# Temporal interaction of pulses in cochlear implants

BAI Bio-Inspired Information Processing

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## ABSTRACT

Speech coding strategies in cochlear implants suffer from channel interaction and temporal interaction of pulse sequences. Earlier studies showed that simultaneous stimulation produces large interaction effects but even non-simultaneous stimulation has a significant effect. The influence of inter pulse distance (IPD) on interaction was previously attributed to refractory effects and investigated in masking experiments.

In this study, we investigated temporal interaction of two individual biphasic pulses at variable distance in cochlear implant patients. The first of the two pulses was subthreshold with a fixed charge in relation to the channel's threshold. This first pulse preconditions the auditory fibers for the following next pulse, the probe. This double pulse constellation with different IPDs allows us to evaluate temporal interaction in the range from 20 µs up to 20 ms. We tested the interaction by threshold adjustment of the probe amplitude (6 subjects on apical and / or middle electrode, pulse phase 40 µs, single pulses 4 Hz).

The main result is that a subthreshold pre-pulse significantly reduces the probe threshold (up to 18% ± 7%, pre-pulse amplitude 20% below threshold, IPD=20 µs). The interaction between two successive pulses lasts at least 300 µs. It grows with increasing (subthreshold) pre-pulse amplitude and decreases with IPD.

This interaction will impact coding strategies, therefore it is important to predict and correct not only simultaneous interactions but also temporal interactions.

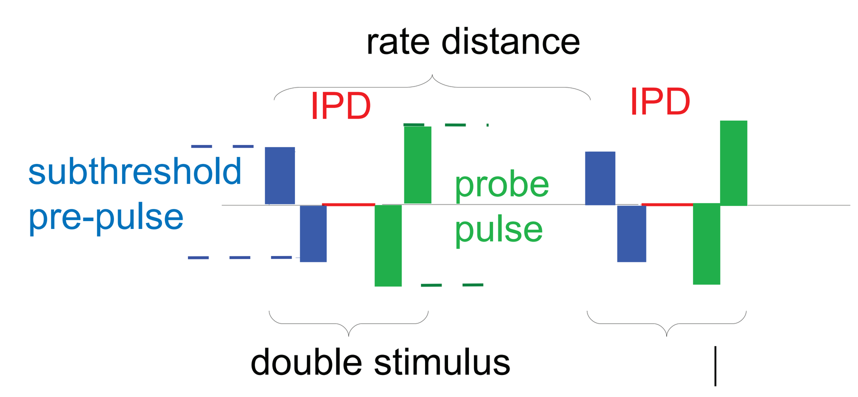
## Methods

We tested 6 subjects of age 40.8± 11.7 (mean±std). They were experienced CI listeners (implanted > 1 year) with the Med-El device PulsarCI100. 5 subjects are postlingually deafened one prelingually.

The stimuli for the Med-El Pulsar devices were applied directly via the RIB II (research interface box) provided by the University of Innsbruck. Stimuli were presented at electrode 1 (most apical) and electrode 6 (middle) for all subjects.

Subjects were ask to adjust stimuli at hearing threshold (method of adjustment). Each measurement was repeated 5 times. First, we determined the threshold of the probe stimuli. Second, we determined the threshold of the combined double stimulus with fixed subthreshold pre-pulse by varying the probe amplitude.

## Stimuli




Double sitmuli were given at a stimulation rate of 4 Hz. Biphasic pulse parameters are: phase 40 µs, gap 30 µs, polarity anodic starting for the pre-pulse and cathodic starting for the probe pulse. The IPD was varied in the range of 20 µs to 20480 µs.

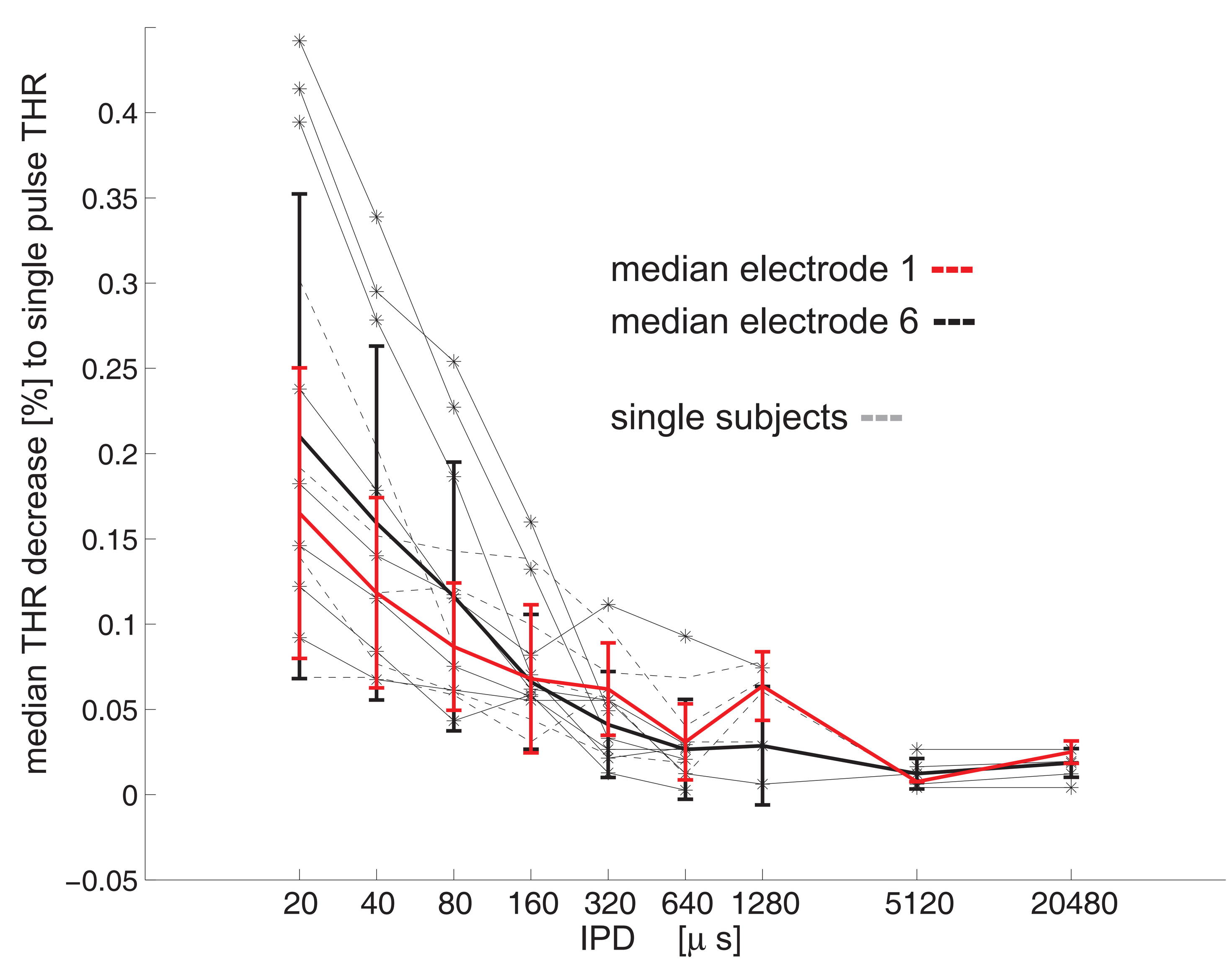
Subthreshold level ot the pre-pulse was 20 % below threshold. The amplitude of the probe pulse was adjusted to hearing threshold while the pre-pulse amplitude kept fixed which guarantees a certain amount of charge to precondition the neuronal response of the second probe stimuli.

## Results: temporal interaction causes threshold decrease

The result of two succesive stimuli is a change of the threshold which we measured at the probe amplitude. This indicates that a prestimulus thoug it is subthreshold influences the following pulse. This leads to a threshold shift for the following probe pulse.

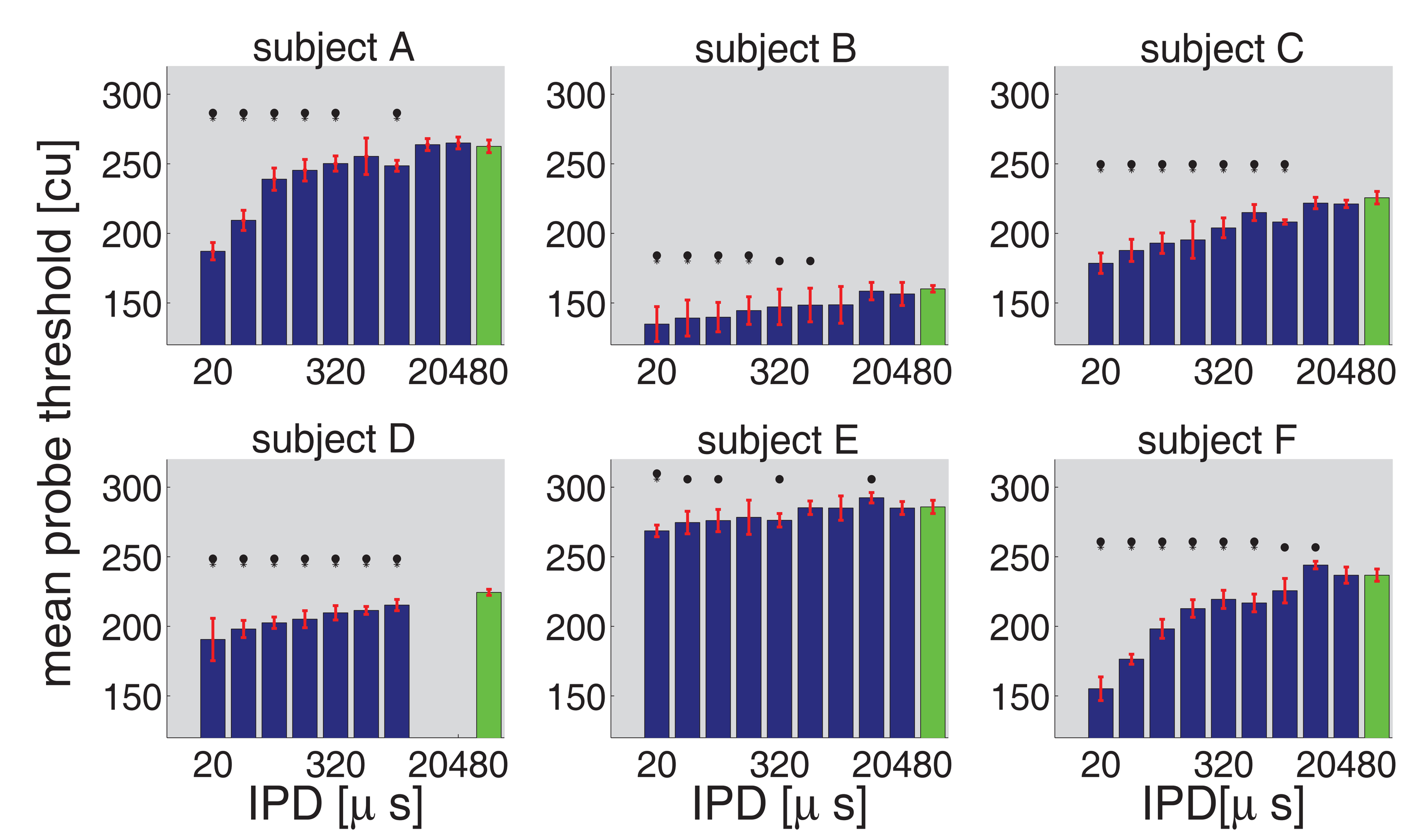
With our double stimulus the effect was threshold reduction for the probe pulse. The reduction effect was largest for the shortest IPD at 20 µs and decreased monotonically for longer IPDs. The threshold reduction effect lasted for up to 1280 ms.

For all subjects we tested the threshold reduction effect in comparison to the original single pulse threshold was significant up to 320 µs (paired t-test $p<0.05$).

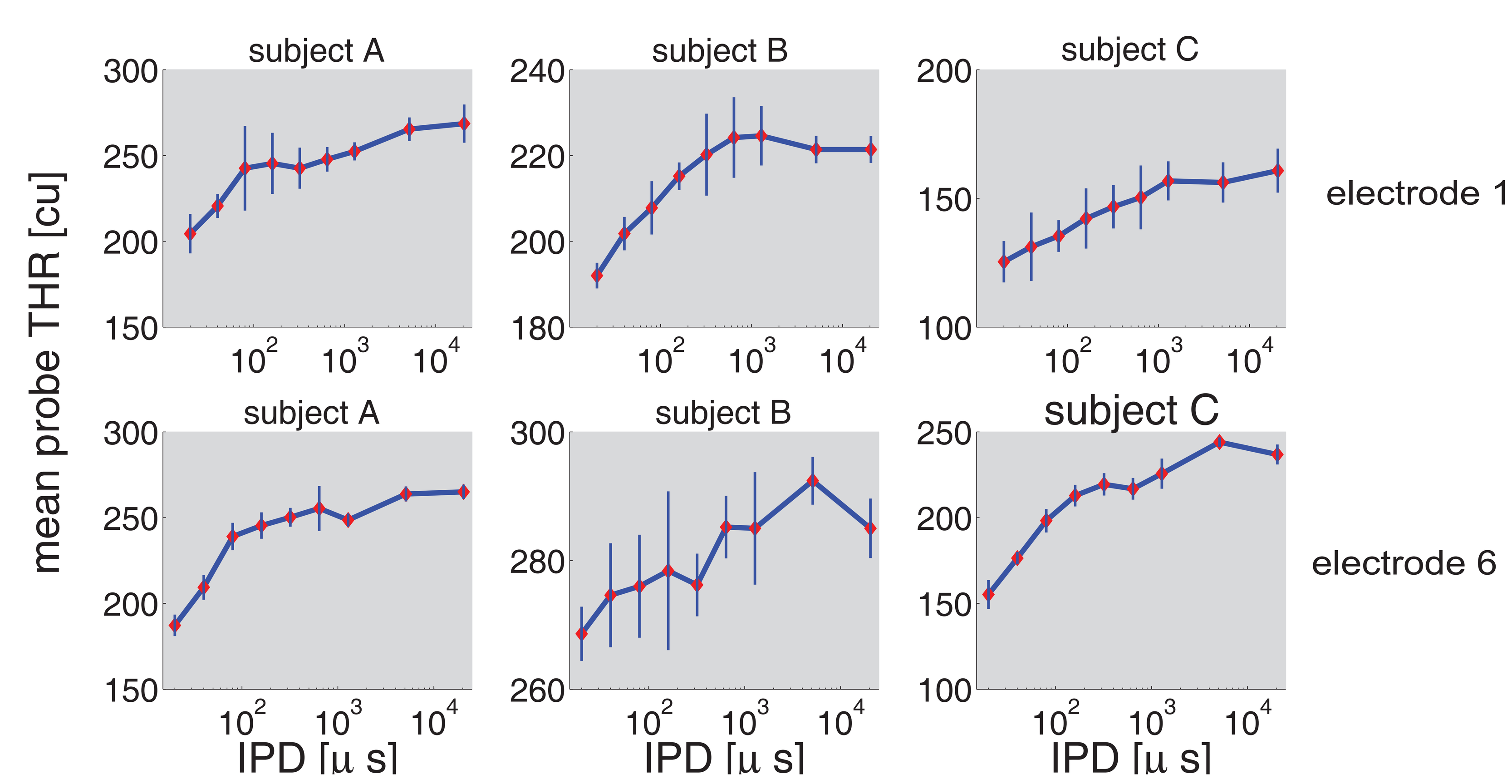



A threshold decrease effect is shown for all subjects and electrodes over IPD. The threshold decrease is given as median over all subjects and normalized in percent of the single probe pulse threshold. The threshold effect is not different between the two electrodes. The median threshold decrease for both electrodes is about 15 to 20% (median 16% ± 6%) at a pulse distance of 20µs.

The effect varies between subjects because of very different absolute threshold values and different dynamic ranges in electrical amplitudes. The threshold reduction effect decreases over time. With more than 1ms IPD no temporal interaction effect is visible.




Mean threshold of the probe for 6 subjects at the middle electrode. The reference value (green) is the single probe pulse threshold. The marked thresholds (stars) are significantly different to the single pulse threshold. The variation in measurements is indicated by the standard deviation (red lines).




Mean threshold THR of the probe for 3 subjects at the apical electrode Nr.1 (three upper graphs) and the middle electrode Nr.6 (three lower graphs).

## References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## Conclusion

In summary, our measurements revealed significant temporal interaction effects from sub-threshold pulses. We expect that mostly neuronal dynamics are responsible for the observed temporal interaction effects, which we will analyze in the next step with model calculations.

This interaction will impact coding strategies, therefore it is important to predict and correct not only simultaneous interactions but also temporal interactions.