Music Perception by Cochlear Implant Users

Joseph Crew[1] and Qian-Jie Fu[1,2]
[1]Department of Biomedical Engineering, USC, Los Angeles, CA
[2]Department of Auditory Implants and Perception, House Ear Institute, Los Angeles, CA

1. Introduction

Many deaf patients can achieve good speech understanding in quiet conditions with a cochlear implant (CI). However, music perception and appreciation remains a major challenge for CI users. Most CIs represent the entire spectrum of sound using 16 to 22 electrodes. While this coarse spectral resolution may be adequate for speech recognition, it is not sufficient to code musical pitch information [1]. This study aims to identify music perception tasks that are especially difficult for CI users.

2. Methods

In this study, pilot data was collected and analyzed for 6 CI subjects. Subjects were recruited without regard to musical training or experience, device type, or device configuration. All subjects had more than 2 years of implant experience. Subjects were tested using their clinically assigned speech processors and settings. All stimuli were presented in a sound treated booth at 65dBA via a single loudspeaker. CI subject performance was evaluated using several music perception tasks and one speech-in-noise task. Table 1 shows detailed information for each subject. Note that a unilateral user is someone with a CI in one ear, a bilateral user is someone with a CI in both ears, and a bimodal user is someone with a CI in one ear and a hearing aid in the other ear.

Table 1: Detailed information for each subject.

	Age	Years w/ CI	Model	Configuration	Etiology
S1	64	5	F	unilateral - left	Meniere's
S2	53	5	F	unilateral - right	Familial
S3	61	11	H	unilateral - left	Sudden
S4	61	16	H (left), C (right)	bilateral	Ototoxicity
S5	67	14	H	unilateral - right	Birth Defect
S6	73	2	F (right)	bimodal	Noise Damage

** F – Nucleus Freedom, H – Advanced Bionics Harmony, C – Advanced Bionics Clarion*

3. Speech-in-Noise Test

Speech Reception Threshold (SRT) – SRTs are defined as the signal-to-noise ratio (SNR) needed to produce a score of 50% correct in a sentence recognition task. The stimuli were HINT sentences presented in speech babble. During testing, a sentence was played at a target SNR. If the subject repeated more than 50% of the words correctly, the SNR was reduced by 2 dB; if the subjected repeated less than half of the words correctly, the SNR was increased by 2 dB. The SRT was calculated as the average of eight reversals in SNR.

4. Music Tests

1. Musical Note Discrimination – This task is a three-alternative forced-choice (3AFC) procedure in which three musical notes were played. Two of the notes were identical, and the third was different. Subjects were then asked to click on the box which corresponded to the different note. This task was used to measure CI subjects' ability to discriminate acoustic frequencies in isolation.

2. Melodic Contour Identification (MCI) – For this test, subjects were asked to identify the target contour by clicking on one of the nine response choices shown in Figure 1. The target contours consisted of five notes of equal duration and equal timing. The frequency spacing between successive notes in the contour was varied between 1 and 6 semitones.

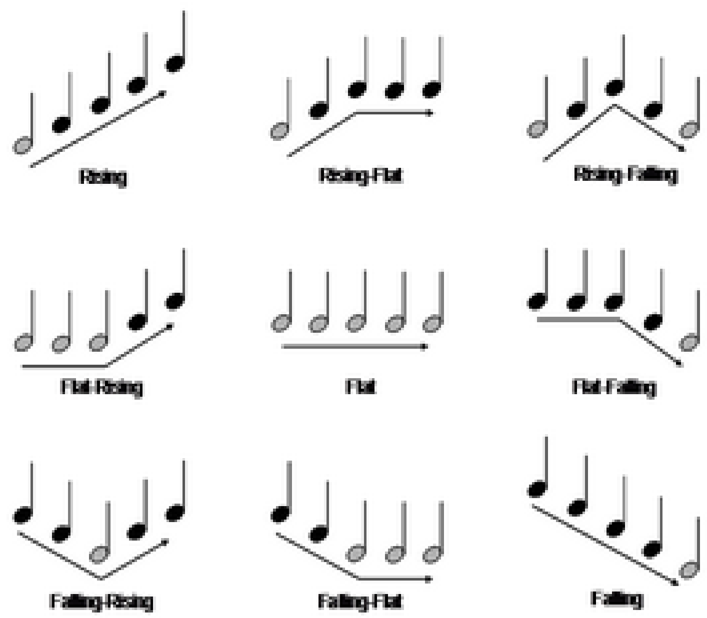

Figure 1: Nine melodic contours used in the MCI and MCS tests.

3. Melodic Contour Segregation (MCS) – This task is identical to the MCI task except a competing instrument is also played along with the target contour. The masking contour was always flat. This task was performed twice: once with a competing instrument that is overlapping spectrally with the target stimulus (A4), and once with a competing instrument that is much higher than the pitch range of the target contours (A7).

4. Musical Chord Identification – A simple major or minor chord (three notes, no inversions) was played to the subject. The subject was then asked to identify whether the stimulus was a major or minor chord.

5. Musical Instrument Identification – Subjects were asked to identify which instrument played a simple five-note test melody (Rising, Falling, or Flat contours in Fig. 1) from among six different response choices. Figure 2 shows the possible responses.

Figure 2: Six instruments used in the Musical Instrument Identification task: piano, violin, trumpet, clarinet, organ, and glockenspiel.

6. Familiar Melody Identification – Subjects were asked to correctly identify familiar melodies presented to them. The stimuli consisted of the first one or two phrases of 12 familiar melodies. Figure 3 shows the 12 different response choices. This task was performed under two different circumstances: once with the rhythm (timing) cues intact, and once with the rhythm cues removed. With the rhythm cues removed, all of the notes were of equal duration, and the timing between notes was constant (i.e. there were no pauses).

Yankee-Doodle	Twinkle-Twinkle Little-Star	Star-Spangled Banner	Old-MacDonald had-a-Farm
This-Old-Man	She'll-be-Comin' Round-the-Mountain	Mary-had-a Little-Lamb	Lullaby-and-Goodnite
London-Bridge-is Falling-Down	Happy-Birthday to-You	Take-me-out-to the-Ballgame	Auld-Lang-Syne

Figure 3: Twelve familiar melodies used in the FMI tasks.

5. Results

Figure 4 shows the music perception results for these six subjects. The SRT scores for subjects S1 through S6 were 11.3 dB, 5.0 dB, 6.1 dB, 1.9 dB, 12 dB, and 4.6 dB respectively.

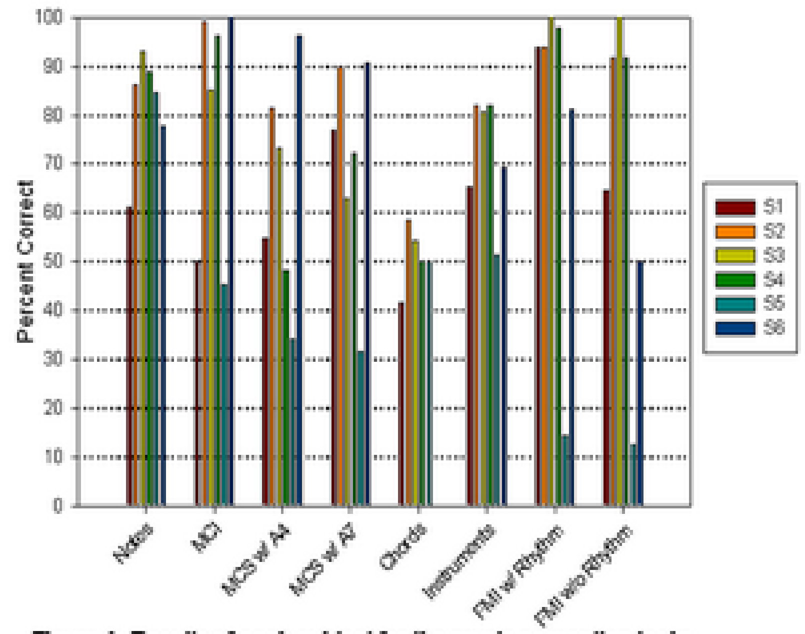

Figure 4: Results of each subject for the music perception tasks.

6. Discussion

In terms of mean performance, the most difficult task was major/minor chord identification, followed by MCI with an overlapping masker, FMI without rhythm cues, MCI with a non-overlapping masker, musical instrument identification, MCI with no masker, FMI with rhythm cues, and finally, musical note discrimination. As with previous studies, the results showed a wide range in CI subject performance. The FMI and MCI tasks exhibited very high across-subject variability, while the major/minor chord identification task exhibited relatively low variability (because all subjects performed at chance-level). MCI performance was poorer with a competing masker, and FMI performance was worse, for some subjects much worse, when the rhythm cues were removed.

In general, CI performance was much poorer when multiple notes were presented in unison (i.e., MCI with or without a masker, note discrimination vs. chord identification).

References:

[1] R.V. Shannon, Q.J. Fu, J.J. Galvin (2004) The Number of Spectral Channels Required for Speech Recognition Depends on the Difficulty of the Listening Situation. *Acta Otolaryngol Suppl (2004) 552*, 50-54.

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