Neurological & Behavioral Responses to Musical Features in Adolescent Cochlear Implant Users Before and After Intensive Music Training

B. Petersen[1,2], E. Weed[1,4], E. Pedersen[5], M. Hansen[1,3], S. Derdau[4], P. Sandmann[6], E. Brattico[7, 8], P. Vuust[1,2]

[1] Royal Academy of Music, Aarhus, Denmark, [2] Center for Functionally Integrative Neuroscience, Aarhus University Hospital, Aarhus, Denmark, [3] Department of Psychology and Behavioural Sciences, Aarhus University, [4] Department of Aesthetics and Communication - Linguistics, Aarhus University, [5] The Maersk Mc-Kinney Moller Institute, University of Southern Denmark, Denmark, [6] Cluster of Excellence "Hearing4all", Department of Neurology, Hannover Medical School, Germany, [7] Brain and Mind Laboratory, Department of Biomedical Engineering and Computational Science, Aalto University, Finland, [8] Cognitive Brain Research Unit, Institute of Behavioral Sciences, University of Helsinki, Finland

BACKGROUND & AIMS

Cochlear implants (CIs) are designed to provide deaf individuals with speech comprehension. Perception of music is challenging[1,2,3], but neural correlates of residual prerequisites for music perception have been found in postlingually deaf adult CI users and in children with CIs[4,5]. By contrast, little is known about music perception in the new generation of prelingually deaf adolescents who grew up with CIs. Recent studies, however, indicate that to keep pace with their normal hearing (NH) peers, supplementary measures of rehabilitation are important throughout adolescence[6]. Music training may provide a beneficial method of strengthening not only music perception, but also linguistic skills, particularly prosody.

This study aimed to investigate

1) the behavioral and neural correlates of music perception in prelingually deaf adolescent CI users and

2) the potential effects of an intensive musical ear training program on adolescent CI users' discrimination of music and speech.

PARTICIPANTS & METHODS

Eleven adolescent CI users (6 girls, M_{age} = 17.0 y) participated in a short intensive music training program formed by three elements: rhythm-training, singing and ear training. The active music making was supplemented with daily computer based listening exercises. Ten NH peers (2 girls, M_{age} = 16.2 y) formed a reference group, which followed standard school schedule and received no music training (Table 1).

Before (T1) and after (T2) the intervention period, both groups underwent EEG recordings and behavioral tests for perception of music and emotional prosody. EEG was recorded with a musical multifeature MMN paradigm[7], presenting a standard randomly violated by musical deviants (Figure 1). The MMN was measured as the peak amplitude at the Fz electrode site, within a 40 ms. window centered at the most negative point at 75 - 205 ms. Mixed-effects ANOVAs identified main effects of group, time and deviant type, and possible interactions between these effects. The behavioral data were analyzed using the non-parametric Wilcoxon signed rank test.

Group	Girls /Boys	Mean age at project start	Age range	Mean implant experience (y)	Uni-/bilateral implant
CI grp.	6/5	17.0 (SD 0.9)	15.6-18.8	9.47 (SD 4.2)	(2/9)
NH grp.	2/8	16.2 (SD 0.5)	15.3-17.0	-	-

Table 1. Demographic data for the 2 experimental groups.

RESULTS & STATS

For the adolescent CI users we found significant and consistent MMNs for timbre, intensity and rhythm deviants, but not for pitch. NH listeners produced significant MMNs for all six deviants. We found a significant main effect of Group (F=8.4; *p*=.009), mainly driven by larger mean amplitudes in the NH participants for deviants Pitch (t=-2,5; *p*=.02, Guitar (t=-2,3; *p*=.04) and Rhythm (t=-2,4; *p*= .03), compared to CI users (Figure 2). The analysis on MMN latencies showed a significant main effect of Group, (F=83.6; p<.001), driven by overall shorter MMN mean latencies in CI users than in the NH participants. We found no effect of training on either MMN amplitude or latency.

Behaviorally, the CI users improved their discrimination skills within all musical domains after training, resulting in a significant overall progress. In particular, discrimination of melodic contour and rhythm showed a significant progress. The NH group produced significantly higher average scores than the CI group at both sessions (Figure 3). We found no effect of the music training on discrimination of emotional prosody.

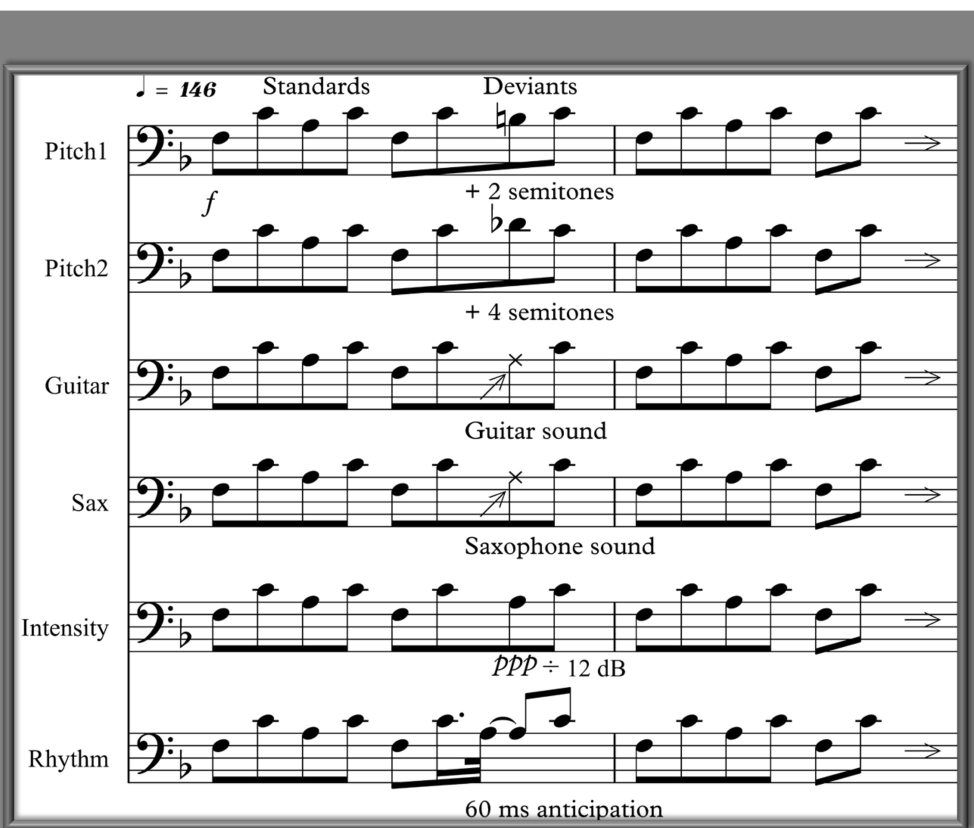

Figure 1. "Alberti bass" patterns alternating between standard sequence played with piano sounds and a deviant. Deviants were introduced randomly and patterns were pseudorandomly transposed to the keys of G, A or C. Each tone was 200 ms in duration, with an ISI of 5 ms. Comparisons were made between the third note of the standard sequence and the third note of the deviant sequence.

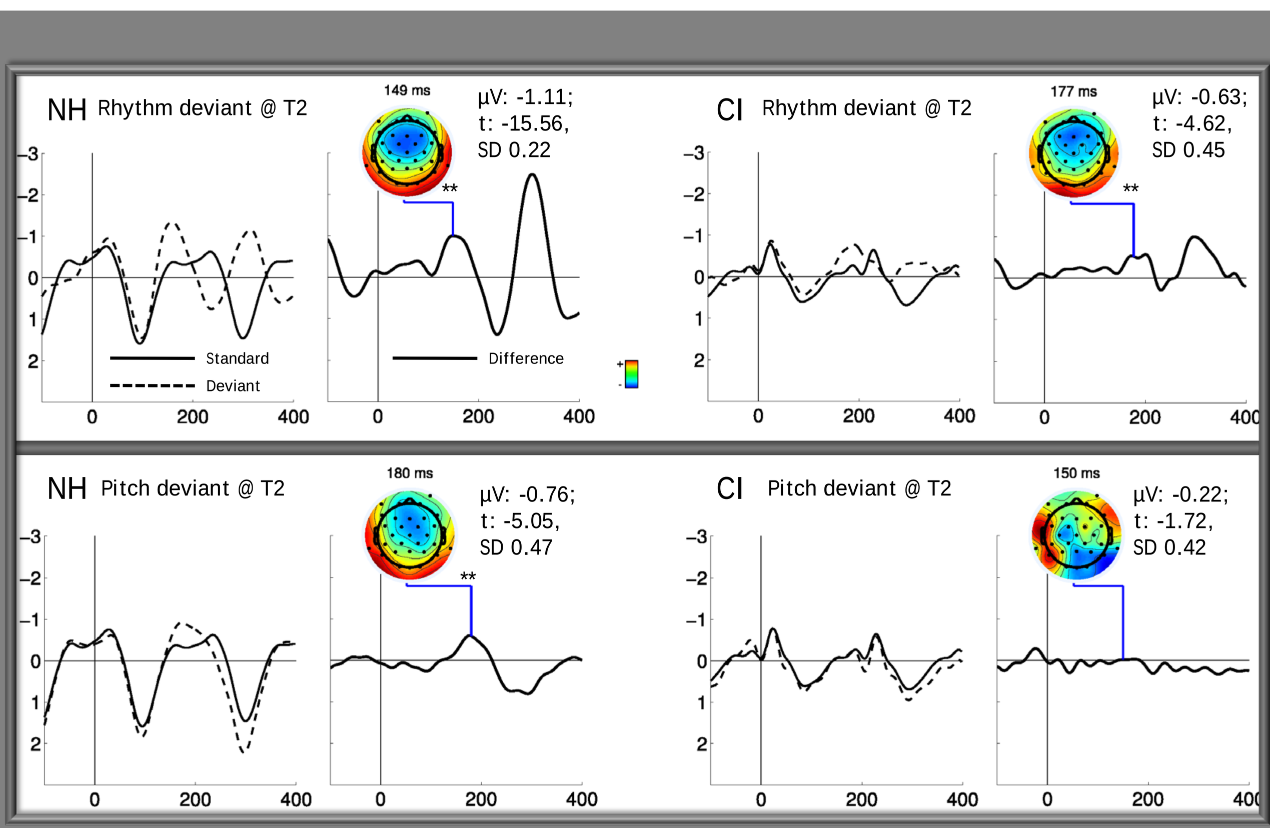

Figure 2. Grand average ERPs and EEG voltage isopotential maps for Rhythm and Pitch deviants in the two experimental groups at T2. For each deviant left panels show responses to the standard (solid line) and to the deviant (dotted line). Right panels show difference waves. Isopotential maps illustrate the difference between the responses to deviants and standards averaged in an interval of ±3 ms around maximal peak amplitudes.

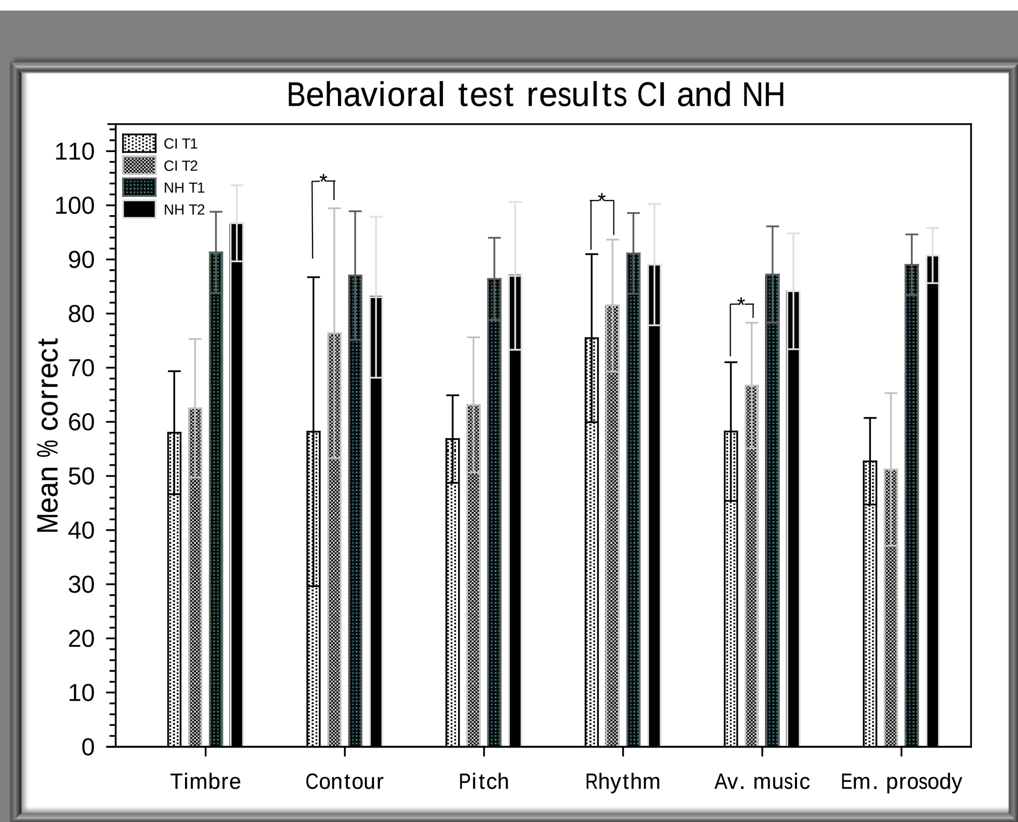

Figure 3. Behavioral scores for the two experimental groups at T1 and T2. Timbre: discrimination of 8 different musical instruments; Contour: identification of the direction of 5-note melodic patterns; Pitch: ranking of 2 pitches; Rhythm: discrimination of rhythm patterns; Av. music: overall music discrimination performance averaged across tests; Em. prosody: recognition of 3 different spoken emotions.

DISCUSSION

The findings of this study are novel, indicating residual neural discrimination prerequisites for musical feature changes in prelingually deaf adolescent CI users, who are late implanted and have only experienced the degraded sound from the implant. Moreover, behavioral discrimination of rhythm and melodic contour may be significantly improved, even from short term training. By contrast, detection of changes in pitch is poor and unaffected by music training. Finally, the multifeature MMN paradigm could be a useful tool for assessing auditory rehabilitation following cochlear implantation, also in a clinical context.

REFERENCES

[1] B. Petersen, et al., "Singing in the key of life: A study on effects of musical ear training after cochlear implantation,", *Psychomusicology: Music, Mind and Brain* (2012).

[2] W. B. Cooper et al., "Music perception by cochlear implant and normal hearing listeners as measured by the Montreal Battery for Evaluation of Amusia," *Ear and Hearing* (2008).

[3] K. Gfeller, et al., "Accuracy of cochlear implant recipients on pitch perception, melody recognition, and speech reception in noise," *Ear and Hearing* (2007).

[4] Sandmann, P., et al. Neurophysiological evidence of impaired musical sound perception in cochlear-implant users. *Clinical Neurophysiology*, (2010)

[5] Torppa, R. et al. Cortical processing of musical sounds in children with Cochlear Implants. *Clinical Neurophysiology*, (2012).

[6] A. Geers, et al., "Long-term outcomes of cochlear implantation in the preschool years: From elementary grades to high school," *International Journal of Audiology* (2008).

[7] P. Vuust, et al., "The sound of music: differentiating musicians using a fast, musical multi-feature mismatch negativity paradigm," *Neuropsychologia* (2012).

The Royal Academy of Music Aarhus / Aalborg

MUSIC IN THE BRAIN

Address for correspondence: Bjørn Petersen, Royal Academy of Music, Aarhus, Denmark/Center of Functionally Integrative Neuroscience, Aarhus University Hospital, Aarhus, Denmark.
Voice: +45 2728-7919. e-mail: bpe@musikkons.dk; bjorn@pet.auh.dk

CFIN

Aarhus University Hospital