様式３

論　文　内　容　の　要　旨

氏　名　（南　宇人）	
論文題名	Functional roles of alpha oscillations in visual perception and their neuroanatomical basis （視覚情報処理におけるアルファ波の機能的役割とその解剖学的基盤）

論文内容の要旨

Introduction: Neural oscillations at around 10 Hz, called alpha oscillations, appear most saliently among all neural oscillations especially during the rest. In recent years, correlation between characteristics of alpha oscillations such as power/frequency/phase and various perceptual phenomena has been established. However, there has not been conclusive evidence about the causal contribution of alpha oscillations to visual perception. In this dissertation, I first focused on a phenomenon called motion-induced spatial conflict where illusory visual vibrations are experienced at around 10 Hz. To prove a causal link between the alpha oscillation and the illusory jitter perception, I utilized inter- and intra-individual variations and manipulations of the intrinsic alpha frequency. Second, I focused on the neuroanatomical basis of inter-individual differences in the alpha power and frequency, which is known to be correlated with several visual phenomena. To study the relationship between microstructural properties of white matter tracts connecting visual areas and alpha oscillations, I utilized both diffusion-weighted imaging (DWI) and quantitative MRI (qMRI).

Purpose/Methods: In the first part, to verify whether the alpha oscillation contributes to the illusory jitter perception, I investigated whether perceived frequency of illusory jitter is correlated with inter/intra-individual variability in the intrinsic alpha frequency. I also invented a method to manipulate alpha frequency, which was enabled by amplitude modulated transcranial alternating current stimulation (AM-tACS). The illusory jitter frequency was estimated by the constant method, while the alpha frequency was measured by magnetoencephalography (MEG). Furthermore, I performed the source analysis on MEG during the observation of illusory jitter. In the second part, to investigate the relationship between the amplitude and frequency of alpha oscillations and microstructural properties of the major white matter tracts connecting visual areas and, I measured MEG during rest, DWI and qMRI for the same participants.

Results/Discussion: There was a strong correlation between alpha frequency during rest and illusory jitter frequency across participants. Also, small fluctuation of alpha frequency within participant was correlated with the illusory jitter frequency. In addition, when the frequency of the alpha oscillation was increased or decreased by amplitude modulated-tACS, the illusory jitter frequency also changed reflecting the change in the alpha frequency. From these experiments, I found that the illusory jitter directly mirrors the intrinsic alpha frequency. Furthermore, the phase synchronization of alpha oscillations was found to be increased between IPL and IT, which are located in the dorsal and ventral areas respectively. Illusory jitter may arise from the cyclic correction of the dissociation between positional representation in dorsal and ventral visual pathways. In the second part, the power and frequency of alpha oscillations were found to be significantly correlated with the tissue structural properties in optic radiation (OR), which connects LGN and V1. The results suggest that alpha oscillations may originate from the interaction between LGN and V1. In conclusion, I elucidated a functional role of alpha oscillations in visual processing and neuroanatomical substrate characterizing alpha oscillations.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

10 Hz程度で生じる脳内の電気的振動はアルファ波と呼ばれ、古くから様々な研究が行われてきた。特に近年では、視知覚に様々な影響を及ぼすことが知られている。しかし、視知覚の元となる脳内の処理に対してアルファ波が原因として関与することを明確に示した研究は、ほとんど存在しない。そこで本研究では、等速で移動する赤と緑の縦縞があたかも振動しているように見える錯視(jitter錯視：motion-induced spatial conflict)に着目し、jitter錯視の周波数がアルファ波の周波数によって因果的に決定されるか調査することを目的とした。主要な結果は以下の3点である。(1)複数の実験参加者で計測した安静閉眼時のアルファ波の周波数がjitter錯視の周波数と相関した。(2)参加者内のアルファ波の周期のゆらぎに応じてjitter錯視の周波数もゆらいだ。(3)200 Hzの搬送波を10 Hz付近の変調周波数を持つように振幅変調した電流刺激を用いてアルファ波の周期を変化させたところ、jitter錯視の周波数もアルファ波の周波数に応じて変化した。以上の結果は脳内に元々存在するアルファ波の周波数がjitter錯視の周波数を決定していることを明瞭に示している。次いで、アルファ波の周波数や振幅が個人間で異なる理由を探るために、MRIで解剖学的な研究を行った。その結果、視覚情報を大脳皮質に伝える視放線と呼ばれる線維束の構造特性がアルファ波の周波数や振幅の違いと相関することを発見した。上記の通り、本論文はアルファ波の機能およびその解剖学的基盤について重要な知見を明らかにしたものであり、博士論文として十分に価値あるものと認める。