# Study of transcranial electrical brain stimulation (tES) methods with MEG in tinnitus

*TINNET COST Action Short-Term Scientific Mission Report*

We studied immediate effects of tACS on ongoing auditory-evoked brain activity with magnetoencephalography (MEG). By investigating the interaction between auditory stimulation and tACS applied over the auditory cortex in MEG, we aimed at developing a method for investigating the interplay between auditory cortical activity and tACS.

This kind of study was needed, since there are a growing number of trials investigating the outcomes of tACS as a treatment for tinnitus. However, in order to draw conclusions on tACS-related changes in symptoms or behavior, we should first assure ourselves that the stimulation actually reaches the relevant areas of the cortex in the first place. Whereas transcranial magnetic stimulation (TMS) penetrates the skull relatively easily and in a predictable way, this does not apply to electrical stimulation, where modeling the distribution of electrical current in the head is a very challenging task. Thus, it would be beneficial to have ways to monitor the targeting of tACS (and tDCS) before beginning the search for any possible effects.

## *Work carried out during the mission*

We recruited 19 healthy volunteers to take part in the experiments. The study was conducted in the CIMeC research center in Mattarello (TN), Italy. Measurements were done with a 306-channel Elekta Neuromag MEG device. The tACS was applied using a neuroConn DC-stimulator PLUS –device with MEG-compatible accessories such, that the stimulator itself could be placed outside the magnetically shielded room. The experiment consisted of the following measurement blocks:

1. Resting-state 5 min
2. Auditory steady-state (ASSR) @ 41 Hz, 5 min
3. ASSR @ 41 Hz + tACS @ 12 Hz
4. tACS @ 12 Hz
5. ASSR @ 41 Hz + tACS @ 6.5 Hz

The order of blocks 2 to 5 was balanced between participants.

To elicit the ASSR, we used a train of 100-μs rectangular clicks, repeated at 41 Hz. The auditory stimulation was presented with a MEG-compatible loudspeaker ~3 m in front of the subject. Before the first measurement block containing auditory stimulation, the level was adjusted by finding the hearing threshold for a 0.5-s burst of the auditory stimulus. The level was then set to 40 dB above hearing threshold.

The peak-to-peak current of sinusoidal tACS was set to 1.5 mA, and it was applied bilaterally to the temporal areas with two 35-cm$^2$ saline-soaked electrode pads. The

electrodes were kept in place by means of a swimming cap, which also ensured even pressure and good contact. The impedance of the electrodes was kept at approximately 20 kΩ. The stimulation device also monitored the contact throughout the session. Should the impedance grow too high, the device would terminate stimulation. This ensured that the correct amount of current was achieved for all participants.

Both the auditory and electrical stimulation were applied continuously throughout the measurement block. During the measurement blocks, subjects were watching a silent movie and instructed to stay awake and relaxed.

The data was analyzed with the Fieldtrip Matlab-toolbox. Bad channels were identified from the pre-stimulation period of each measurement block and removed, but no other artifact rejection was applied. Then, a comb filter with a 3-Hz stopband width was applied to the raw data. The filter had zeros at multiples of the tACS frequency, i.e. at 12, 24, 36, 48, … Hz for the 12 Hz tACS. The data was cut into ~4-s epochs such, that the epoch length was aligned with the ASSR to ensure constructive summation of the evoked ASSR between epochs. After epoching, the data was projected into source space using a LCMV beamformer. The source-level signals were then averaged over epochs and and the power spectral density was calculated from the average, using FFT.

## *Main results*

tACS was well tolerated by all participants, and no aversive effects were encountered.

Auditory responses could be identified at 41 Hz both without tACS and with it, the response being notably stronger on the right auditory cortex, which is in line with previous studies. This means that despite the huge artifacts caused by the tACS, the much weaker signals originating from brain activity could nevertheless be recovered and compared to normal measurements without tACS.

The 12-Hz tACS was found to decrease the ASSR at 41 Hz. In the preliminary analysis carried out so far, the 12-Hz tACS caused a significant reduction in the ASSR power in the right auditory cortex (Fig. 1). One possible application of this result could be the targeting and individual adjustment of a tACS treatment and its parameters in tinnitus patients. Also, the tACS-induced change in ASSR could be used as a marker in discriminating between different types of tinnitus.

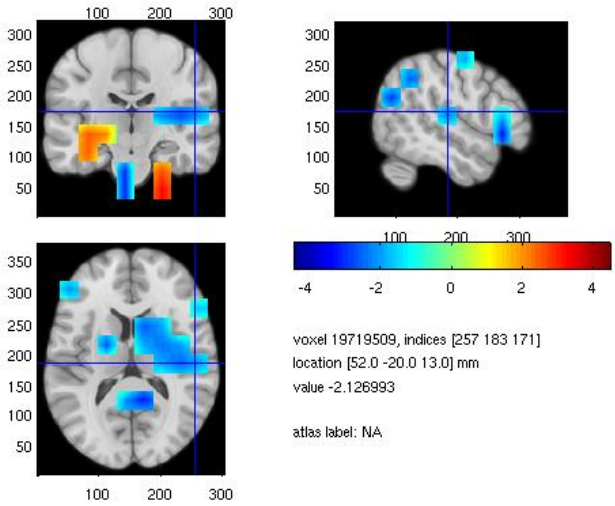


Figure 1 -- Statistically significant reduction of power in the right auditory cortex at 41 Hz. t-test values masked at $p < 0.05$ level.

## *Collaboration and dissemination of results*

The data analysis will continue after the STSM to investigate also the effects of lower 6.5-Hz stimulation to the auditory response. A manuscript is being prepared to publish the results of this study in a peer-reviewed journal. Also, the methodological advances related to using an electrical stimulator in the MEG will be presented in an international conference. The work is part of the applicant's doctoral thesis and the study will also be included as part of the thesis.

## *Confirmation from the host institution*

The confirmation by the host institution of the successful excecution of the STSM is included as an attachment to this report.