氏　　　　名	藤　岡　孝　子
学位（専攻分野）	博士(理学)
学 位 記 番 号	総研大甲第705号
学位授与の日付	平成１５年３月２４日
学位授与の要件	生命科学研究科　生理科学専攻 学位規則第４条第１項該当
学 位 論 文 題 目	Toward Music,Pitch,and Timbre,in the Human Auditory Cortex:A Magnetoencephalographic Study
論 文 審 査 委 員	主　査　教授　　定藤　規弘 教授　　柿木　隆介 教授　　小松　英彦 教授　　栗城　眞也（北海道大学）

論文内容の要旨

The objective of this doctoral study is to enlighten the cortical representation of sounds in terms of the hierarchical structure of music, which consists of elements such as pitch and timbre. The hypothesis that the neural basis underlying musical perception, learning, and memory is facilitated in the human physiology is generally accepted in science. However, the cognitive mechanisms in music have been less investigated than in language processing. The technique of magnetoencephalography allows us to explore the reaction of the human brain to acoustical events completely non-invasively with high temporal resolution at which latency and with high spatial resolution in which area the brain was activated.

The first experiment aimed to investigate the tonotopic organization of very high frequency pure tones in the human auditory cortex which had never been examined by brain imaging methods. High frequency sounds above 5000 Hz are not recognized as musical pitch but are highly important for the sound localization and auditory scene analysis. The results showed that tonotopic organization at lower frequencies reported in previous studies is also preserved up to the upper limit of the audible frequency range. The corresponding representation area is rather small compared to the middle range of audible frequencies. The observed decrement of the AEF magnitude might reflect the fact that the pitch perception is degraded. In addition, the experimental results confirmed that air-conducted ultrasound signals don't have a cortical representation.

The second experiment was designed to find out how the tonotopic organization correlates with the perception of pitch and timbre of complex sounds. From a physical point of view, musical sounds are complex sounds with spectral and temporal structures producing a sense of pitch and timbre. These complex sounds are most basic elements to form higher structured musical objects such as coherent streams and melody. Therefore, the question was whether the tonotopic organization of complex periodic sound representations in the auditory cortex reflects solely frequency information, similar as observed for pure tones, or reflects the perception of pitch and timbre. Various missing fundamental (MF) sounds (complex sounds composed of harmonics of a fundamental frequency F_0 but without the F_0 itself) were used as stimuli to differentiate the effect of periodicity, mainly perceived as pitch, and of the harmonic composition, mainly perceived as timbre. The stimulus parameters were widened from the previous study in which a smaller subset of stimuli was used. Thus, the comparison among the wide variation of stimulus conditions allowed us to examine more general principles of the cortical representation of complex sounds. In a middle periodicity condition, the results were consistent with a previous study showing that the locations of the N1m sources did not reflect the spectral components but were more likely related to the fundamental frequency representing the "virtual pitch". The differences of source locations for MF sounds and pure tones were found more clearly in the tonotopic maps. The tonotopic gradients for both pure tones and complex MF sounds were observed in similar configurations in the medial-lateral direction, whereas in inferior-superior and anterior-posterior directions the tonotopic gradients were significantly different. These results indicated that the cortical representation of complex sounds reflects the perception of pitch and timbre differently from that for pure tones.

In summary, the results of the two experiments of this study indicated that the auditory cortex responds differently to the acoustical events reflecting the various perceptual qualities of the sounds, especially in a quite early stage within 100–200 ms after the event occurs. Those auditory evoked magnetic fields responses are closely correlated not only with the physical features of the sound, but also to highly cognitive processing of spectral and temporal structures of the sound.

論文の審査結果の要旨

申請者は、音の脳内表象を探求する目的で、音高(pitch)と音色(timbre)に関する認知過程を脳磁計測（Magnetoencephalography, MEG）を用いて研究した。
音高は純音においては周波数と平行する。そこでまず聴覚誘発脳磁場（Auditory evoked magnetic fields, AEF）のN1m反応（100ms付近の長潜時反応，第2次聴覚野起源）の周波数依存性を調べた。その結果，5000Hz～14000HzまでTonotopyを観察した。即ち周波数の増大とともに、N1m活動源は外側から内側へ、“下方から上方へ”連続的に移動した。N1mの振幅は5000Hz以上で顕著に減少し、超音波帯域では無反応であることを確認した。

このTonotopyが音高や音色という感覚量にどのように対応するのかを決定するために第2実験を行った。即ち、音楽を構成する基本要素である複合音によるTonotopy構造が、純音と同じく周波数のみに依存するのか、それとも音高や音色という感覚量を反映するのかを検証した。基本周波数（F_0）の欠けた倍音の集合である調波構造複合音（Missing fundamental complex sound, MF音）は、音色は異なるが、基本周波数と同じ音高を与えること(virtual pitch現象)が知られている。これを用いてMF音に対するN1m反応の位置を、MF音の平均周波数に対してマップした。すると純音によるTonotopy構造とは異なる分布を示した。 即ち、平均周波数の増大につれてN1m活動源は両側聴覚野において内側から外側へ、“上方から下方へ”移動した。したがってtonotopy構造は音高のみで決定されるのではなく、複合音に起因する音色の違いも影響することが明らかとなった。

これらの知見は、大脳皮質聴覚野における音高および音色の表現形式に示唆を与えるものである。実験は注意深く遂行されており、問題点も的確に指摘され、議論されていた。以上の理由で、審査委員会は全員一致で本論文が博士論文にふさわしいとの結論に達した。

専門分野およびその基礎となる分野に関して口頭で審査し、博士号を得るのに十分な知識と理解力を有する者と判断した。また語学力については、本論文および国際学術誌に掲載された参考論文について検討した結果、十分な英語能力を備えているものと結論した。