# MUSIC IN THE BRAIN

## Music in the deaf adolescent brain

by Bjørn Petersen

### Digital hearing

The cochlear implant (CI) is a neural prosthesis that provides profoundly deaf individuals with the opportunity to gain or regain the sense of hearing. The implant transforms acoustic signals into electric impulses, which are delivered to an electrode array implanted within the cochlea. The electrodes stimulate intact auditory nerve fibers at different places in the cochlea, thus mimicking the tonotopic organization of the healthy cochlea. The clinical impact of the device is extraordinary, allowing postlingually deafened adults to restore speech comprehension and deaf children to acquire language. Perception of music with a CI is challenging, primarily because CIs are designed to provide recipients with speech comprehension[1, 2, 3]. Nevertheless, neural correlates of residual prerequisites for music perception have been found in postlingually deaf adult CI users and in children with CIs[4, 5].

### A new generation

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 aural 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. To gain new insight and test our hypothesis we initialized this study, aiming to investigate:

1. The behavioral and neural correlates of music perception in prelingually deaf adolescent CI users
2. The potential effects of an intensive musical ear training program on adolescent CI users' discrimination of music and speech

### Participants

The participants were all recruited from Frijsenborg Efterskole (post-school) in the city of Hammel, Denmark. Eleven adolescent CI users signed up for the study. The young CI users had a severe-profound/profound congenital or prelingual hearing loss and had received their CI at different points of time in childhood or adolescence (Mage at implant = 7.5 years; range: 2.2-14.9 years). The participants committed themselves to two weeks of music training. The program was based on three elements: rhythm training, singing and ear training. The active music making was supplemented with daily computer based listening exercises. Ten NH peers formed a reference group, which followed their everyday school schedule and received no music training (Table 1).

| 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 | 9.5 (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.

### EEG and tests

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 six musical deviants: 1) pitch deviant 1 (+2 semitones), 2) pitch deviant 2 (+ 4 semitones), 3) guitar deviant, 4) saxophone deviant, 5) intensity deviant (-12 dB) and 6) rhythm deviant (-60 ms) (Figure 1). The MMN was measured as the peak amplitude at the Fz electrode site, within a 40 milliseconds (ms) window centered at the most negative point at 75 - 205 ms. The behavioral tests included musical instrument identification, melodic contour identification, rhythmic discrimination, pitch ranking and emotional prosody recognition. 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.

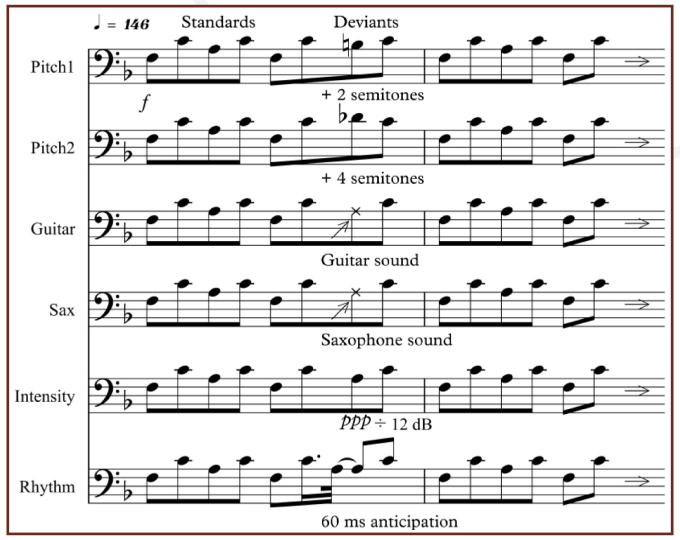


**Figure 1**
"Alberti bass" patterns alternating between standard sequence played with piano sounds and a deviant. Deviants were introduced randomly and patterns were pseudorandomly transposed to the keys of G, A or C. Each tone was 200 ms in duration, with an ISI of 5 ms. Comparisons were made between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

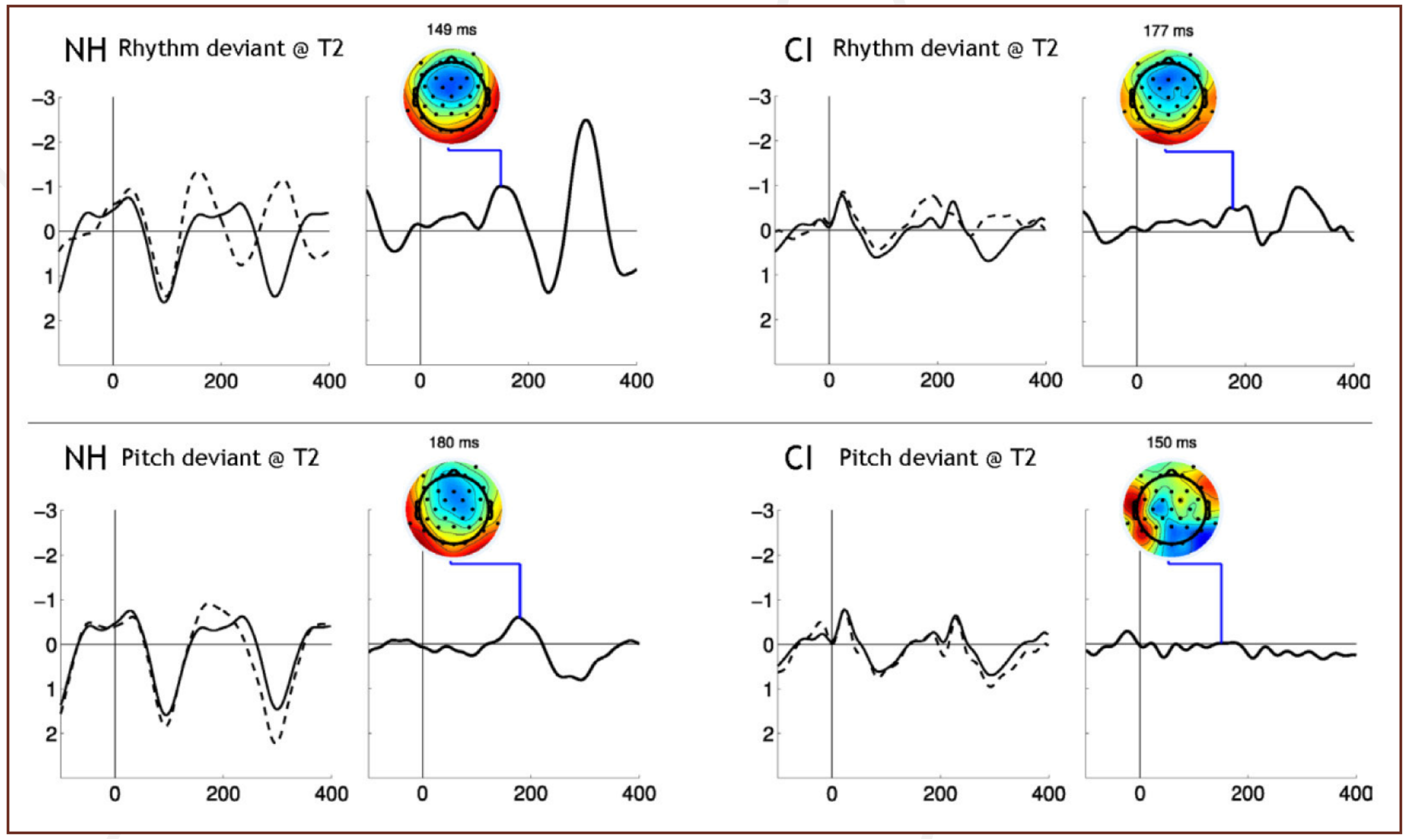


**Figure 2**
Grand average ERPs and EEG voltage isopotential maps for Rhythm and Pitch deviants in the two experimental groups at T2. For each deviant left panels show responses to the standard (solid line) and to the deviant (dotted line). Right panels show difference waves. Isopotential maps illustrate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

### Results

For the adolescent CI users we found significant and consistent MMNs for guitar, saxophone, intensity and rhythm deviants, but not for pitch. NH listeners produced significant MMNs for all six deviants, which were also larger in amplitude than those of the CI users. With regard to MMN latencies we found significantly 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 (Figure 2).

#### NEW FACE at CFIN

**Stine Derdau Sørensen**, research assistant, is MA in linguistics. Her main interest is how music training can affect language perception in cochlear implant users. She is currently affiliated with the Department of Otorhinolaryngology, Aarhus University Hospital, and works in close cooperation with the Music In the Brain group on developing a fun and motivating music training application for smartphones.

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 recognition of emotional prosody.

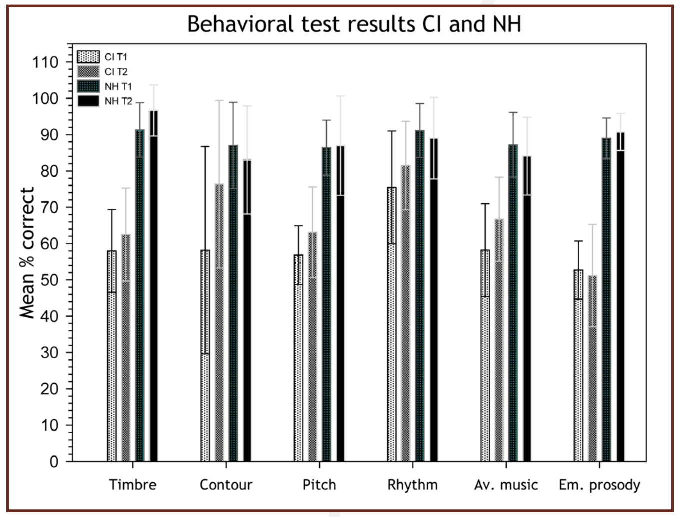


**Figure 3**
Behavioral scores for the two experimental groups at T1 and T2. Timbre: discrimination of 8 different musical instruments: Contour: identification of the direction of 5-note melodic patterns; Pitch: ranking of 2 pitches; Rhythm: discrimination of rhythm patterns; Av. music: overall music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

## Coda

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, whereas detection of changes in pitch is poor and unaffected by music training.

For most of the young CI users, this project was their first experience with structured and targeted music making and indeed challenging. Nevertheless, they generally responded with great enthusiasm and engagement to the different exercises and tasks. In particular, rapping and creation of rap lyrics proved appealing and relevant, and the participants exhibited a marked progress in their performance. Considering the fact that rap is speech, articulated in rhythmic phrases, it seems as an obvious path to follow for young CI users, both as a measure of training and a possible form of artistic expression. Maybe the world will one day see its first profoundly deaf rapper? Indeed that would mark the ultimate success of the cochlear implant.

Teenage CI users engaged in rapping
Photo:

This article is based on two studies:

1. Petersen, B., Weed, E., Sandmann, P., Brattico, E., Hansen, M., Derdau, S., Vuust, P: Brain Responses to Musical Feature Changes in Adolescent Cochlear Implant Users; Frontiers in Human Neuroscience, doi: 10.3389/fnhum.2015.00007
2. Petersen, B., Derdau S., Raben Pedersen, E. and Vuust, P: Perception of Music and Speech in Adolescents with Cochlear Implants – A Pilot Study on Effects of Intensive Musical Ear Training; The Danavox Jubilee Foundation. Presented at ISAAR, 2013.

## 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).
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5. R. Torppa, et al. "Cortical processing of musical sounds in children with Cochlear Implants", Clinical Neurophysiology (2012).
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7. P. Vuust, et al., "The sound of music: differentiating musicians using a fast, musical multi-feature mismatch negativity paradigm", Neuropsychologia (2012).