P080

Auditory Implants

Exploring Temporal Mechanisms of Pitch Perception Using the Apical Electrodes of a MED-EL Cochlear Implant

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INTRODUCTION

Most cochlear-implant (CI) signal-processing strategies are based on Continuous Interleaved Sampling (CIS), which band-pass filters the input signal and extracts its envelope at the filter output, which is then used to modulate the amplitude of a fixed-rate pulse train (*Fig. 1C*). As such, **CIS largely discards temporal fine structure (TFS) information**[(1)].

To convey the TFS of incoming signals, MED-EL's **Fine Structure Processing (FSP) strategy**[(2)] detects the positive zero-crossings in the band-pass filter output (*Fig. 1A*), which then triggers a short burst of pulses (*Fig. 1B*) to the 4 most apical electrodes (e1-e4).

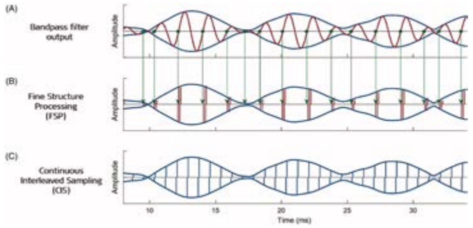

***Fig. 1.** Stimulation with the FSP strategy at the apical electrodes (A-B). CIS is applied to all other electrodes (C). Figure courtesy of Dhanasingh and Hochmair (2021).*

For the FSP strategy to work:

I. Temporal pitch perception should be accurate at the apex of the cochlea (Exp. I)

II. The pitch of a harmonically-related multi-electrode stimulus should be (Exp. II):
- **Equal to its fundamental frequency (F_0)**
- **Unaffected by inter-channel interactions**

EXPERIMENT I

METHOD:

Participants: 8 experienced MED-EL users

Procedure:
- **Place-pitch ranking** of e1 to e4 using the midpoint comparison (MPC) procedure[(3)]
- **Rate-pitch ranking** of 8 pulse rates (80-981 pps) using the MPC procedure for:
  - (i) single-electrode apical (e1) stimulation
  - (ii) single-electrode mid (e8) stimulation
  - (iii) simultaneous multi-electrode apical (e1-e4) stimulation
- Neural health measured at e1 and e8 by the **polarity effect (PE)** = detection threshold difference between 99-pps triphasic pulses with cathodic (TP-C) vs. anodic (TP-A) dominant polarity[(5)]

RESULTS:

- 4/8 patients demonstrated apical (e1/e2) place-pitch confusions
- The upper limit of temporal pitch did not differ between the 3 stimulation conditions (*Fig. 2*)
- Rate-pitch ranking was not correlated to place-pitch ranking or the PE

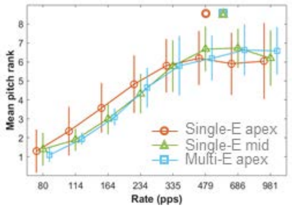

***Fig. 2.** Mean rate-pitch ranks and SD as a function of pulse rate and stimulation condition. Coloured shapes at the top of the graph indicate the upper limit estimates.*

EXPERIMENT II

METHOD:

Participants: 8 experienced MED-EL users

Procedure: **Rate-pitch ranking** of 11 multi-electrode stimuli (*Fig. 3*), presented to e1-e4 and including a simple approximation of the FSP strategy ([1234]xSD, shown by box), using the MPC procedure

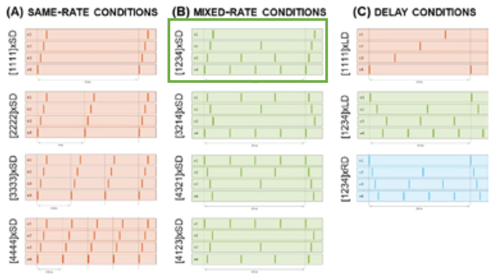

***Fig. 3.** Visualisation of 10 ms of the 11 multi-electrode stimuli used in Experiment II. [numbers]*100 refer to the rate that was applied to e1-e4. SD = 100-µs Short Delay; LD = maximised Long Delay; RD = Reversed Delay.*

RESULTS:

- The pitches of harmonically-related mixed-rate stimuli were ranked between 100 and 200 pps (*Fig. 4*)
- Maximising the inter-electrode delay (SD vs. LD) increased the pitch of both same- and mixed-rate stimuli
- Stimulation order (SD vs. RD) did not affect the pitch rank

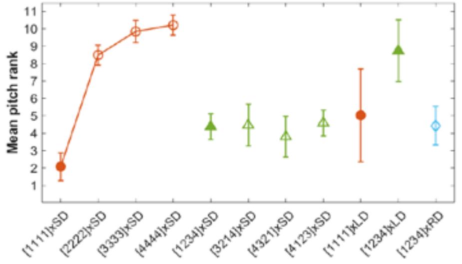

***Fig. 4.** Mean rate-pitch ranks and SD as a function of stimulation condition.*

DISCUSSION

I. There is no justification for conveying TFS cues specifically or exclusively to the apical electrodes in order to increase the upper limit of temporal pitch - in line with earlier studies[(5)].

II. There is no evidence that presenting multiple harmonically-related rates to different apical electrodes elicits a pitch percept at F_0. In addition, the pitch was affected by between-channel interactions.

Additional findings (not shown): (i) the PE correlated with the average threshold and (ii) the PE did not differ between apical and mid-array stimulation, contrary to some model predictions[(6)].

Practical implications: Strategies that deliver a different temporal code to each electrode are likely to elicit a complex pattern of auditory-nerve responses as a result of spread of excitation, which might additionally vary with frequency-dependent phase distortions (e.g., due to reverberation[(7)]).

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