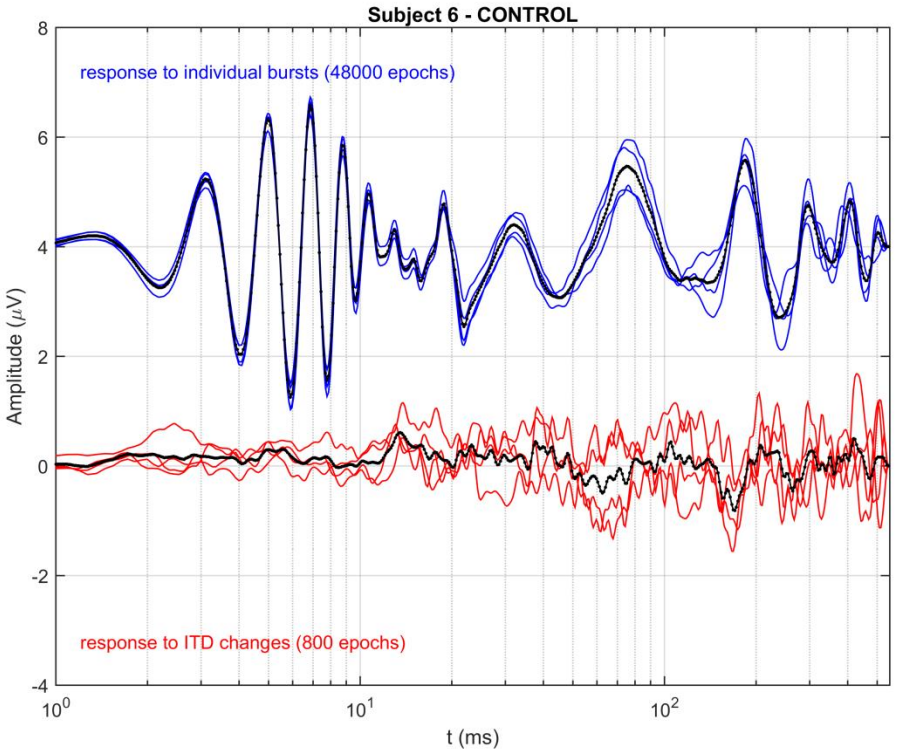
Results: subject 5



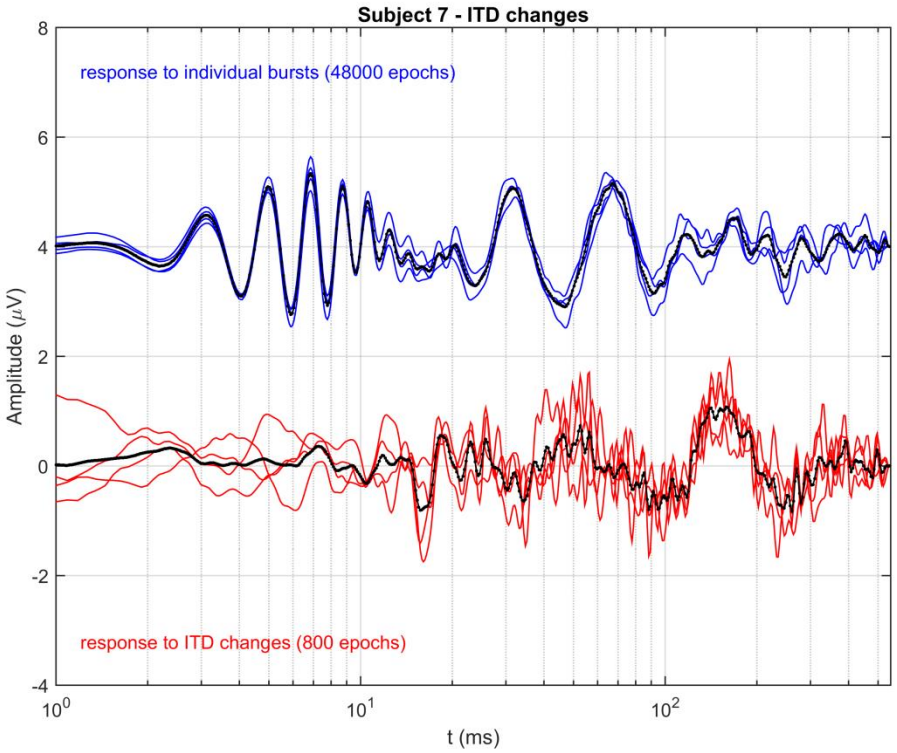


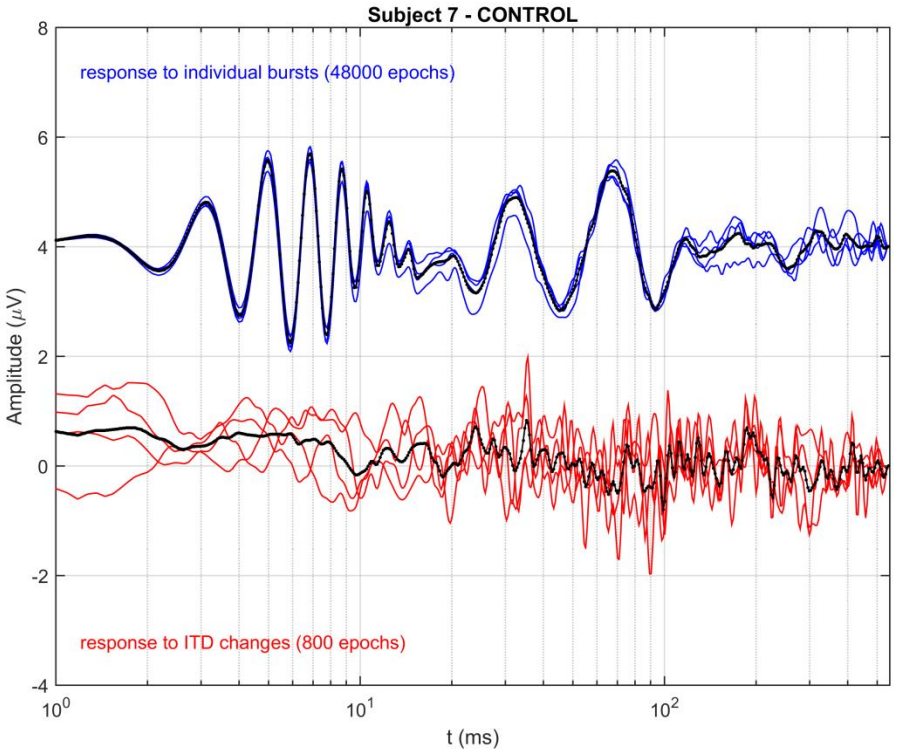
Results: subject 6



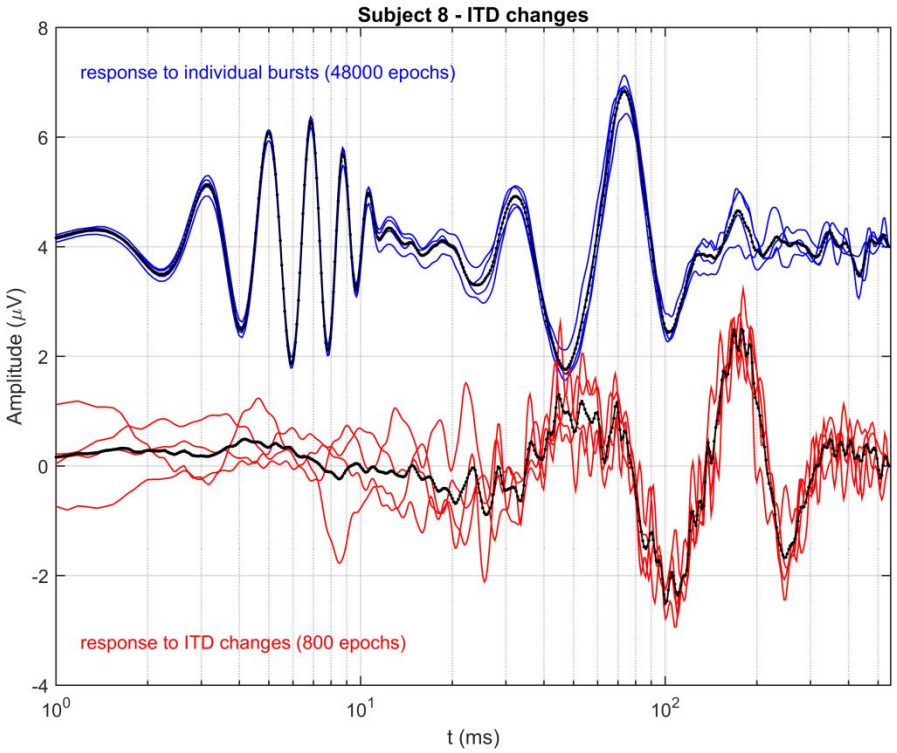


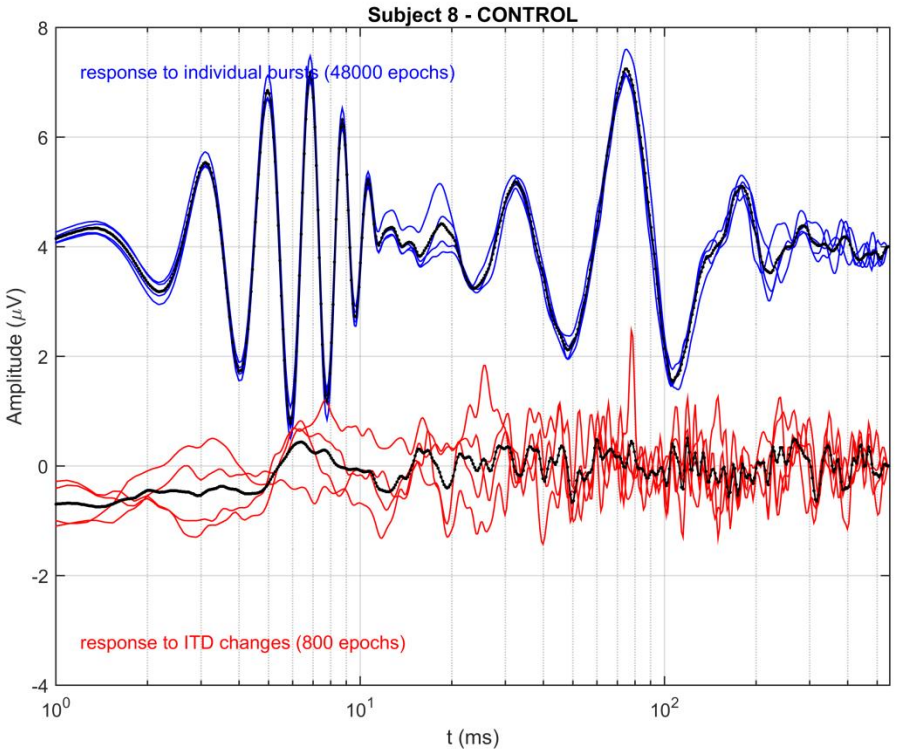
Results: subject 7



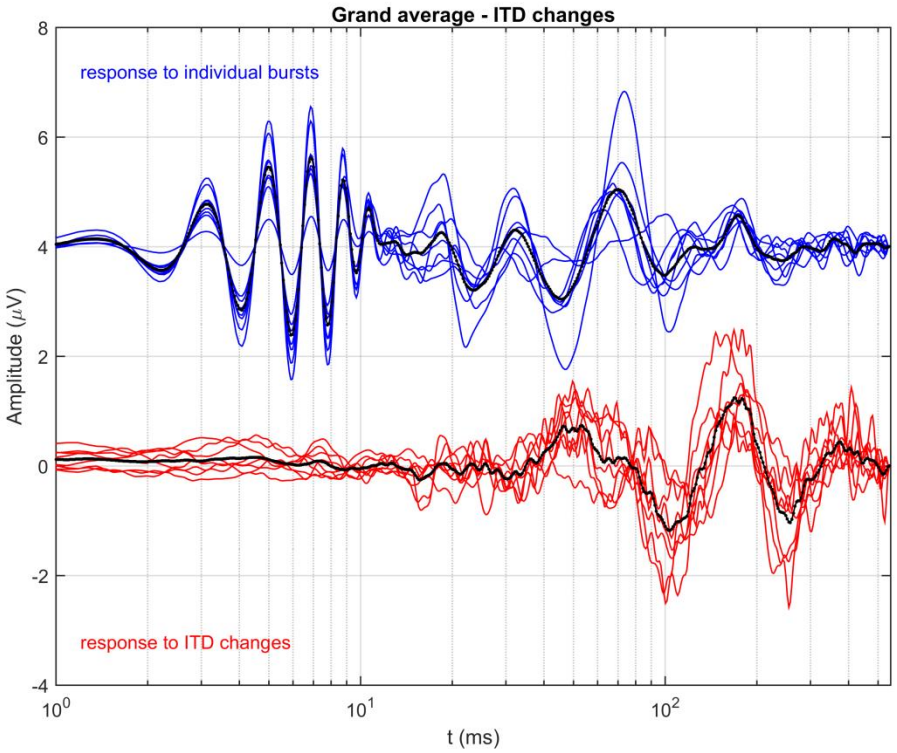


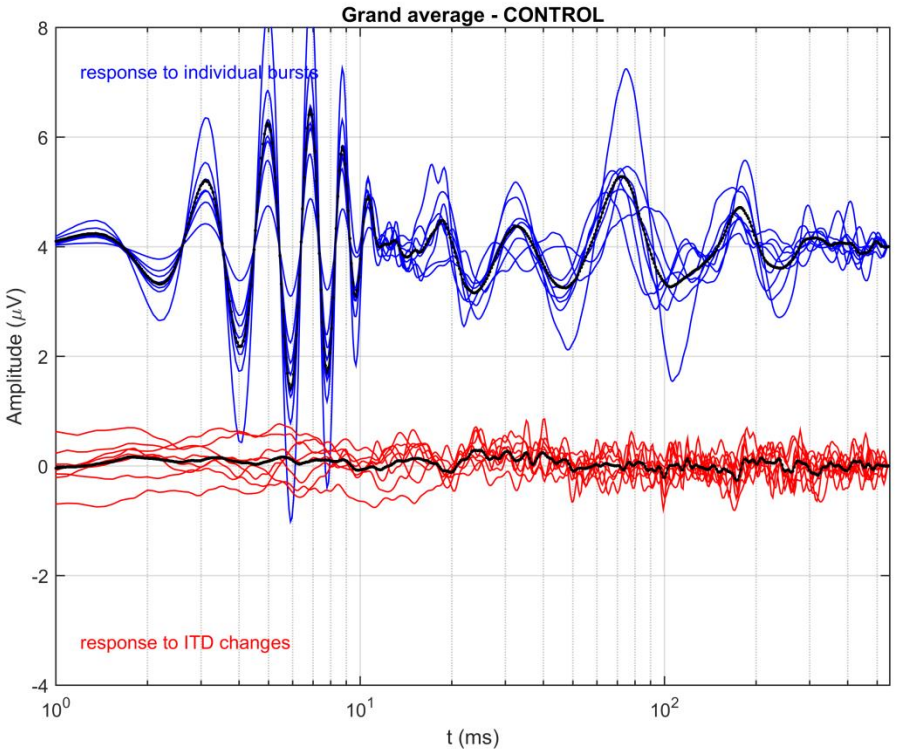
Results: subject 8

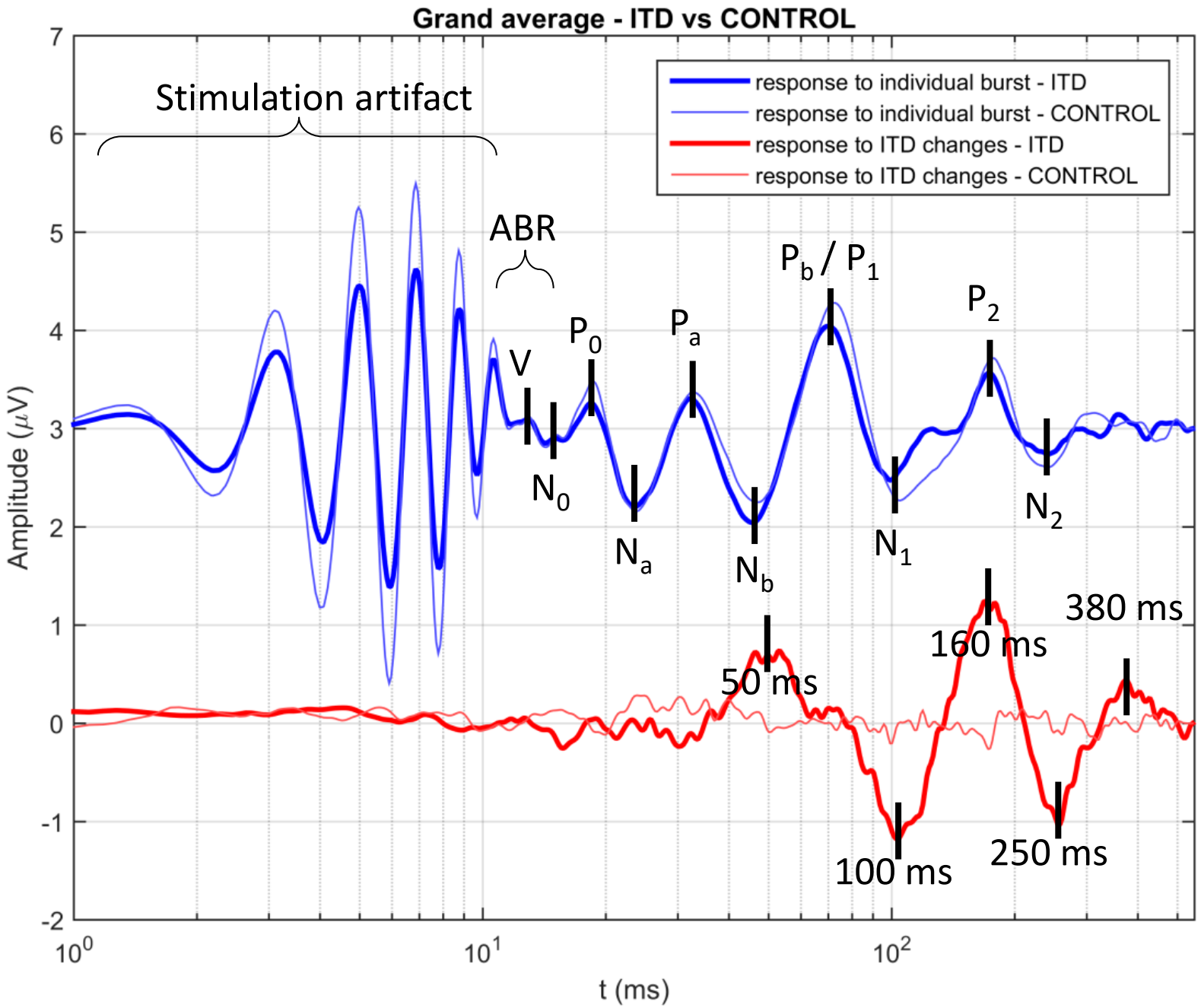




Results: Grand average






Grand average - ITD vs CONTROL
response to individual burst - ITD
response to individual burst - CONTROL
response to ITD changes - ITD
response to ITD changes - CONTROL
Stimulation artifact
ABR
V
N0
P0
Na
Pa
Nb
Pb / P1
N1
P2
N2
50 ms
100 ms
160 ms
250 ms
380 ms
Amplitude (μV)
t (ms)
7
6
5
4
3
2
1
0
-1
-2
10^0
10^1
10^2

Conclusions

- Procedure for obtaining evoked response associated with binaural perception
- Evoked response associated to ITD-changes
  - Design of the stimulus
  - Deconvolution methods
- Better understanding of binaural perception
- Objective measure of binaural activity
- Objective assessment of auditory disorders related with binaurality

Thanks for your attention!

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