

CLINICAL APPLICATIONS OF MUSIC

Alberte Seeberg, Monica Ipsen, Andreas Højlund, Bjørn Petersen

Music in the lives of cochlear implantees

“With every mistake we must surely be learning”¹.

The song line by Harrison nicely paraphrases the essence of the predictive coding theory. Our understanding of the world is to a large degree based on erroneous presumptions made right. For patients with a hearing loss who must learn to listen through a cochlear implant (CI) this is particularly true, as every sound must be perceived, recognized and understood anew. This includes the sound of music which for many CI users is a long-lost life ingredient that they hope to be able to enjoy again. At MIB, researchers have a long history of studying music and CIs, recently reporting on a novel MMN-paradigm that can estimate musical discrimination abilities and thresholds in CI users². Here, we report on behavioral and qualitative data also collected as part of the study.

A tiny window of opportunity

The transmitted frequency range of a CI is approximately ~200 Hz to ~8500 Hz. This limited range negatively impacts music perception, especially impeding perception of pitch and timbre. Hence, CI users’ ability to identify musical instruments³ shows great variance and a performance which is generally poorer than that of normal hearing controls^{4,5}.

Another reported deficit is the reduced ability to discern dynamics or intensity in music, which is ascribed to the high level of compression in the CI-signal. This issue affects the ability to perceive the emotional effects of music, such as a dramatic buildup with a crescendo⁵.

The missing ability to distinguish pitch differences, intensity levels and timbral cues makes it hard to segregate the musical properties, and these will become a blur of noise. Some studies, however, have reported increased music discrimination ability following musical training, most promisingly within musical instrumental recognition, indicating a plastic potential^{6,7}.

Who, what & with which?

Twelve recently implanted CI users (CIre, Mage: 60.5y, range 34-80; f = 3) and 15 experienced CI users (CIex, Mage: 54.6y, range 18-77; f = 10) took part in the study. The mean CI experience was 63 mths. for CIex and 0.7 mths. for CIre.

The CI-users’ music discrimination skills were measured with a three-alternative forced choice task (3-AFC) in which a 4-tone musical pattern was presented twice in the standard and once in the deviant condition. In the deviant condition, the standard third note was randomly violated by an intensity, pitch, timbre or rhythm deviant at four different levels of magnitude (1, 2, 3, 4; see MIB

annual report 2017 p. 42 for an illustration). The deviant could randomly occur in either of the three patterns and the participants were instructed to click the deviant pattern on a computer screen. The hit rates were converted to percent correct scores for each deviant level. All participants received the sound through a direct audio input, bypassing microphones and ruling out any residual hearing.

Moreover, all participants filled out a questionnaire, mapping different aspects of their relationship with music such as musical background, music enjoyment, music listening habits and rating of the sound of music with their implant.

To investigate if any demographic or music-related factors predicted the participants’ discrimination accuracy, we applied a mixed-effects logistic

regression approach. All models in the analysis included the participants’ binary responses (correct or incorrect) as the dependent variable and participant IDs as a random effect.

How low can you go...

... in magnitude of the deviation and still be able to discriminate? While no remarkable differences were found between groups in discrimination of deviation magnitude in neither pitch or rhythm, experience with the CI seems to positively affect discrimination of intensity and timbre deviants (Fig. 1). For the intensity deviant, the group difference also tends to increase with increasing magnitude, reflecting the lack of differentiation in the CIre group. For CIex the discrimination threshold is reached at the smallest deviant level, at which the group average is at chance level. By contrast, for the timbre deviant, experience

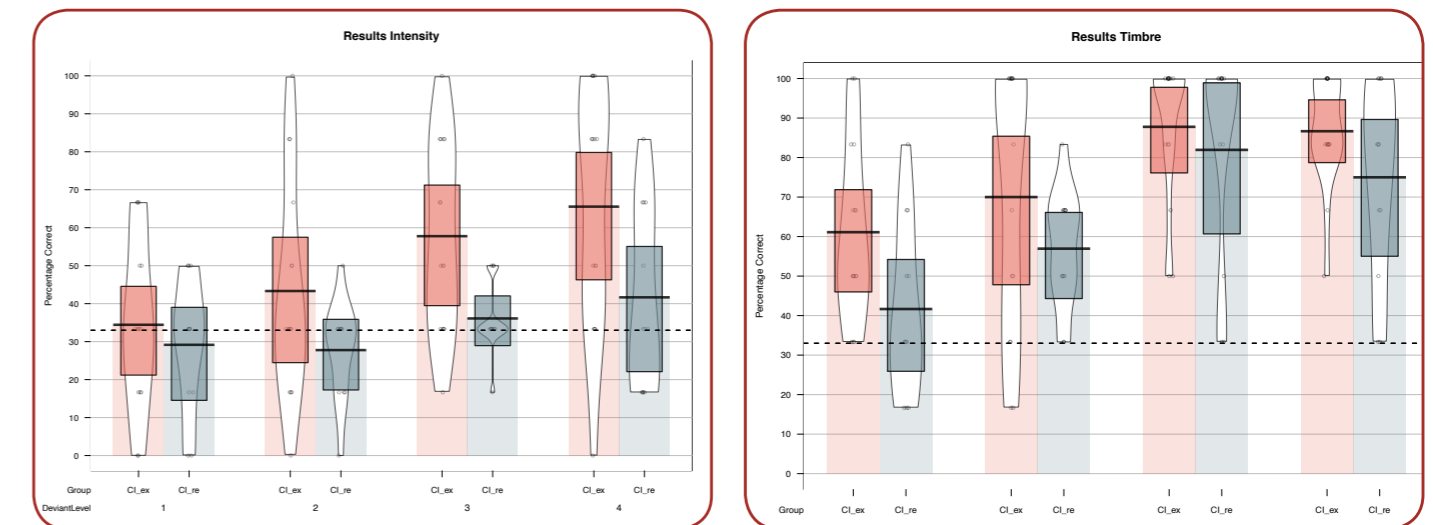


Figure 1. Violin plot showing discrimination accuracy for both groups and all deviant levels in the intensity deviant (left) and the timbre deviant (right).

appears advantageous at all levels of deviation, albeit most prominently at the two smallest levels of deviation.

Apart from more CI-experience, the participants in the Clex group may also benefit from optimized individual mappings of the sound processor algorithms. Given the short adaptation period, it is likely that participants in the Clre group will not yet have acquired personalized and well-adapted mappings, which again may reduce perception of the dynamic and timbral properties of music in particular. Interestingly, despite very little experience, the recently implanted participants scored on par with the experienced in discrimination of the different levels of the rhythm and the pitch deviants. This confirms a) that the high temporal resolution, reflected in recurring reports of near normal rhythm discrimination⁵, is established very quickly after switch-on and b) that even though some discrimination of pitch is possible, potential progress is constrained by the poor representation of frequencies in the CI².

Just keep listening

Listening habits, i.e. the extent to which the CI-users choose to listen to music, showed a robust effect on overall discrimination accuracy (Fig. 2). The effect, however, was only prominent for participants listening to music for 9 or more hours per week. This indicates that CI-users who report a very high degree of music listening also seem to most optimally be able to identify fine-grained details in music.

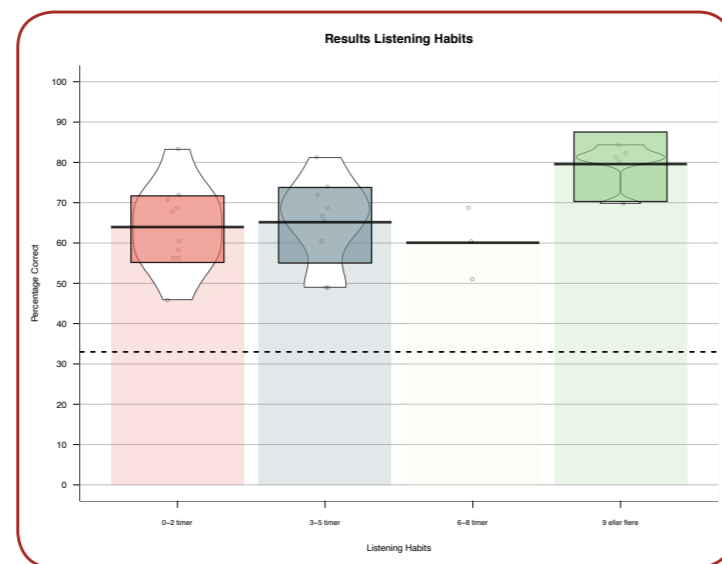


Figure 2. Discrimination accuracy in percentage across groups for different levels of listening habits, measured as hours of listening to music per week.

The result reflects a classical hen and egg case, in which it is unclear if it is the music listening efforts that improve the discrimination skills or it is a generally better implant outcome that improves the quality of music, and thus the inclination to listen to music. If it is the former, it could support the recommendation to include music-training in CI-recipients' rehabilitation measures⁸. Not only could this positively affect the ability to perceive salient properties of music, potentially improving music appreciation, but it might also generalize to other challenging listening tasks, such as speech perception in background noise and perception of emotional prosody⁹.

Surprisingly, we saw no difference in discrimination accuracy between CI-users who

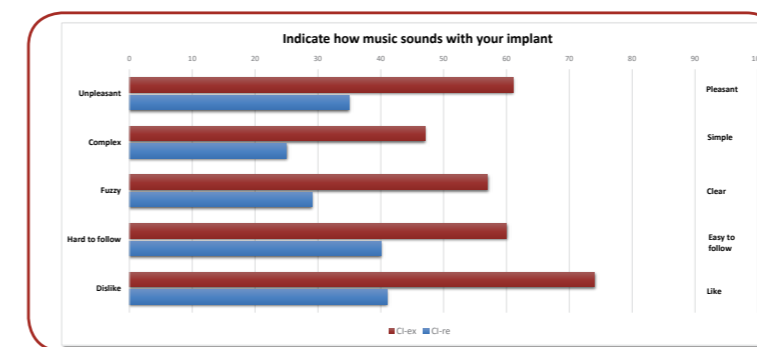


Figure 3. Clre (blue) and Clex (red) ratings of the quality of the sound of music through their CI as indicated on a VAS scale of 0-100 with bipolar adjective descriptors. The average rating was 40 for Clre and 61 for Clex.

report no or very little music listening and those who choose to listen between 2-8 hours per week. This suggests that other factors in music such as rhythm and lyrics may also determine CI-users' inclination to listen to music.

How do you like the sound of music?

In addition to reporting music listening habits and level of music enjoyment, the respondents were required to report the quality of the sound through their implant. The CI-users rated their level of satisfaction on a VAS scale by a value of 0-100 between two bipolar adjective descriptors with 0 being the most negative and 100 the most positive. The results suggested that at this level of detail, CI experience has a significant positive effect on perception of musical sounds, with Clex rating an average of 61 and Clre rating an average of 40 (Fig. 3).

Stylistic preferences

The CI-users were asked to state which styles of

music they enjoyed listening to. Pop, rock, blues, jazz and classical music were preferred by the most respondents, while heavy metal was only preferred by one listener. Unexpectedly, one of three CI-listeners found joy in listening to rap and hip-hop, which may be subscribed to the strong focus on rhythm and lyrics in this genre.

As heard through the grapevine

The questionnaire gave the respondents the opportunity to comment on the different music-related questions, which many chose to do. The comments reflect a vast range of music enjoyment from great enthusiasm over disappointment to mere disgust, confirming previous findings. Diversity aside, a large proportion of the respondents tended to agree that 1) familiarity with a song is a determining factor for music enjoyment, 2) repeated listening of a particular song or piece gradually improves the listening experience, 3) the presence of lyrics adds significantly to the musical outcome, 4) a hearing aid combined with a CI makes the sound richer and more satisfying.

This may indicate that music enjoyment is enhanced by increased top-down processing. While music perception is normally predominantly based on bottom-up processing, familiarity with a song and the presence of lyrics might assist the brain in making meaning of the CI-sound by using existing recollections of what a song used to sound like. One participant commented: "Music is best when I play or sing myself[...]". This may suggest a positive effect of haptic memory for music, in

which the brain's prediction of certain sounds is based on bodily sensations, thereby enabling this information to be used for top-down processing.

To illustrate the different views, we have compiled a number of comments from respondents when invited to elaborate on questions.



“Had a really nice experience in the Berlin Opera.” (Man, 50-55y, CI exp. 5 mths)
 “I listen to music everyday. On my stereo, in the Radio or Spotify on my smartphone (w. streamer).” (Woman, 60-65 y, CI exp. 4.2 y)
 “It sounds just fine. Maybe the bass could be a bit better.” (Man, 55-60y, CI exp. 8.5 y)
 “Today, music sounds more natural than 10 years ago.” (Woman, 60-65y, CI exp. 13.5 y)
 “There is a great difference between the sound of musical instruments. The guitar and saxophone sound very beautiful.” (Woman, 50-55 y, CI exp. 4.4 y)
 “I always listen to music in the car and on TV. E.g. X-factor UK.” (Woman, 35-40y, CI exp. 1 mth.)
 “The sound is 10 times better than with hearing aids.” (Man 15-20y, CI exp. 1y)
 “It has taken some time to learn to listen to music with CIs but it is fine now. I play CDs at home but it is a limited and flat experience. Concerts are MUCH better.” (Woman, CI exp. 2y)
 “Just recently begun hearing music and it was wonderful.” (Woman 60-65y, CI exp. 1.5 mth.)



“Not all forms of music sound good. One of the genres that sounds significantly better after CI is opera. On the other hand music with a lot of bass sounds strangely toneless.” (Woman, 60-65y CI exp. 4y)
 “Music sounds pretty spacy.... as if all the midrange tones are on helium.” (Man, 55-60y, CI exp. 3mths)
 “I listen to Abba's Super Trouper - it is unpleasant but I detect the rhythm! (Man, 75-80y, CI exp. 14d)
 “Everything sounds like bells.” (Man, 30-35y CI exp?)
 “Through speakers the music sounds horrible whereas music has a clear sound when it is not electric.” (Man, 50-55y, CI exp. 5m)
 “Music is best when i play or sing myself but it sounds a bit as if played in a bucket.” (Man, 30-35y, CI exp. 4m)



“I cannot hear music.” (Man, 65-70y, CI exp. 10d)
 “It would be completely pointless and unpleasant to take the chance with a concert.” (Man, 80-85y, CI exp. 4.5 mths)
 “No pleasure but it can be recognized.” (Man, 70-75y, CI exp. 14d)
 “I never listen - all I hear is noise.” (Man, 80-85y, CI exp 6 mths)
 “Simultaneous musical instruments sound like cats' music.” (Woman, 70-75y, CI exp. 4.5 m)
 “Trying (to listen to music) is risky business.” (Man, 80-85, CI exp. 6m)
 “My guitar stands in a corner unused. If I sing, I hear myself singing wildly out of tune” (Man, 80-85y, CI exp. 6m)

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