CLINICAL APPLICATIONS OF MUSIC

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The Times They Are A Changin'

Two Novel EEG Paradigms for Studying Music Discrimination in Electric Hearing

The Past

Since the advent of cochlear implants (CIs) in the early 1990s, an increasing amount of research has reported on the perception and appreciation of music in CI users. Since 2007, researchers from MIB have contributed to the field with several studies which investigated the potential of targeted musical ear training to improve CI users' music discrimination abilities[1,2]. Typically, musical skills are measured by behavioural methods. However, to provide objective measurements and an understanding of the cortical changes which underlie the auditory progress, neuroimaging methods are in demand.

Due to metal parts in the CI's speech processor, neither functional MRI or MEG are feasible and may even be hazardous. PET measurements have been used but are limited with respect to the spatial and temporal resolution and the invasiveness of the procedure. By contrast, EEG is a non-invasive, silent and objective method which enables recording of event-related brain potentials (ERPs) and offers the opportunity to investigate the neural basis of perception with a high temporal resolution.

Although the recording of EEG in CI users represents many challenges, it has shown to be a viable and reliable method for the measurement of auditory functioning. Particularly, the mismatch negativity (MMN) response has been proven a strong tool for measuring auditory functioning in CI users (for a review see[3]). At MIB, we successfully applied a modified version of the 'Musical Multifeature' paradigm[4] in two previous studies to investigate music discrimination skills in adult and adolescent CI users[2,5].

The Present

The current study was initiated in cooperation with the Danish CI manufacturer Oticon Medical (OM) with two goals. In the first step, the goal is to develop and validate two new musical EEG paradigms to be used in future CI research. In a parallel step, we aim to examine the effect of a novel sound compression strategy (xDP). Compared to the typical automatic gain control, xDP leaves room for a wider dynamic range, which could prove beneficial for the music perception of CI users.

As data collection from CI users has not been concluded at the time of writing, only results from normal-hearing (NH) participants are reported. The aim is to include twelve experienced and twelve recently implanted CI users, of whom six are expected to use an OM implant.

The Paradigms

We created an MMN 'Musical Multifeature' paradigm including four deviants (intensity, pitch, timbre and rhythm) at four levels of magnitude (S, M, L and XL), using the Alberti bass configuration introduced by Vuust et al.[4] and a no-standards approach introduced by Kliuchko and colleagues[6]. To account for the limited musical abilities of the CI users, deviation magnitude was adjusted such that the changes would be detectable through a CI. The novelty of the paradigm is a significantly reduced duration and potentially more precise estimations of the participants' discrimination thresholds as compared to previous MMN paradigms used in CI research.

As a secondary measure, we adapted a version of The 'Free-Listening' EEG paradigm, introduced by Poikonen and colleagues[7] and inspired by the approach first presented in[8] (for more details see the feature by Haumann and Menchke on page 36.) The adapted version presents three musical pieces: a short version of the tango composition Adios Noniño and two versions of Danish composer Anne Linnet's song "Forårsdag": the original and an instrumental version (here, only tango results are reported). The paradigm represents a completely novel and ecologically valid approach for investigating music perception in CI users.

The Procedures

Seventeen young adults (mean age 25y, range 21-31; females 9) and fourteen older adults (mean age 63y, range 55-77; females 7) with normal hearing were recruited for the study with the purpose of validating the efficacy of the paradigms. The older adult group was chosen as age matched controls for the CI participants.

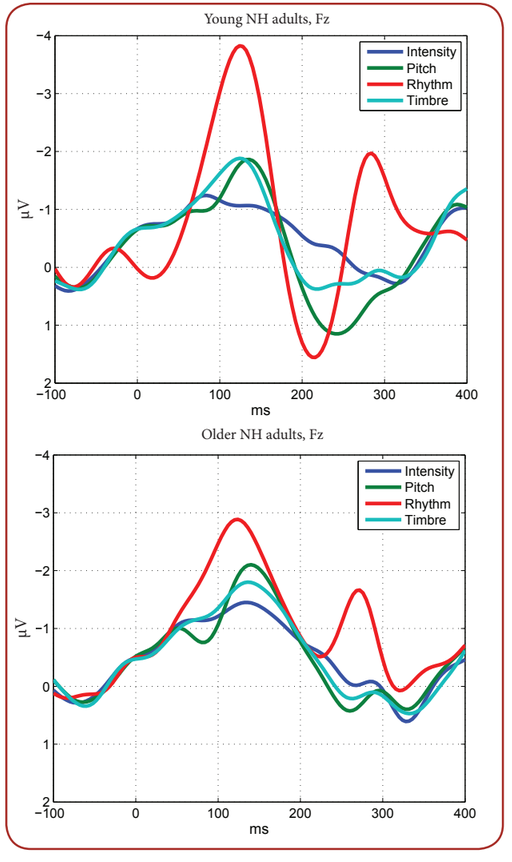


Figure 1: *Average MMN difference waves for all four deviants across levels in the Young adult and Older adult groups, respectively.*

EEG was recorded with 32 electrodes and the participants received audio through in-ear Shure headphones at approximately 70 dB SPL. EEG data from the MMN paradigm were pre-processed with SPM12 and analysed in SPSS 20. Data from the Free-Listening paradigm were analysed using MIR toolbox for the musical features and Fieldtrip for the EEG data.

For provision of supplementary behavioural data, participants completed a three-alternative forced choice task, testing discrimination of the same musical parameters and levels of magnitude as presented in the MMN-paradigm.

The Products

The study's main finding was that the new MMN paradigm elicited significant responses to all four deviants at all levels of magnitude (Figure 1). In addition, there was a consistent relationship between MMN amplitudes and deviation magnitude; the larger the deviation, the larger the MMN response (Figure 2). In addition, we found that MMN amplitudes were largest to the rhythm deviant, whereas gradually lower to timbre, pitch, and intensity deviants. Finally, group comparisons showed that MMN amplitude for the rhythm deviant was significantly higher in young adult as compared to older adult NH listeners (Figure 1).

As a preliminary finding, we were able to show significant MMN responses for all deviants except intensity in single subject analyses. With clinical application in mind, this is important since it suggests potential use of the MMN paradigm for

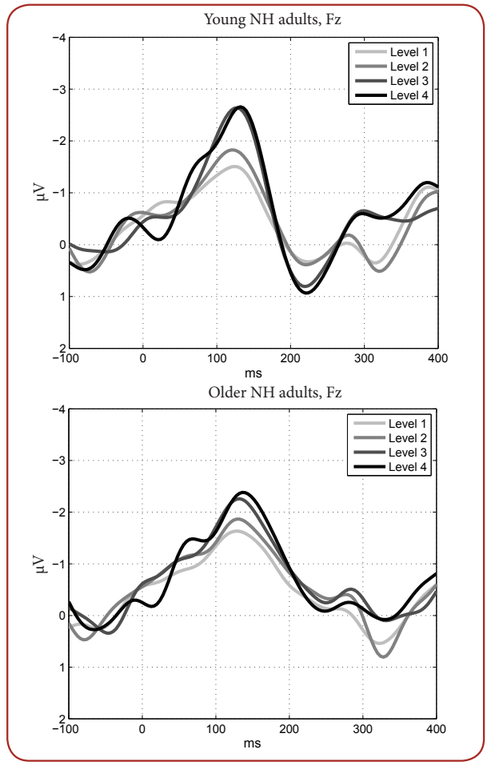
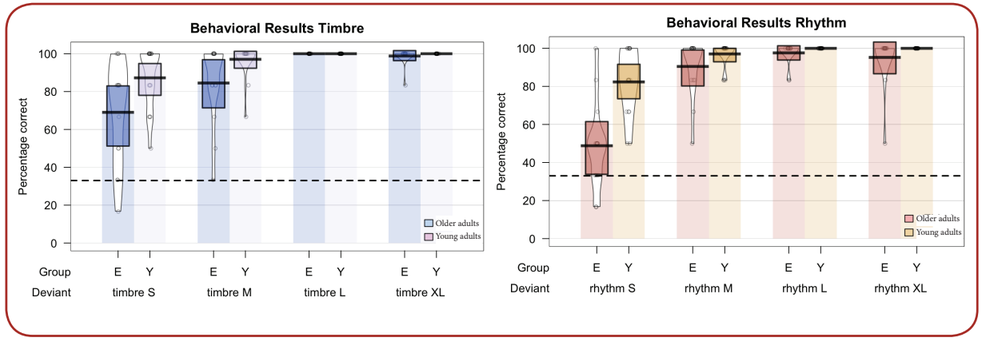


***Figure 2**: Average MMN difference waves across deviants as a function of deviation magnitude levels.*

objective prognostication and assessment of CI functioning in individual CI patients.

Unsurprisingly, behavioural test results showed an overall trend towards ceiling effects for larger deviants. For smaller levels, young adult NH listeners showed a higher discrimination accuracy

***Figure 3:** Violin plots showing behavioural hit rates for the timbre and rhythm deviants. The dotted lines indicate chance level.*



than the older adult group, particularly for timbre and rhythm (Figure 3). Moreover, across deviant levels and experimental groups, higher MMN amplitudes tended to predict higher behavioural test scores. Finally, for the rhythm deviant, we found a statistically significant relationship between MMN amplitudes and behavioural test scores.

The free-listening paradigm elicited significant P2 responses for the features brightness, spectral flux, RMS and roughness (Figure 4). By contrast, P2 response to the zero-crossing rate feature was nonsignificant.

The Parallels

In line with previous studies, we found significantly larger amplitudes in the young adult group than in the older adult group, for the three largest rhythm deviants. Moreover, correlation analyses showed a positive correlation between age and MMN amplitude for the rhythm deviants, further indicating an advantage of young age in detection of subtle details in rhythm[8,9]. This, confirming findings by Näätänen et al.[3], was also reflected in behavioral performance.

In comparison with previous MMN studies[4,6,10], we found MMN amplitudes that were smaller, especially for the pitch and intensity deviants. However, as Vuust et al. propose[10], the complexity of a multi-feature paradigm might influence pitch and intensity deviants the most. Thus, the high complexity of the new paradigm, incorporating levels as well as a no-standards design, might explain the observed diminished amplitudes.

In contrast to pitch and intensity, the timbre and especially the rhythm deviants seem to elicit quite robust and large responses, even compared with other studies[4,5,7]. The reason could be that these deviants are more noticeable in nature than the other deviants, even in a fast an ever-changing paradigm like this.

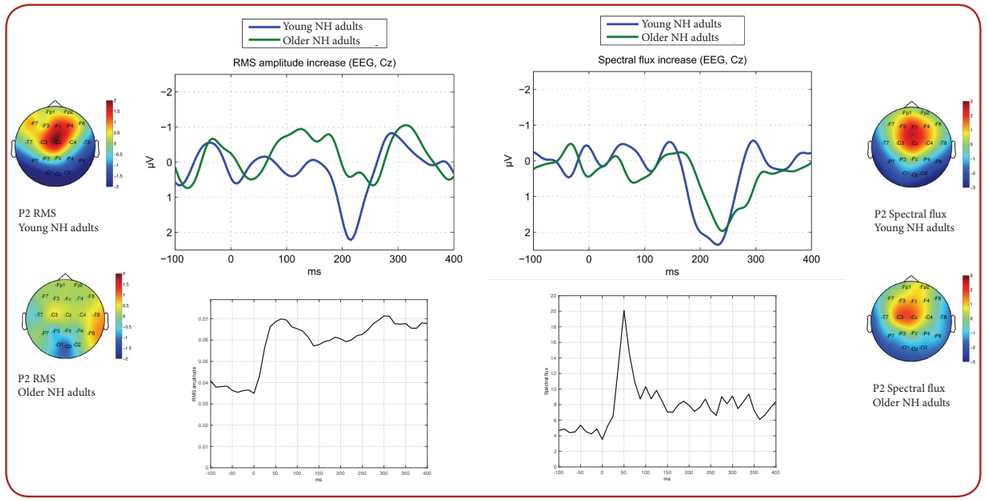


Figure 4: *ERP responses to the two musical features RMS and Spectral flux are shown in the top of the figures. The averaged representations of the musical features are shown below. Topoplots centred around the time of the P2 response for the young adult and older adult group are presented in the side.*

In the Free-Listening EEG paradigm, we found significant P2 responses for all features except zero-crossing rate. This indicates that our paradigm is capable of eliciting significant brain responses even by a tango piece that is half the duration of the one used by Poikonen et al[7]. In line with previous studies, components were largest on the central region of the scalp, suggesting that the activity primarily originates from the auditory cortices[7].

The Prospects

In the present study, normal hearing listeners were subjected to two novel musical EEG paradigms to validate the usefulness of these paradigms in future CI studies. We found significant MMN responses to all deviants at all levels of magnitude in both groups and a synchrony between MMN amplitude and deviation magnitude. The result is encouraging and indicates that the new Musical Multifeature paradigm is both accurate and feasible despite a high complexity. Furthermore, significant P2 responses were elicited by all but one musical feature of the Adios Noniño piece, suggesting promising potential for using the Free-Listening paradigm forward on. Based on previous experience, we are confident that future analyses of data from CI users will further support these findings with the perspective of bringing important new knowledge about music perception and CI.

This study, including preliminary CI data, was presented at the CIAP and CI2017 conferences, July 2017 and is under preparation for submission[12].

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MIB AT THE DHL RELAY RACE

On a rainy evening in August 2017, MIB and CFIN participated with more than 30 runners and walkers at the annual DHL Relay Race. The DHL Relay Race is the world's largest running event taking place in 5 Danish cities.

Participants can either participate in a 5 x 5 km relay race or a 5 km walk.

In Aarhus, 47,000 people participated over 3 days - nearly 2,000 of those were from Aarhus University.

Photos: Suzi Ross