Occipital alpha oscillations negatively correlate with the vividness of mental imagery in healthy participants

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Abstract

Mental imagery is the ability to evoke visualizations in the absence of external stimuli. Some individuals lack mental imagery (aphantasia), while others have the ability to evoke hyperrealistic imagery (hyperphantasia). The vividness of imagery depends on top-down communication to occipital areas. However, the neuronal correlates of mental imagery are still not fully understood. Here, we found a strong and significant linear correlation between mental imagery and EEG eyes-closed resting-state occipital alpha power. This finding suggests that alpha oscillations may be a biomarker for suppressed communication from occipital to frontal areas leading to less vivid or absent imagery.

Keywords: mental imagery; EEG; alpha oscillations

Introduction

Mental imagery is the ability to evoke visualizations in the absence of external stimuli. It is thought to emerge from the interaction of early visual, higher-order visual, and frontal areas (Marks, 2023; Zeman, 2024). A recent study showed that imagery content can be decoded from the primary visual cortex (V1) even in aphantasic subjects (Chang, 2025). Thus, the vividness of imagery seems unrelated to the presence of visual information in V1, instead it depends on inter-area communication (Dijkstra, 2017). However, the precise neuronal mechanism mediating the strength of imagery remains unclear.

Here, we hypothesize that occipital alpha oscillations reflect a state of suppressed communication from V1 to higher cortical areas (Morales-Gregorio, 2024), which could alter the vividness of mental imagery. Higher alpha oscillations are known to precede suppressed visual perception (Hanslmayr, 2007; Romei, 2008), thus we hypothesize alpha oscillations could also be a biomarker for the vividness of visual imagery.

Methods

EEG recordings. To test our hypothesis, we performed resting-state EEG measurements with closed eyes (n=18). We used the standard 10-05 cap design (*ANT Neurosystems*), with 124 contacts. The EEG was recorded at 1 kHz. The resting-state recordings consisted of 5 min with open eyes, followed by 5 min with closed eyes. The resting state was recorded twice per participant, before and after a memory task. Here, we focus on the eyes-closed activity. All procedures were approved by the ethical committee of the General University Hospital in Prague (VFN) in accordance with Czech and European regulations for research with human participants and data protection (Grant number: 157/24 S-IV).

Alpha power estimation. We estimated the alpha power (8-12 Hz) of each electrode by fitting the aperiodic 1/f component of the power spectral density and measuring the relative height of the alpha peak (Donoghue, 2020). Sample alpha power is shown for 4 different subjects in Figure 1.

Mental imagery. We measured the strength of mental imagery using the Vividness of Visual Imagery Questionnaire (VVIQ2) (Marks, 1995). The test consists of 32 items that the subjects had to imagine with closed eyes and provide a score of the vividness from 1 to 5. The lowest possible score in VVIQ2 is thus 32 and the highest is 160. Roughly half of the subjects completed the original English-language questionnaire, while the rest completed a Czech translation (translated with permission from D. Marks).

Results

We found a broad distribution of alpha spectral power peaks across subjects. Some subjects exhibited nearly no alpha oscillations, while others had very strong occipital alpha oscillations (Left panels in Figure 1).

To test our hypothesis that alpha oscillations negatively impact the vividness of mental imagery we calculated the correlation (both Spearman and Pearson) between the highest occipital alpha peak and the VVIQ2 score.

The full data reveals a moderate correlation between the two (Right panel in Figure 1, red color fit). The correlation coefficient is -0.36 (Pearson, p=0.04) or -0.4 (Spearman, p=0.02), we report the p-values of the associated test with the null hypothesis that the samples are uncorrelated. The data shows a monotonic downward trend with the exception of two subjects with very low VVIQ2 and alpha peak. When those two subjects are excluded (red dots, considered outliers) the correlation dramatically increases to -0.68 (Pearson, $p < 10^{-4}$) or -0.66 (Spearman, $p = 10^{-4}$).

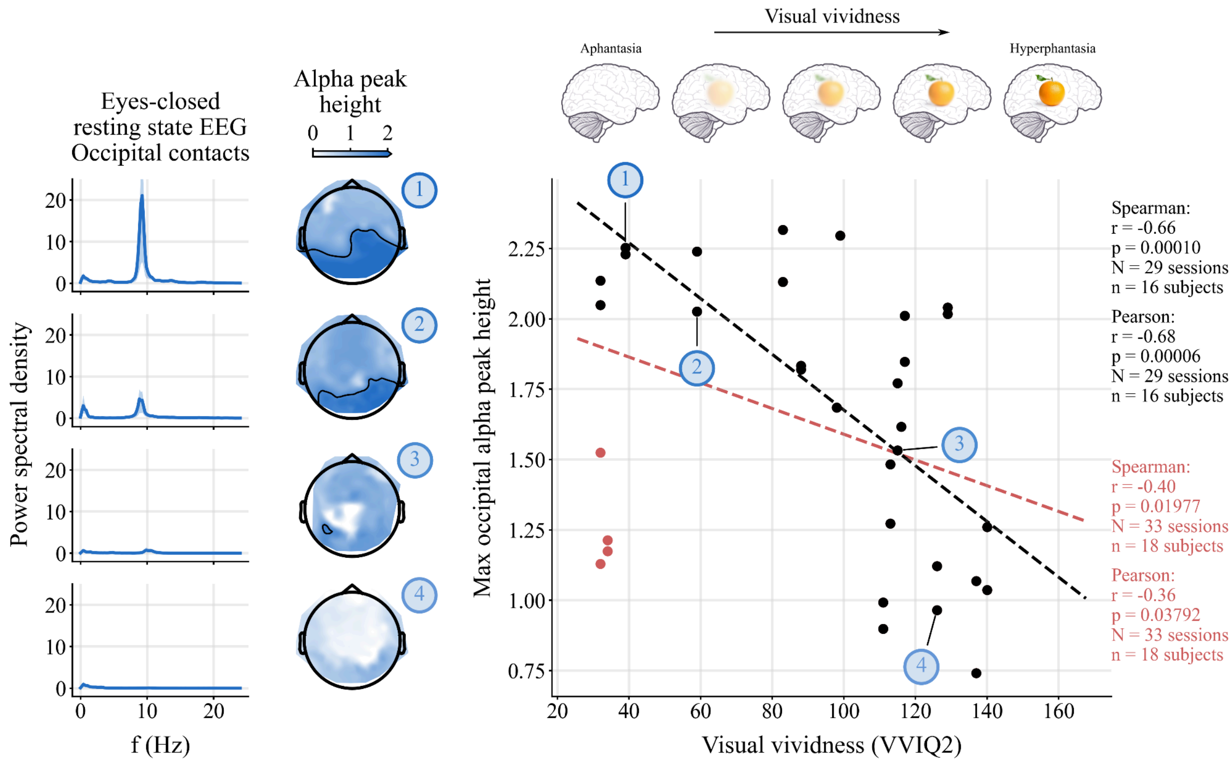

Figure 1: Occipital alpha power correlates with the vividness of mental imagery. (Left) Example power spectral density and alpha peak heights for 4 selected subjects. (Right) Scatter plot of the alpha peak (8-12 Hz) height at the occipital electrode with the strongest alpha activity and the Vividness of Visual Imagery Questionnaire score (VVIQ2). Note that there are 2 observations for most participants, which have the same VVIQ2 but different alpha power. The results of Pearson and Spearman correlation tests are shown. The correlation is particularly strong when excluding outliers (red colored, n=2 subjects, N=4 sessions).

Discussion

We found a significant negative correlation between the vividness of mental imagery and the resting-state occipital alpha oscillations. This result suggests that alpha oscillations play a role in the formation of mental imagery, The negative correlation implies that alpha oscillations co-occur with the suppression of mental imagery, similar to the correlation of alpha oscillations with the suppression of visual perception (Hanslmayr, 2007; Romei, 2008). Further analysis of the presented data, such as inter-area communication could further clarify the role of alpha oscillations in mental imagery.

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