Brain Stimulation 11 (2018) 118–124

Contents lists available at ScienceDirect

Brain Stimulation

journal homepage: http://www.journals.elsevier.com/brain-stimulation

Optimized auditory transcranial alternating current stimulation improves individual auditory temporal resolution

Alina Baltus [a], Sven Wagner [b], Carsten Hermann Wolters [b], Christoph Siegfried Herrmann [a, c, *]

[a] Experimental Psychology Lab, Cluster of Excellence "Hearing4all", European Medical School, Carl von Ossietzky University, Oldenburg, Germany
[b] Institute for Biomagnetism and Biosignalanalysis, University of Muenster, Muenster, Germany
[c] Research Center Neurosensory Science, Carl von Ossietzky University, Oldenburg, Germany

ARTICLE INFO

Article history:
Received 21 February 2017
Received in revised form
10 October 2017
Accepted 14 October 2017
Available online 17 October 2017

Keywords:
Auditory processing
Temporal resolution
Individual gamma frequency
Transcranial alternating current stimulation
Current flow simulations

ABSTRACT

Background: Temporal resolution of cortical, auditory processing mechanisms is suggested to be linked to peak frequency of neuronal gamma oscillations in auditory cortex areas (individual gamma frequency, IGF): Individuals with higher IGF tend to have better temporal resolution.
Hypothesis: Modulating ongoing gamma activity with transcranial alternating current stimulation (tACS) is expected to improve performance in gap detection (GD) tasks (shorter GD thresholds) if the frequency is higher and to decrease GD performance (longer GD thresholds) if the frequency is lower than IGF.
Methods: For 26 healthy participants the IGF and temporal resolution were identified using an auditory steady state response (ASSR) paradigm and a between-channel GD task. Finite element modelling was used to generate an optimized tACS electrode montage (one channel per hemisphere: FC5-TP7/P7 and FC6-TP8/P8). Afterwards, GD thresholds were examined during tACS (tACS frequency group A: above IGF, tACS frequency group B: below IGF). Relative changes of GD thresholds were compared between groups. Additionally, effects of tACS on oscillatory activity were investigated comparing relative changes of ASSR amplitudes before and after stimulation.
Results: Performance of group-A-participants improved significantly during tACS in comparison to performance of group-B-participants. Significant relative changes of ASSR amplitudes were found in both groups.
Conclusion: The possibility to improve gap detection with individualized stimulation protocols for tACS further supports the link between oscillatory activity and temporal resolution, whereby the improvement of temporal resolution is particularly relevant for the clinical aspect of auditory tACS.
© 2017 Elsevier Inc. All rights reserved.

Prior presentation of the research at meetings

Baltus A, Herrmann CS. Transkranielle Wechselstromstimulation verbessert die auditorische Lückendetektion. 42. Tagung Psychologie und Gehirn 2016; 162.

Baltus A, Herrmann CS. Individual gap detection ability can be enhanced with transcranial alternating current stimulation. Proceedings of the 18th World Congress of Psychophysiology (IOP2016) of the International Organization of Psychophysiology (IOP) 2016; 68. https://doi.org/10.1016/j.ijpsycho.2016.07.224.

Introduction

A growing body of evidence suggests a relationship between frequency of neuronal oscillations and rapidity of sensory processing mechanisms [1,2]. In audition, associations between frequency of endogenous neuronal oscillatory activity and temporal resolution of perception have been observed [3]. Behavioral measures of individual auditory temporal resolution, determined via a between-channel gap detection (GD) task [4], could be linked to an individual gamma frequency (IGF) of auditory cortex areas [3]. Much evidence suggests that the phase of endogenous ongoing

* Corresponding author. Experimental Psychology Lab, Department of Psychology, European Medical School, Carl von Ossietzky University, Oldenburg, Germany.
E-mail address: christoph.herrmann@uni-oldenburg.de (C.S. Herrmann).

https://doi.org/10.1016/j.brs.2017.10.008
1935-861X/© 2017 Elsevier Inc. All rights reserved.

oscillations modulates near-threshold stimulus perception in humans [5,6], leading to the idea that conscious perception is shaped by discrete temporal processing windows [7–10]. Not only normal functioning but also changes in sensory processing might be dependent on frequency shifts of processing units. In elderly, a slowing down of processing speed and a decline in temporal acuity might be associated with a general lowering of the frequency of endogenous oscillations [11]. This is supported by a decrease of the peak frequency of the envelope following response to amplitude modulated stimuli [12] during aging. Evidence for a slowing down of auditory processing speed during aging comes also from animal models: aged rats show a deterioration of processing speed in auditory cortex [13].

Given these results, it would be of advantage to influence endogenous brain oscillations to change the frequency of brain oscillations [14]. One possibility to modulate the frequency of ongoing neural oscillations is transcranial alternating current stimulation [15], where a weak electric current is applied to the scalp. Finite element method (FEM) simulations of the current flow show considerable current strength and aspired current directions [16–20] in targeted areas depending on the setup of the stimulation protocol [21–23].

Not only is the stimulation montage crucial for a successful modulation of the frequency. The physical concept of the Arnold tongue determines whether the frequency of the endogenous oscillation can be modulated or is unaffected by the external stimulation [24,25]. Depending on a combination of stimulation strength and the difference between stimulation frequency and endogenous frequency, the frequency of the endogenous oscillation can be modulated. More specifically, the closer the stimulation frequency is to the endogenous frequency the weaker the stimulation intensity needs to be in order to modulate the endogenous frequency. This fact is essential to take into account if modulation of endogenous neural oscillations is aspired.

The purpose of the current study was to establish a tACS electrode setup that is especially suited to stimulate targets in auditory cortices with optimal current orientation (aim 1) and to investigate the link between the individual frequency of auditory cortex and behavioral performance in the between-channel GD task (aim 2). To achieve aim 1, FEM modelling was used to find optimized tACS stimulation setups for auditory cortex stimulation. To achieve aim 2, individual GD thresholds as well as individual frequencies were examined. In addition, the latter were used to individualize the stimulation protocol for tACS: individuals were electrically stimulated either slightly above or below their IGF while their GD threshold was re-examined. Based on the idea that higher IGF leads to finer temporal resolution, we hypothesized an increase in performance in the GD task for the individuals who were stimulated above their IGF and the opposite for the individuals who were stimulated below their IGF. We were indeed able to improve GD performance with tACS above the IGF but did not change performance with tACS below the IGF.

Methods

Participants

For the experiment, 26 participants (mean age: 24 ± 3.2 years) were included. Participants were subdivided into two groups (6 males and 7 females per group). Group sizes resembled the number of participants in a comparable, crossmodal study [2]. Written informed consent was obtained from each participant and the study was approved by the local ethics committee. All procedures were performed in accordance with the Declaration of Helsinki. A short questionnaire was used to check for exclusion criteria. After finishing the experiment, participants were asked to fill out a questionnaire about sensational side-effects of the applied tACS to control for perceptually relevant interfering factors. All participants were naïve regarding the aim of the study and were untrained in the GD task.

EEG

The experiment was carried out in an electrically shielded cabin. EEG was recorded with 32 sintered Ag/AgCl-electrodes attached to an elastic cap (Easycap GmbH, Herrsching- Breitbrunn, Germany), a nose-tip reference and a ground electrode at AFz. Impedances were kept below 10 kΩ for each electrode. The EEG signal was digitized with the BrainAmp system and recorded with the BrainVision recorder (BrainProducts, Munich, Germany). Sampling rate for digitization was 5000 Hz (resolution of amplification was 0.1 μV).

Optimizing the auditory tACS electrode arrangement

Recent methodological developments in the domain of FEM modelling of transcranial electric stimulation [22] and electrode setup optimization [23] provide insight into electric current flow in the brain during transcranial electric stimulation and allow the computation of an stimulation electrode arrangement optimized for auditory tACS.

The initial step of the optimization of the stimulation electrode arrangement is to define targets (electric dipoles) in the auditory cortices. For this purpose, dipoles in both auditory cortices of the auditory N1 measured in a combined auditory evoked potential/ auditory evoked field study were estimated for one exemplary subject (not part of the study cohort). The next step was to find a stimulation pattern which is optimal in a way that the direction of current flow in the target areas is parallel to the defined targets and current densities in the target areas are maximal (while they are minimal in the remaining areas of the brain). For the stimulation pattern, 74 possible electrode locations (extended 10-10 EEG electrode system) were allowed with stimulation intensities between −2 mA and +2 mA with anodic (cathodic) currents summing up to +2 mA (−2 mA) so that the sum of all currents is 0.

For modelling the current flow through the head, high resolution multimodal MRI (T1w, T2w, DTI) of the exemplary subject were used to segment the head (volume conductor) into the compartments skin, skull compacta, skull spongiosa, cerebrospinal fluid, grey and white matter, to model white matter anisotropic conductivity and to create a geometry-adapted hexahedral FEM mesh as described in detail in Ref. [22].

The mesh was then used to simulate the discretized current flow depending on the applied currents using the FEM. The computation necessary to find the optimal solution (one specific value for each of the 74 electrodes) makes use of an optimal control problem with control and pointwise gradient state constraints as described in Ref. [23].

After finding the optimized stimulation pattern (one specific value for the 74 electrode positions, Fig. 2A), the current densities and current flow directions were recalculated using two stimulation electrodes, one anode and one cathode, per hemisphere (Fig. 2B). Recalculation showed desired current density patterns in auditory cortex areas (Fig. 2C and D).

Download English Version:

https://daneshyari.com/en/article/8681542

Download Persian Version:

https://daneshyari.com/article/8681542

Daneshyari.com