MUSIC IN THE (deaf) BRAIN

Musical ear training with cochlear implants

by Bjørn Petersen

> "What would you do if I sang out of tune,
> would you stand up and walk out on me?"
>
> Ringo Starr in "With a little help from my friends" (Lennon & McCartney 1967).

Electronic ears

A Cochlear Implant (CI) is a neural prosthesis that helps deaf people to hear. A surgically inserted electrode in the cochlea stimulates the neurons, whereby the auditory nerve is activated. This way sound signals reach the brain's auditory system, in many cases allowing recipients to converse on the phone. The implant is most successful in users who suffer from an acquired hearing loss and have developed language before their deafness. In the case of prelingually deaf patients, whose pattern-recognition system has never been established, the central auditory system must learn to interpret a whole new set of inputs, which takes time and training[1].

Technological amusia

Despite this immense technological and medical achievement, CI users face several limitations in their auditory perception. The degraded spectral and temporal resolution of the implant makes perception of music very poor. It is like "walking colour-blind through a Paul Klee exhibit" as American CI recipient and author Michael Chorost describes it[2]. To some it may well be far worse, which is sad since music in many cases has been an essential part of their cultural and social life. Some studies, however, have shown that by training a specific musical listening task intensely, music discrimination abilities can be improved significantly[3, 4]. So far, no studies have examined the effect of training that involves personal tuition and active music making.

Music and language

Music and language rely on brain processing of fundamental aspects of sound sequences such as pitch, timing and timbre. This involves partly overlapping brain structures and recent studies have shown that complex music tasks activate brain areas associated with language processing [5, 6]. This suggests that improved perception of music could generalize to speech perception, especially the prosodic properties of language.

Musical training and testing

Sixteen newly operated adult CI users (21-73 years) matched in two groups, took part in this longitudinal study. Shortly after switch-on of the CI the eight subjects in the music group began weekly one-to-one musical ear training lessons, that contained a variety of musical activities and listening exercises. For home practice, we provided specially adapted audio-visual training material. The remaining eight subjects acted as controls, and did not receive any musical training.

To detect the progress in discrimination of pitch, rhythm and timbre we created a battery of music tests (Figure 1). Perception of speech and prosody was measured with the Hagerman test and a vocal emotion test. Testing took place at three different milestones: (1) Initial (~ first week after switch-on of the implant), (2) after 3 months, and (3) after 6 months.

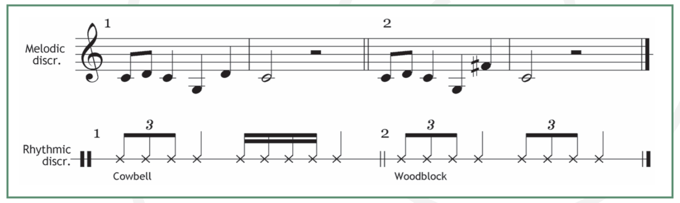

Figure 1
Examples of musical pairs for the melodic (top) and rhythmic (bottom) discrimination tests. In both cases the correct answer is "different".

Brain scanning

To be able to correlate behavioral data with possible changes in brain activity, we used Positron Emission Tomography (PET). PET detects relative changes in regional cerebral blood flow allowing for localization of activated brain areas. We ran four scans at three sequential sessions, concurrently with the behavioral tests. For contrasting stimuli, the subjects listened to either babble or running speech through the external input of their implant.

Change at the "speed of sound"

It is well known that CI recipients adapt quickly to their new hearing, especially in the first months after activation. Our results indeed confirmed this. During the study's 6 months, the music and the control group on average increased their speech perception scores by 160% and 94% respectively (Figure 2). Musical performance also increased in both groups with a larger increase in the music group in almost all tests. The most prominent differences were observed in the abilities to identify melodic contours and musical instruments (Figures 3 & 4). Rhythm and pitch discrimination also showed a difference in favor of the music group, though smaller. We observed a progress but no difference in the ability to discriminate melodies and vocal emotions.

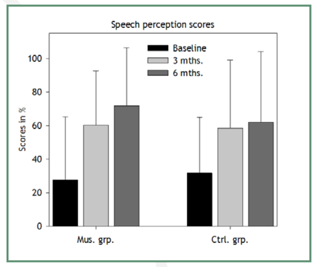

Figure 2
Speech perception scores

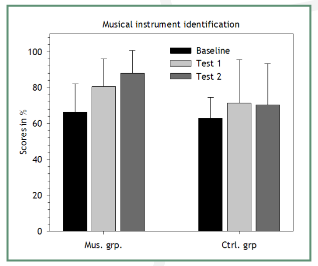

Figure 3
Musical instrument identification scores

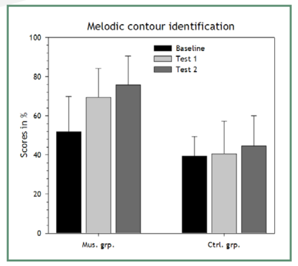

Figure 4
Melodic contour identification scores

Plastic powers in the brain

Such dramatic changes are fine evidence of the powers of neuroplasticity in the human brain. Our approach makes it possible to correlate the observed behavioral development with functional changes in the brain, as shown in two single subjects (Figure 5). In both cases the PET images show an increase in cortical activation and integration of both hemispheres linked to the steep progress in three behavioral tasks. The activation in visual cortex in both subjects has been shown in other studies involving deaf subjects, and is explained by their dependence on visual communication[7].

Every bird sings his song

Music teaching is much like running a shop. If the students return, you were successful - if not, you failed. All subjects in this study returned and completed the training program. In general they found that the different activities were beneficial in their rehabilitation process. Interestingly, singing has proved particularly fruitful and profitable in spite of the obvious intonation challenges. Of course, singing comprises all the important elements of ear training: It is expressive and impressive at the same time, it features pitch, timing and timbre, and, evenly important, it has a linguistic-lyrical dimension.

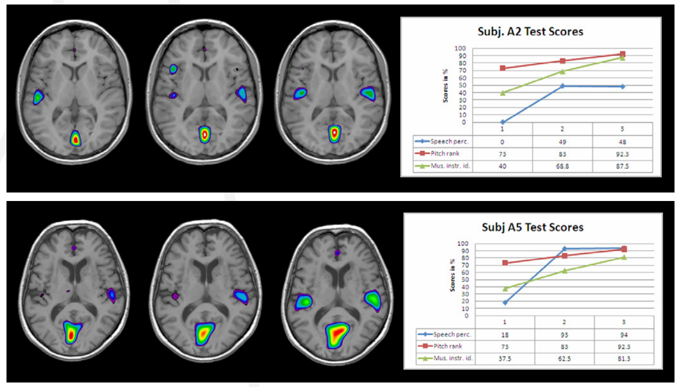

Figure 5
Two single subject cases of neurological and behavioral plasticity as documented in PET scans and behavioral tests done at 0, 3 and 6 months after switch-on of the CI sound processor. PET stimulus is running speech. Top: 21 year old congenitally deaf female; CI=Right ear. Bottom: 70 year old postlingually deaf female; CI=Right ear; duration of deafness: 20 years. (Analysis in progress).

This study has offered a unique and rare chance to study brain plasticity in the human brain – in this case the awakening of hibernated auditory cortices. Also the behavioral results are promising and indicate that the proposed training program has a potential as a complementary method to improve fine grained auditory skills in CI users, thereby contributing to an improved quality of life.

References

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