Music to Electric Ears

Pitch and Timbre Perception by Cochlear Implant Patients

DANIEL PRESSNITZER,[a] JULIE BESTEL,[b] AND BERNARD FRAYSSE[c]

[a]*Equipe Audition, LPE-CNRS UMR 8581, Département d'Etudes Cognitives, ENS, 75230 Paris cedex 05, France*

[b]*Advanced Bionics Europe, Clinical Research Department, 68170 Rixheim, France*

[c]*Service ORL, Hopital Purpan, 31059 Toulouse, France*

ABSTRACT: The sounds of music play with many perceptual dimensions. We devised a set of psychophysical procedures to better understand how recipients of cochlear implants perceive basic sound attributes involved in music listening.

KEYWORDS: psychophysics; hearing impairment; melody; pitch memory

INTRODUCTION

The technology of cochlear implants (CIs) consists of directly stimulating the auditory nerve of profoundly deaf patients to restore some aspects of auditory function. Much research and progress has been made toward improving speech perception by cochlear implant recipients. However, music perception has not received the same amount of interest so far. Music is, however, an integral part of the auditory experience of each and every individual, and there is a growing demand from implant recipients for improvement of their musical experiences. Subjective assessments of music appreciation indicate that whereas rhythm cues are satisfactorily transmitted by the implant, other aspects of music may not be.[1] A common method of evaluating pitch perception consists of testing the recognition of familiar tunes; other performance measures use simple pitch discrimination tasks (for recent reviews, see Refs. 2 and 3). For timbre perception, which is also part of musical listening, performance measures address the recognition of musical instruments.[4] Recognition tasks rely on the familiarity of the listeners with the stimulus to be recognized, and a successful recognition can be attributed to many different cues. We aimed to address pitch and timbre perception by cochlear implant recipients using a set of psychophysical measures of performance that focus on distinct aspects of these musical attributes and that do not rely on the previous musical experience of listeners.

Address for correspondence: Daniel Pressnitzer, Equipe Audition, LPE-CNRS UMR 8581, Département d'Etudes Cognitives, ENS, 29 rue d'Ulm, 75230 Paris cedex 05, France. Voice: +33-1-4432-2673.

daniel.pressnitzer@ens.fr

Ann. N.Y. Acad. Sci. 1060: 1–3 (2005). © 2005 New York Academy of Sciences.
doi: 10.1196/annals.1360.050

PSYCHOPHYSICAL PROCEDURES TO TEST PITCH AND TIMBRE PERCEPTION

The first pitch task was a higher–lower pitch judgement. It is more complex than a discrimination task, because a ranking judgement is requested; however, it still addresses a basic level of pitch processing. The second task involved the comparison of two short random melodies.[5] Listeners first heard a four-note chromatic melody, and then the melody repeated with a pitch difference introduced in one of the notes at random. Their task was to indicate which note had been altered. This task is easy when presented to normal hearing listeners, even if they are nonmusical, provided that a pitch is clearly heard for each of the notes.[5]

Stimuli were bandpass-filtered harmonic complex tones delivered acoustically. The repetition rate of the tones was varied to control pitch, whereas the spectral region remained fixed. This meant that the fundamental frequency of the sounds (~100 Hz) was absent for most trials. Presentation level was roved to reduce cues unrelated to pitch.

The timbre tasks measured just-noticeable differences on two important dimensions of musical timbre: attack time and spectral center of gravity. These dimensions repeatedly appear in multidimensional scaling studies of timbre of musical instruments (e.g., McAdams *et al.*[6]), indicating that they underlie the more salient perceptual differences among instruments. Bandpass-filtered complex tones were again used. For the attack time, the spectral content of the sound was fixed, whereas the temporal envelope was varied. For the spectral center of gravity, the temporal envelope was fixed, whereas the rate of decay between successive harmonics was varied.

All tasks, pitches, and timbres were adaptive procedures with feedback and an N-alternative unforced choice.[7] A training period was included when listeners could ask for feedback before giving their answers.

PITCH, MELODIES, AND TIMBRE

We now describe the first results obtained with these objective tasks, obtained in the framework of a larger clinical study. Subjects were postlingually implanted patients using the Advanced Bionics HiRes™ stimulation scheme.

Listeners had higher–lower pitch-ranking thresholds ranging between 2 and 7 semitones. This is higher than what is observed with a non–age-matched control group (0.2 semitones), but it is in line with previous results.[3] The melody task, however, proved impossible for most implant recipients. Note that all intervals between the notes of the melodies were chosen to be larger than the pitch-ranking threshold for each individual listener. The control group, as expected, displayed ceiling performance for the melody task.

On both dimensions of timbre tasks that we investigated, implant recipients performed almost as well as the control group. The dimensions we investigated were not necessarily familiar to our listeners, and we could not describe in the experimental instructions how they would sound after being processed by the implant. After the feedback received during the training period, however, all listeners could perform the task to a good level of performance.

CUES TO MUSICAL SOUNDS PERCEPTION

Models of pitch perception show that pitch is correlated with spectral cues, fine structure temporal cues, and envelope cues.[5] The processing schemes of the implants as well as inherent limitations of electrical stimulation of the auditory nerve reduce both spectral and fine-structure cues. This could explain the reduced performance of implant recipients for the pitch-ranking task. The melody task raises another question. Memory for pitch is different from memory for other auditory attributes, in that it allows for the short-term encoding of more items.[8] Pitch, thus, is especially suited for conveying melodies that extend in time. If the percepts associated with repetition rate for implant recipients do not have the memorization characteristics of pitch, specific impairments in the perception of melodies would be predicted.

Discrimination along dimensions of musical timbre proved to be accurate in our group of implant recipients. We thus hypothesize that the processing scheme used in the implant provided informative timbre cues, even though they might be different from what listeners were used to hearing before implantation. The fact that these cues can subserve discrimination should allow for musical instrument recognition after some training.

ACKNOWLEDGMENTS

These data were collected as part of a multicentric clinical trial, with the support of Advanced Bionics. We thank Pr. Michel Mondain, Guy de Chauliac Hospital, Montpellier; Pr. Bruno Frachet, Avicenne Hospital, Bobigny; Pr. J.P. Bébéar, Pellegrin Hospital, Bordeaux; and Pr. Olivier Sterkers, Beaujon Hospital, Clichy.

[Competing interests: The authors declare that they have no competing financial interests.]

REFERENCES

1. GFELLER, K. *et al.* 2000. Musical backgrounds, listening habits, and aesthetic enjoyment of adult cochlear implant recipients. J. Am. Acad. Audiol. **11:** 390–406.
2. MCDERMOTT, H.J. 2004. Music perception with cochlear implants: a review. Trends Amplif. **8:** 49–82.
3. MOORE, B.C.J. & R.P. CARLYON. 2005. Perception of pitch by people with cochlear hearing loss and by cochlear implant users. *In* Pitch: Neural Coding and Perception. C.J. Plack *et al.*, Eds. Springer. New York.
4. LEAL, M.C. *et al.* 2003. Music perception in adult cochlear implant recipients. Acta Otolaryngol. **123:** 826–835.
5. PRESSNITZER, D., R.D. PATTERSON & K. KRUMBHOLZ. 2001. The lower limit of melodic pitch. J. Acoust. Soc. Am. **109:** 2074–2084.
6. MCADAMS, S. *et al.* 1995. Perceptual scaling of synthesized musical timbres: common dimensions, specificities, and latent subject classes. Psychol. Res. **58:** 177–192.
7. KAERNBACH, C. 2001. Adaptive threshold estimation with unforced-choice tasks. Percept. Psychophys. **63:** 1377–1388.
8. MCFARLAND, D.J. & A.T. CACACE. 1992. Aspects of short-term acoustic recognition memory: modality and serial position effects. Audiology **31:** 342–352.