# Age-related difference in use-dependent plasticity after divergent thinking session matches posterior-anterior shift in aging (PASA) model

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## Background

Repetitive cognitive activity has the potential to improve cognitive functioning through neuroplasticity. Even several training sessions [Lewis et al., 2009] or hours of practice [Taubert et al., 2010] may be followed by training-induced neuroplasticity. Findings suggest that post-training cortical activity does not return to the pre-task baseline level after short training sessions: local traces of previous activity are observed after completion of forty-minute, or less, training [Henz et al., 2018; Moisello et al., 2013]. Both functional magnetic resonance imaging and electroencephalography (EEG) studies revealed that experience-dependent changes after task performance take place in the cortical regions involved in the task [Hung et al., 2013].

Specific changes of brain activity during experimental task performance are well-documented in the elderly. Large body of research revealed some common patterns of age-related changes across a variety of cognitive functions. The hemispheric asymmetry reduction in older adults (HAROLD) summarizes consistent patterns of age-related asymmetry reduction in prefrontal brain activity, which is thought to reflect a neuro-compensatory process [Duda et al., 2019]. The second leading theory is the posterior-anterior shift in aging (PASA) [Davis et al., 2008], which states that posterior cortical function impairment, manifested in reduction of activity, may induce prefrontal over-recruitment in order to preserve cognitive performance. One may assume, that those general models may appear as patterns of brain activity during divergent problem solving and, therefore, as patterns of post-training traces in baseline activity. However, age specificity of experience-related neuroplasticity in respect to leading theories of age-related changes of brain activity is under-studied.

**The aim of the current study was to investigate the age-related specificity in use-dependent plasticity after divergent thinking session. It may help to reveal if global aging-associated shifts in brain function are presented in neuroplasticity induced by divergent training session.**

On the background of theoretical accounts assuming the existence of basic patterns of age-related changes in brain activity, we expected: 1) different patterns of alpha power post-training changes in younger and older adults; 2) these patterns will be consistent with HAROLD and (or) PASA models.

## Method

31 younger (from 19 to 33 years, Mean age = 21.3) and 30 older adults (from 55 to 75 years, Mean age=64.2) underwent a divergent thinking session with concomitant EEG registration. All subjects were employees or students.

**Creative thinking session** lasted for about 40 min and was formed by
•30 verbal Guilford "Alternate Uses Task", participants 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 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) 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.*
To investigate alpha activity at pre-task (rest1) and post-task (rest2) intervals, we used three-minute recordings in eyes-open condition; EEG data were segmented into 2 s epochs and submitted to further analysis. Considering shift of peak alpha power toward lower frequencies in older adults, bandwidth for the upper alpha band was defined from individual alpha peak frequency to individual alpha peak frequency + 2 Hz. Alpha power spectral density was calculated using Fourier transform via EEGLAB toolbox. Mean alpha power was assessed for frontal, central, temporal- central (and parietal-occipital left areas and for similar right areas.

*Statistical Analysis.* Repeated measures analysis of variance (ANOVA) was calculated in STATISTICA10 with between-subject factor AGE (younger, older group) and within-subject factors TIME (rest1 and rest2 intervals), AREA (frontal, central, temporal-central, parietal-occipital), LATERALITY (left, right hemisphere). Only results remained significant after Greenhouse–Geisser correction adjusting for lack of sphericity were reported.

## Results

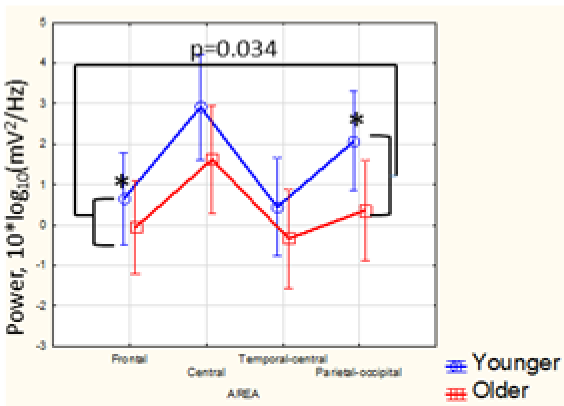
***General effects.***

- Repeated measures ANOVA revealed significant main effects of TIME (F(1, 59)= 41.279, p=0.000), AREA (F(3, 177)= 63.446, p=0.000), which were included in interaction effects of TIME*AREA (F(3, 177)= 46.174, p=0.000). For both younger and older adults, alpha power at rest2 interval was higher than at rest1 interval in all areas (p=0.000) except of frontal. The strongest alpha power increase was observed in parietal-occipital area in comparison to temporal-central, central, frontal areas (0.000<p<0.009).

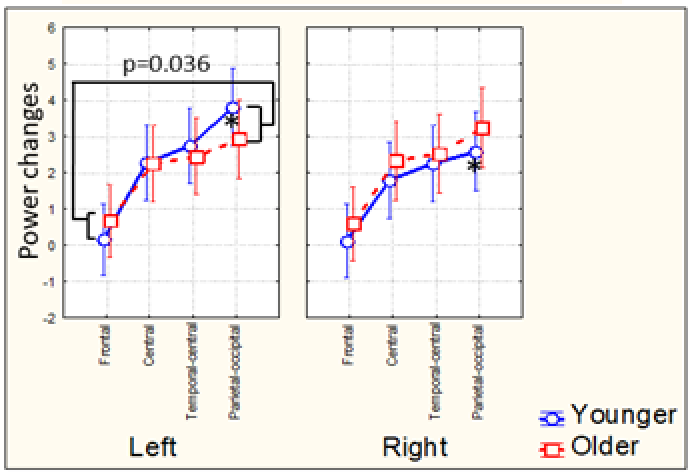
***Effects including AGE factor.***

- The analysis of variance yielded significant main effect of Area*Age (F(3, 177)=3.419, p=0.018). In younger adults, alpha power at central area as well as at parietal-occipital area were higher than at frontal and temporal-central areas. In older adults, alpha power at central area was higher in comparison to other areas. In both rest1 and rest2 intervals anterior-posterior gradient of resting state alpha power (parietal-occipital>frontal) was higher in younger adults than in older (p=0.034) due to significant difference between power in frontal and parietal-occipital areas in younger subjects (p=0.000) only (Fig. A).
- This effect was included in interaction effect of Time*Area*Laterality*Age (F(3, 177)=3.349, p=0.02) (Fig. B). The anterior-posterior gradient (higher alpha power increases from rest1 to rest2 interval at parietal-occipital area, than at frontal area) was higher in younger adults in comparison to older ones (p=0.036). Hemispheric asymmetry (left>right) of alpha power increases from rest1 to rest2 interval was significant only in younger group (p=0.000) and differed (p=0.004) from asymmetry indicator in older group.

A




B




## Summary

- We found that age groups differed in ratio of power strength. First, the anterior-posterior gradient (posterior>anterior) of resting state alpha power in both rest1 and rest2 intervals was higher in younger than in older subjects. This pattern of age-associated differences is in line with previous findings of parietal alpha decreases in aging [Vaden et al., 2012] and matches PASA model, that is, decrease in posterior-anterior gradient in the elderly. .
- HAROLD model states the age-related hemispheric asymmetry reduction in prefrontal brain activity [Duda et al., 2019]. In the current study, lateral effect was observed in the posterior region only, so it matches HAROLD in the direction of lateral age differences, however, localization was different. Our results are consistent with recent findings that quantitatively significant HAROLD effects were not restricted to the prefrontal cortex [Berlingeri et al., 2013], suggesting that model needs to be revise.
- PASA is a well-established aging phenomenon across a variety of cognitive functions; finding of the current study expands the generalizability of the model. The results emphasize that PASA model reflects a global age-associated shift in brain function.

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