Cochlear Implant-Mediated Perception of Polyphonic Pitch

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Introduction

- The ability of cochlear implant (CI) users to perceive music remains severely limited.
- Pitch mapping represents the greatest obstacle to successful perception of music in CI users.
- The majority of studies of CI-mediated perception of music have focused on melody or instrument recognition, while no studies have examined perception of polyphony.
- We hypothesized that CI subjects, as a result of diminished pitch resolution, would show decreased ability to differentiate between single vs. multiple pitches in comparison to normal hearing controls (NH).

Methods

- Participants were postlingually-deafened CI users (n=12; mean age 54.1±13.1 yrs) with ≥1 year of experience and NH controls (n=12; mean age 33.1±12.1 yrs).
- Subjects were presented in a soundbooth with 72 free-field auditory stimuli consisting of 1,2, or 3 pitches (single, interval, chord) within a single octave (f_0 = 261-523 Hz) presented simultaneously.
- Both pure tones and piano tones were included. Stimuli were normalized by RMS value and by equal-loudness contour (ISO 226:2003).
- Subjects were asked to identify the number of pitches heard. For CI users, contralateral earplugs were used to diminish the effects of any residual hearing.
- Notes were mathematically distributed across the octave to minimize over- or under-representation of any given note.

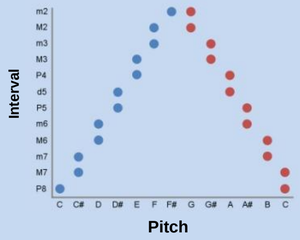


Figure 1: Pitches and musical interval spacing of the intervals.

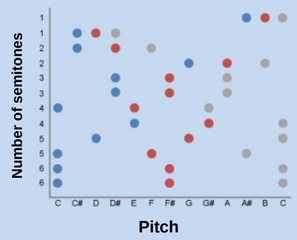


Figure 2: Pitches and semitone spacing of the chords.

Results

	CI	NH	t-test
All Stimuli	43.1 ± 12.3%	66.9 ± 9.4%	p<0.001
Pure Tones	41.7 ± 13.3%	62.0 ± 12.8%	p<0.001
Piano Tones	44.4 ± 14.8%	71.8 ± 16.0%	p<0.001
1 Note	69.1 ± 18.6%	90.6 ± 9.9%	p=0.0026
2 Notes	29.1 ± 14.1%	60.4 ± 14.8%	p<0.001
3 Notes	30.9 ± 20.0%	49.6 ± 13.0%	p=0.0136

Table 1: Mean performance accuracy of each subject group with standard deviation and t-test p-value for each stimulus type.

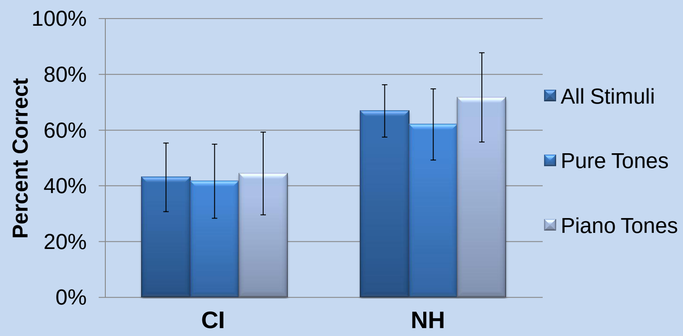


Figure 3: Performance accuracy of each subject group for all stimuli (n=72), pure tones (n=36), and piano tones (n=36).

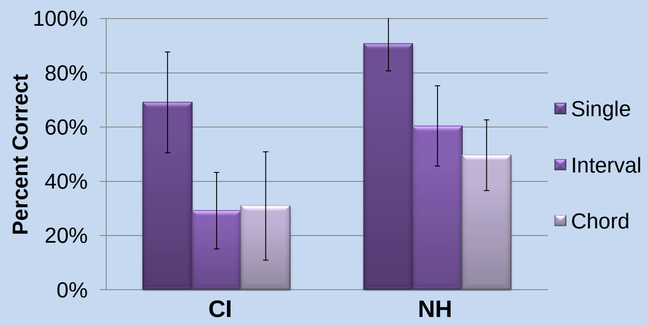


Figure 4: Performance accuracy of each subject group for single notes (n=24), intervals (n=24), and chords (n=24).

CI Confusion Matrix			
Presented	**Identified**		
Cnt Cor Class. %	**Single**	**Interval**	**Chord**
Single	**199 69.1%**	63 21.9%	26 9.0%
Interval	136 47.2%	**84 29.2%**	67 23.3%
Chord	112 38.9%	86 29.9%	**89 30.9%**

NH Confusion Matrix			
Presented	**Identified**		
Cnt Cor Class. %	**Single**	**Interval**	**Chord**
Single	**260 90.3%**	24 8.3%	2 0.7%
Interval	63 21.9%	**174 60.4%**	53 18.4%
Chord	23 8.0%	122 42.4%	**143 49.7%**

Table 2: Confusion matrix for CI (above) and NH (below). The rows represent the category of the sound presented and the columns represent the category of the response given.

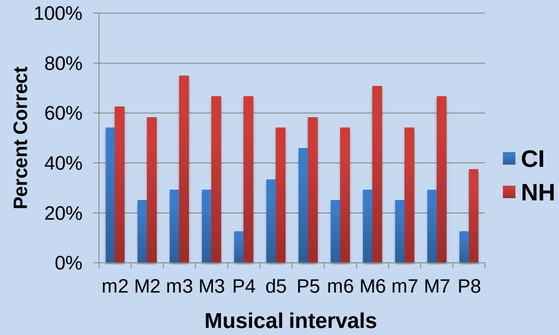


Figure 5: Performance accuracy for intervals as a function of note spacing.

Figure 6: Performance accuracy for chords as a function of semitone spacing.

Conclusions

- Polyphonic pitch perception is poor in CI users.
- CI users identified intervals and chords at below chance levels, and demonstrated perceptual fusion of multiple notes as single pitch units.
- In comparison, NH were much more successful at distinguishing single from multiple pitches, but demonstrated difficulties at distinguishing between two and three note combinations presented simultaneously.
- No statistically significant differences between pure tones and piano tones for either group.
- Limitations in polyphonic pitch separation are likely to underlie poor perception of harmony in CI users and require further attention in order to improve cochlear implant-mediated perception of music.