Possibility to use divergent tasks for baseline alpha rhythm modulation in older adults

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Background

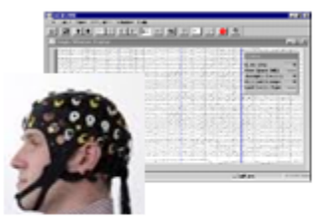
- Preservation of cognitive abilities is extremely important in aged adults. Findings reliably revealed that alpha power attenuates in aging [Vaden et al., 2012] whereas distractibility tends to increase [Gazzaley et al., 2008]. One may suppose association between abilities to ignore irrelevant information and to sustain high alpha power in aged adults, given that alpha waves and are considered as mechanism of suppression of task-irrelevant information [Jensen and Mazaheri, 2010]. Indeed, recent advances in transcranial alternating current stimulation have demonstrated causal link between the parietal alpha rhythm and inhibitory abilities in aged group; this alpha rhythm modulation caused improvement of inhibitory abilities in aged subjects reaching performance of younger ones [Borghini et al., 2018]. These findings suggest that alpha power enhancement may be useful to preserve cognition, especially top-down inhibitory capacity, in later life.
- It is well known that repetitive activity leaves local traces after the performance, manifested as local changes in spectral power [Henz et al., 2018]. Previous studies have highlighted that those traces after task performance are frequency and spatial specific to a certain task [Moisello et al., 2013]. One interesting question is **whether alpha rhythm modulation can be achieved using cognitive task implementation?**
- Large body of research revealed robust evidence of alpha power enhancement during divergent problem solving [Fink and Benedek, 2014]. The reason for alpha increases is the nature of creativity tasks. Such kind of cognition require internally driven processes accompanied by inhibition of bottom-up processing as well as task-irrelevant information during memory search. Given established relationship between alpha power and divergent thinking, divergent tasks may be candidate cognitive activity for modulation of resting state alpha rhythm.

The aim of the study -
to confirm or disprove the occurrence of alpha enhancement after performance of divergent tasks of verbal and visual mode in older adults.
To this aim, we investigated the changes in resting state alpha rhythm that followed creative thinking session.

The hypothesis
Based on evidence of positive associations between divergent thinking and alpha power , particularly in older adults , we expected alpha power strengthening after divergent thinking session.

Method

29 right-handed elderly adults (64±6 years) participated in the current study. All subjects were full time employed and high-functioning individuals.



Creative thinking session lasted for about 40 min and was formed by
•30 verbal Guilford "Alternate Uses Task", he or she had to generate unusual uses for common objects (Guilford et al., 1978)
•30 figural Torrance test "Incomplete figures", participants had to create the meaningful figure based on fragment, presented on the screen (Torrance, 1984)
The sequence of presentation of verbal and figure blocks alternated among the subjects.

EEG was recorded **prior to (rest1), during and immediately after (rest2) creative training.**

- EEG recordings **during successfully resolved tasks** were used to assess on-task activity. For each appropriate test trial, 1 s after task presentation and 1 s before button press, signaling about finding the solution, were excluded from further analysis.
- As for **resting-state intervals**, three-minute recordings in eyes open condition were taken for the EEG analysis.
- In all cases, EEG data were segmented into 2 s epochs.

EEG registration and preprocessing. The EEG data were recorded from 52 Ag–AgCl electrodes mounted in an elastic cap according to the modified version of the international 10–20 system using "Neuroscan 4.4" (USA) during visual and verbal blocks as well as at resting state before (rest1 condition) and directly after (rest2 condition) task performance. Fronto-central electrode was used as the ground, and electronically linked mastoid electrodes as reference. Electrode impedances did not exceed below 5 kΩ. The EEG was digitized at a rate of 250 Hz and amplified using Neuroscan amplifiers with a gain of 250 and a bandpass of 0–50 Hz. Artifacts from EEG data were rejected by independent component analysis via the EEGLAB toolbox

EEG processing.

For **analysis at derivation level**, alpha power spectral density was calculated using Fourier transform via EEGLAB toolbox. Bandwidth for the upper alpha band was defined as [(individual alpha peak frequency) to (individual alpha peak frequency +2)]. Mean alpha power was assessed for frontal, central, temporal- central (and parietal-occipital left areas and for similar right areas.

For **analysis at cortical localization level**, current source density (CSD) was estimated via standardized Low Resolution Brain Electromagnetic Tomography (sLORETA).

For **region of interest (ROI) analysis**, MNI coordinates of voxel with maximum difference between CSD in rest1 and CSD in rest2 was used as a "seed". A cluster of voxels (ROI) was selected within the circle centered at seed, 15 mm in radius. For ROI analysis, eLORETA transformation matrix was used. We calculated ROI from CSD changes from rest1 to rest2 and ROIs of induced by visual and verbal tasks CSD changes.

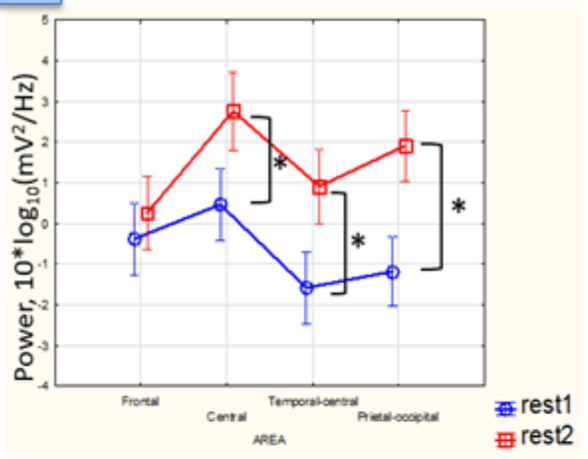
Statistical Analysis. Repeated measures analysis of variance was calculated to assess the difference between alpha power in rest1 and rest2 intervals, linear Pearson correlation were calculated in STATISTICA10. Statistical analysis of CSD estimates was performed using statistical nonparametric mapping with 5000 randomizations in the LORETA package.

Resuts

Alpha rhythm modulation after divergent thinking session.

- The analysis of variance yielded significant main effects of TIME (F(1, 29)=19.449, p=0.000), AREA (F(3, 87)=33.252, p=0.000), which were included in interaction effects of TIME*AREA (F(3, 87)=21.009, p=0.000) (Fig. A). Alpha power increased in rest2 interval as compared with rest1 interval, however, this finding had spatial specificity. The effect was most pronounced at central, temporal-central and parietal-occipital as compared to frontal cortical sites (p=0.000), due to the absence of significant difference in the frontal region.
- Consistent with the analysis of variance at scalp derivation level, alpha CSD was higher in rest2 interval in comparison with rest1 interval (Pmax=0.019). Significant differences were found in Parietal lobe (27 voxels) with maximum T value (T=3.73) in the Superior Parietal lobule (BA 7) (Fig. B).

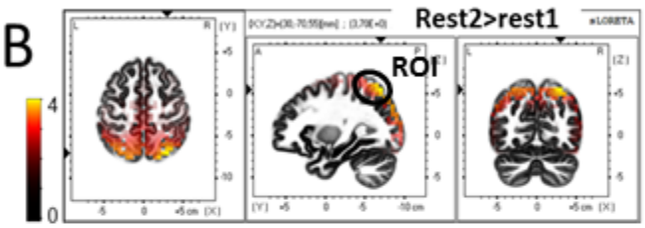
A



Analysis of alpha activity during visual and verbal divergent thinking task.

- CSD during visual divergent thinking task was higher than at rest1 interval (Pmax=0.0003) localized in Parietal lobe (406 voxels), Occipital lobe (342 voxels), Frontal lobe (205 voxels), Temporal lobe (31 voxels) with maximum T value (T=6.27) in the Superior Parietal lobule (BA 7) (Fig. C). Nevertheless, there was no significant changes of CSD from rest1 interval to verbal divergent thinking task performance. Those effects indicate that changes in resting state EEG from rest1 to rest2 interval are more likely formed by activity during visual task performance.
- Induced by visual task CSD changes were higher than changes from rest1 to rest2 interval (Pmax=0.0002) distributed throughout the entire brain. Significant difference were found in Frontal lobe (2105 voxels), Parietal lobe (1146 voxels), Temporal lobe (807 voxels), Limbic lobe (682 voxels), and Occipital lobe (761 voxels). Induced by verbal task CSD changes were lower than changes from rest1 to rest2 interval (Pmax=0.0004) in Frontal lobe (503 voxels) and Parietal lobe (92 voxels). Therefore, CSD estimates at rest2 interval were less prominent but preserved the same activity pattern as during visual divergent thinking task; at the same time it was higher than during verbal divergent thinking task.

B



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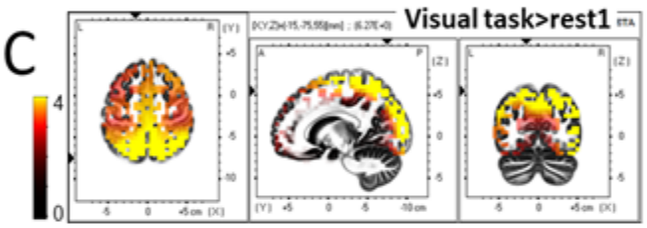

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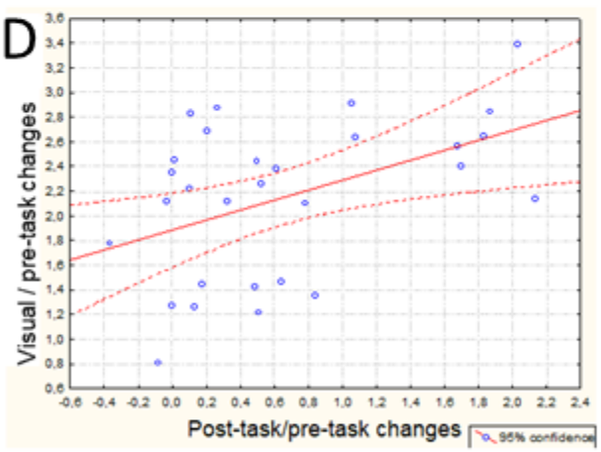

Region of interest (ROI) analysis.

- Correlation analysis of CSD estimates within ROIs revealed positive association between visual task and post-task intervals (r=0.46, p=0.013) (Fig. D), while no significant correlations were found between verbal task and post-task intervals. This finding provides additional evidence for the prominent role of visual domain.
- Additionally, ROI estimates extracted from visual/pre-task changes were positively correlated with visual originality (r=0.48, p=0.008), suggesting that CSD estimates of visual/pre-task changes within ROI reflected specific to visual creativity aspects of task performance.

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Summary

- The current study examined changes in resting state alpha rhythm that followed 30-40 minute divergent thinking session in older adults. We expected alpha power strengthening after divergent thinking session. Both EEG alpha power analysis and CSD analysis at cortical sources level revealed increases of alpha measures from rest1 to rest2 interval, which is consistent with our hypothesis. Alpha power enhancement was most prominent at central and posterior sites, statistical nonparametric mapping solution also localized difference between CSD rest2 and rest1 estimates in posterior brain structure – the Superior Parietal lobule (BA 7). The findings suggest **that divergent problem solving may be useful tool to induce alpha rhythm enhancement**.

- Results of follow-up analysis of alpha activity during visual and verbal divergent thinking suggest that changes in resting state EEG from rest1 to rest2 interval were specific to previous visual task performance.

- Given the role of alpha power in selection and suppression of irrelevant information age [Jensen and Mazaheri, 2010] as well as causal link between alpha power and inhibition abilities in older [Borghini et al., 2018], enhancement of baseline alpha power may have positive effect on inhibitory capacity.