The Effect of Stimulation Rate and Number of Maxima on Music and Speech Perception for CI patients

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Background & Literature

- Cochlear Implant (CI) Research
  - Well documented as a hearing prosthesis for profound hearing loss\(^1\)
  - Speech focused due to primary goals in CI design targeting speech and language perception
  - Speech perception outcomes able to be reasonably good\(^2\)
  - Limited studies on CI music perception and effects of CI parameters on music perception
Quick refresher on CI parameters..

- **Stimulation rate**
  - Rate of electrical pulses delivered to the auditory nerve from the implant

- **Number of Maxima**
  - Number of peaks selected from all the active channels to deliver the impulses through based on the Advanced Combination Encoding (ACE) algorithm
Key studies on stimulation rate & maxima for CI recipients

- **Arora et al (2009)**
  - Overall best speech performance with *stimulation rate between 500Hz to 900Hz* when testing 275Hz/350Hz/500Hz/900Hz³

- **Plant et al (2002)**
  - Overall best speech performance at *8 maxima and no further improvement with further increase* when testing 6/8/12/16 maxima⁴

- **Kang et al (2009)**
  - Pitch discrimination intervals average around *three semitones but range from one to 8 semitones*⁵
Can we improve speech and music perception by changing the stimulation rate and number of maxima?
Method

- Participants
  - 5 Singaporean bilateral/bimodal CI users aged 16 to 57
  - Cochlear Nucleus 5/Nucleus 6 processor w/ 6 months experience
  - CI24M or later electrode array w/ minimum 20 intra-cochlear electrodes in use
  - English-speaking
  - ACE strategy
Method (cont’d)

Three Test Conditions

- **Base**
  - Stimulation Rate = 720Hz
  - Maxima = 8

- **High Rate Condition (HRC)**
  - Stimulation Rate = **1800Hz**
  - Maxima = 8

- **High Maxima Condition (HMC)**
  - Stimulation Rate = 720Hz
  - Maxima = 20
Method (cont’d)

- **Test Battery**
  - **Music Perception Tests**
    - University of Washington – Clinical Assessment of Music Perception (UW-CAMP)
      - Pitch ranking task
    - Music Quality Rating Test (MQRT)
      - Subjective music ratings
  - **Speech Perception Tests**
    - CNC50
      - Monosyllabic words in quiet
    - Australian Speech Test in Noise (AuSTIN)
      - Open-set sentences in noise
Method (cont’d)

- Reading Span Test
  - Verbal working memory to check if working memory affected perceptive test results

- Music Background Questionnaire
  - Gather information on formal music training, self-rated music ability and music listening habits
Results & Findings

- Between-subject analyses: **no statistically significant differences** from changing the stimulation rate and number of maxima on perceptive tests.

- Within-subject analyses: **variable clinically significant differences** within each participant from changing the stimulation rate and number of maxima on perceptive tests.
UW-CAMP

Pitch Discrimination Threshold

Subject

*Lower scores are better
CNC50

CNC50 Words % correct

*Higher scores are better

Subject

Word % score

SG1 SG2 SG3 SG4 SG5 Group Mean

CNC50 Words % correct

*Higher scores are better

Subject

Word % score

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CNC50 Words % correct

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Discussion

- Integrating **between-subject findings** with previous studies
  - Arora et al (2009): Best speech perception with stimulation rate at 500 to 900Hz + variable results when increasing stimulation rate from 720Hz to 1800Hz => **Increasing stimulation rate beyond 900Hz to 1800Hz may not improve speech perception**
  - Plant et al (2002): Best speech perception no lesser than 8 maxima + variable results when increasing number of maxima => **increasing number of maxima beyond 8 up to 20 may not improve speech perception**
  - Kang et al (2009) Pitch discrimination results from our findings were consistent with the findings from Kang et al’s study => **Average of 3 semitones, range from 1 to 8 semitones.**
Conclusion

- Changing the stimulation rate and number of maxima may result in variable effects on the patient’s speech and music perception.
- Effects on speech and music perception are mutually exclusive.
- Effects on subjective music quality suggest different parameters may affect different aspects of music listening for different CI candidates.
- Answer to research question: Yes, improvement to speech or music perception is possible, but results vary across individuals.
Limitations & Future Research

- Small sample size - affects statistical analyses
  - Future studies will benefit from larger sample size allowing more accurate statistics and trends to be found

- Non-localised speech samples – affects speech scores due to accent differences
  - Beer can - > beacon
  - They are playing -> the air plane
  - Future studies can use localised speech samples to avoid accent unfamiliarity

- No acclimatisation period to test MAPs – test result may not accurately reflect test performance, introduces bias toward base MAP due to familiarity
  - Allow user to have time to get used to the new MAPs, results may change with familiarity

- More research into other parameters and their effects on music e.g. pulse width, inter-stimulus interval, etc
References


4. Parameter selection and programming recommendations for the ACE and CIS speech-processing strategies in the Nucleus 24 cochlear implant system

5. Development and validation of the University of Washington Clinical Assessment of Music Perception test
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Q&A
UW-CAMP: Pitch Test

Select which note sounded higher in pitch

1  2
MQRT (1-3)

Please rate the sound quality of each musical piece on the scales provided. There are no right or wrong answers. This is solely your opinion about how each song sounds through your cochlear implant.

- **Pleasantness**
  - Unpleasant
  - Pleasant

- **Naturalness**
  - Unnatural
  - Natural

- **Richness**
  - Tinny
  - Rich
Please rate the sound quality of each musical piece on the scales provided. There are no right or wrong answers. This is solely your opinion about how each song sounds through your cochlear implant.

Fullness
- Fullness
- Fuller
- Just Right
- Emptier

Sharpness
- Sharper
- Just Right
- Duller

Roughness
- Rougher
- Just Right
- Smoother

Save ratings and move to next song
Test Setup