# Pitch Ranking of Complex Tones using a Model of the Virtual Channels in the Nucleus Freedom System

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## Introduction

Nucleus Cochlear Implant (CI) devices provide 22 stimulation channels that stimulate 22 intracochlear positions. Increasing the number of stimulation channels is expected to improve perception of musical notes. One way to increase the number of currently available electrode arrays would be to use Virtual Channels (VC) formed by stimulating two adjacent electrodes simultaneously. It was shown in [1] that VC stimulation can result in the perception of an intermediate frequency between adjacent electrodes. One approach to study the effect of VC on music perception is to examine tone discrimination for 43 and 22 Channels with complex and pure tones to avoid the effect of overtones in different frequency ranges (155-207Hz, 311- 415Hz and 554- 830Hz) and with different semitones (ST) distances.

## Hypothesis

43 Channel mode increases frequency representation. This could help in musical note discrimination, leading to better discrimination of smaller semitone distances than with 22 channels.

## Materials

A CI acoustic model is used to simulated CI patients using Normal Hearing (NH) subjects. The model assumes that there is no change in effective stimulation width between 43 and 22 channels.

Test tones were initially taken from the RWC Music Database [2]: Instrument no. 31 (clarinet), variation 1, normal articulation, and mezzo dynamics were chosen for this experiment. Initial analysis showed that the temporal pattern of the partials in the clarinet tones varies a lot from certain tones to others, providing additional cues which the test subjects might use instead of the pitch to identify the different tones. To minimize these additional cues, all tones were altered to have the same amplitude envelope, and had duration of 0.5 sec. The starting and ending of all tones were faded with 30 msec attack and release times.

## Methods

Sound samples were prepared using clarinet tones (experiment 1) and pure tones (experiment 2). Pure tones were used to determine the effect of harmonics. Three tones (D#, F and G#) 1, 3 and 6 semitones higher than the reference tone (D) from octaves 3, 4 and 5 (figure 1) were processed using an acoustic CI model, whose resynthesis consisted of the superposition of modulated narrowband noise signals with bin to channel allocation used in CI processors. A pair of processed notes (1 test and 1 reference) was then presented and the subject was asked to state which one was higher in pitch. The test consisted of presenting a total of 9 pairs of sounds, each pair being repeated 8 times and randomized. The test was repeated 3 times for each subject. 4 normal hearing (NH) subjects took part in this pilot test.

## Procedure

All tones were processed using 22 and 43 channels with the acoustic model using a stimulation width of 1mm. Sound samples were then normalized to have equal loudness. NH subjects were seated in front of a loudspeaker at a distance of 1.5 m. Sounds were presented at a level of 70 dBA. Macarena [3] software was used to play a set of two notes that was randomly chosen from the 3 octave groups. The group was also randomly selected to minimize learning effects of notes sequence. For each group the same number of repetitions was presented. The tone pairs were presented sequentially with a pause in between of 0.5 sec. The same reference note (D) was used for different groups. Levels were roved ± 6 dB to avoid loudness cues from being used.

## Results

Experiment 1 used complex tones processed with the acoustic model where 4 NH subjects were tested. A test of variance (ANOVA) showed that there is no statistically difference between 22 and 43 channels with a significance level of 95%.

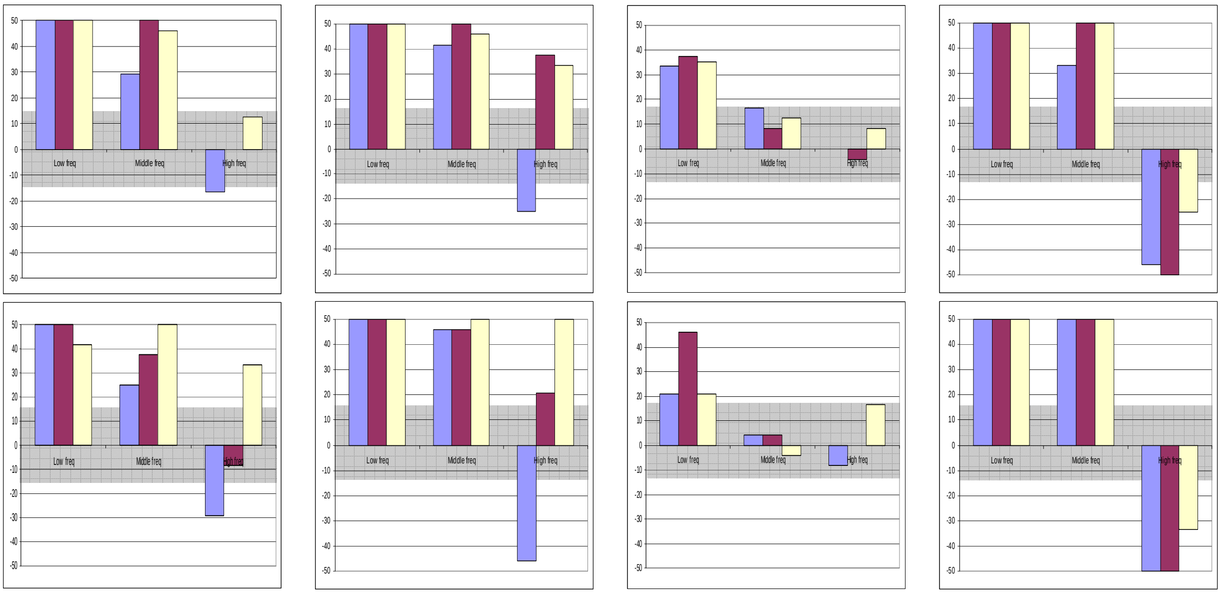

*Figure (1): Results of 43 (1st row) and 22 channels (2nd row) for 1 ST (Violet), 3 ST (Red) and 6 ST (Yellow) in the low, middle and high frequency ranges for complex to. Shaded area is a chance level.*

The results showed that:

1-Semitone differences for lower octaves are easier to discriminate.

2-Different notes have different pitch and timbre which sometimes may mislead the subject.

Two-way ANOVA (mode and subject) showed that the results are subject dependent at the 95% significance level for all modes.

Experiment 2 used pure tones processed with the acoustic model where the same 4 subjects were tested. An ANOVA test showed that there is also no statistically difference between 22 and 43 channels with significance level of 95%.

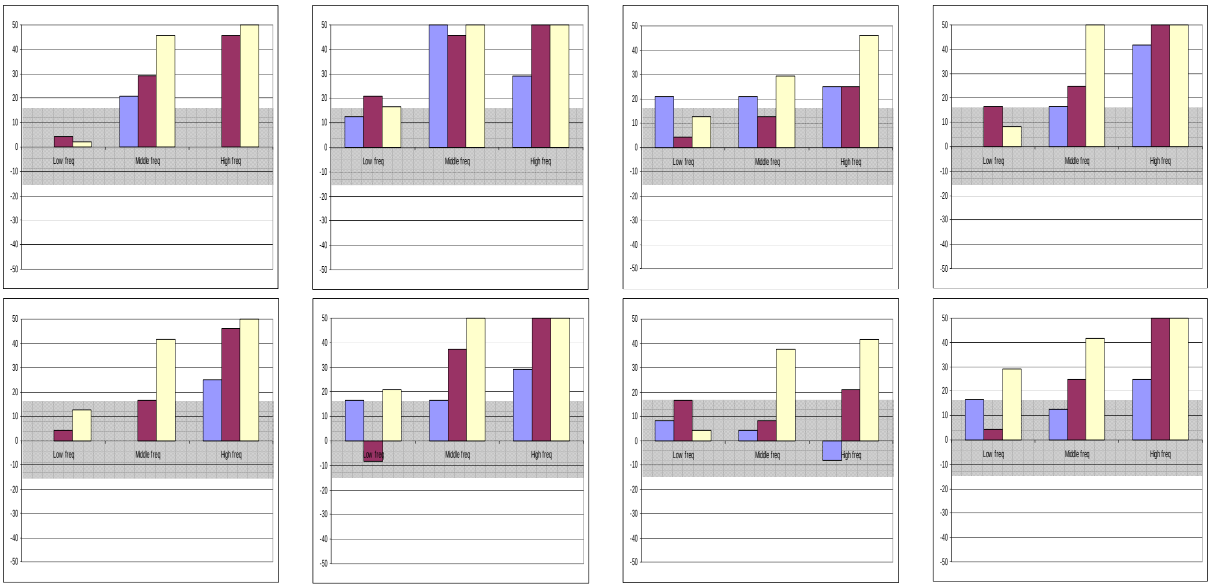

*Figure (2): Results of 43 (1st row) and 22 channels (2nd row) for 1 ST (Violet), 3 ST (Red) and 6 ST (Yellow) in the low, middle and high frequency ranges for pure tones. Shaded area is a chance level.*

The results showed that:

All subjects show the expected trend in pitch ranking performance: 6 ST difference is easier than 3 and easier than 1 ST.

Semitone discriminability for pure tones in the lower octave range are more difficult than those with complex tones

## Discussion

The acoustic model used a noise band in the resynthesis algorithm with a stimulation band of 1 mm. This was chosen to be a little bit bigger than the inter-electrode distance of Nucleus Implants (0.75mm) with the assumption that this mimics some CI patients that might benefit from the virtual electrode due to having a small width of stimulation. If the acoustic model used sinusoidal waves for the resynthesis, the results would have been almost like the results from the second experiment with an increasing trend with the semitone increase but this would be misleading even if another implant model was used [4].

## Summary

Two tests are carried out, one using complex tones and the other using pure tones. In the first test the subject hears two tones with 1, 3 and 6 ST difference and is asked to state which tone is higher in pitch, while in the second test only the fundamental component of the tones is used. In both test, all tones are processed with an acoustic model that uses noise band of 1 mm stimulation width in the resynthesis algorithm. The results obtained from the pure tone test follow an increasing trend with the increase of ST difference between tones and they are different from the results of the complex tone.

## Conclusion

Pitch ranking performance of normal hearing listeners for CI simulations of pure tones is different from the performance for CI simulations of complex tones. A slightly different timbre is a cue that might affect pitch discrimination.

The differences between 43 and 22 channel modes using standard frequency to channel mapping are not statistically significant, neither with pure nor complex tones.

## References

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