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論　文　要　旨　(博士)

論文題目	脳波を用いた知覚・認知情報の抽出に関する研究

(要旨　1,200字程度)

我々の行動や思考が，脳によって生み出されていることが明らかにされてから，脳機能を解明しようとする研究が発展を続けている．さらに，安全かつ手軽に脳信号を計測できる非侵襲計測技術の普及は，脳内信号を様々な分野に応用しようとする動きを加速させた．例えば産業界では，人々の商品に対する興味を脳内信号から直接抽出するニューロマーケティングが注目されており，また医療分野では，口頭での意思伝達が困難な患者のために，脳から情報を抽出して意思を代替して伝達する装置が開発されようとしている．こうした脳内信号からヒトの意思を解読して，機械に出力する技術はブレインコンピュータインタフェース(Brain-computer interface: BCI)と呼ばれる．BCIでは，解読すべき神経活動が，脳内でどのような信号として表現されているかを知ることが重要である．すなわち，解読すべき情報が，いつ・どこで・どのような信号として脳で符号化されているか解明し，解読すべき神経信号を高速，高精度に解読するアルゴリズムが必要不可欠である．本論文は，こうした背景のもと，ヒトの非言語情報の中から，特に認知と知覚に関わる脳活動の解読と抽出に関して論じたものである．

本論文ではまず，脳における認知成分の解読を目的とし，ヒトが感じる不自然さについて検討した．不自然さは，記憶や経験に関わる高次認知成分であり，その脳内符号化に関しては，未だ十分な知見が得られておらず，その解明は高次認知機能を理解する有効な視点を与える．本論文では，不自然さは単一の感覚刺激だけではなく，複数の感覚刺激の組み合わせでも発生するという予測のもと，プライミング手法を利用したクロスモーダル実験を行い，脳波の30Hz以上の振動成分であるガンマ帯にその影響が反映されていることを明らかにした．またこれまでの研究により，不自然さの影響は脳波の振幅成分にも反映されることが報告されていることから，不自然さを高速，高精度に解読するための特徴抽出及び判別法を提案した．その結果，わずか単一呈示の脳波データから80%以上の精度で不自然さを解読することに成功した．

さらに本論文では，我々が意識せずとも自発的に複数の知覚解釈が発生する知覚闘争現象について論じ，自発的知覚交代には14-28Hzのベータ帯振動が関わっていることを明らかにした．また，知覚交代に関わる脳処理を明らかにするため，従来の実験法にSSVEPと呼ばれる脳波成分を導入する新しい実験手続きを提案し，従来法より高い時間精度で知覚交代の活動潜時および脳活動を特定することができた．

以上，本研究は脳で符号化されている認知と知覚に関わる視覚神経処理の解読とそれらを効率良く抽出する手法を示した．本研究は，今後，ヒトの脳活動を用いた産業応用へと発展させる新しい技術基盤を与えるものとして貢献できると考える．

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Abstract

Title	Extraction of neural processes for perception and cognition using EEG

(800 words)

Research that attempts to understand the brain function has been evolving since our behavior and mind have been revealed correlated with neural processing. Moreover, the spread of non-invasive recording technique that makes it possible to measure brain signals safely and easily has accelerated the application of brain signals to various fields. For example, the neuromarketing that estimates consumers' cognitive and affective response to market stimuli from the brain signals has attracted attention. In medical field, the devices that decode the information from the brain and transmit message to people have been developed for patients with difficulty in oral communication. These techniques are called brain computer interface (BCI). In the BCI research, it is important to know how the neural activity is expressed in the brain. In other words, the issue is to find when, where, and how the specific brain activity is encoded in the brain. Further we have to develop an algorithm to decode neural signals with high-speed and high-precision. This thesis aims to discuss the extraction and decoding of the nonverbal information such as brain activity related to cognition and perception.

First, this thesis has studied the feeling of unnaturalness. Unnaturalness is higher cognitive state related to memory and experience. However, evidence related to encoding unnaturalness in the brain is not sufficient. This study conducted a cross-modal priming experiment to investigate not only unnatural stimuli of single sensory but also unnaturalness caused by combination of different modalities. As a result, neural signals in the gamma-band might reflect multisensory processing of different modalities and unnaturalness of visual stimuli. These methods can be used as an extraction of neural information about cognitive function. This result suggested that gamma band activity might be a new index to extract the human unnaturalness.

Second, this thesis proposed feature extraction and discrimination method in order to decode the unnaturalness with high-speed and high-accuracy. As described above, we had decoded the effects of unnaturalness from gamma-band activity. However, in general, an oscillatory activity is likely to be contaminated by artifacts generated by eye movement. In addition, signal to noise radio of oscillatory activities is low compared with that of ERP component. Therefore, it is difficult to extract cognitive information such as unnaturalness in real-time recording. For this reason, this thesis discussed to extract unnaturalness from ERP amplitude that is used for the BCI technique to date. Previous studies demonstrated that the amplitude of the oddball ERP component is modulated by the naturalness of visual stimuli. To estimate unnaturalness from single-trial ERP, this thesis proposed a method that combines several signal analyses: Specifically individual component analysis (ICA) as pre-processing method, principal component analysis (PCA) as feature extraction and weighted multi-support vector machines (mSVM) as classification method were employed. By this method, the effect of unnaturalness was decoded with an accuracy of more than 80% from a single-trial ERP.

Next, this thesis studied perceptual rivalry that produces spontaneous switching between unchanging ambiguous figures. As to perceptual rivalry, timing of perceptual switching is

variable and unpredictable. In order to know how the neural activity is expressed in the brain, this thesis recorded EEG related to spontaneous switching by the two proposed methods. The one method is modified discontinuous presentation. By this method, right-parietal beta-band activity increased in the periods 50-150 ms after the onset of the ambiguous perceptual switching. These results indicate that activity in the right-parietal beta band reflects spontaneous switching between rivaling percepts. Moreover, this thesis proposed a new experimental procedure using SSVEP in order to elucidate the brain activity related to perceptual switching. This method is modified continuous presentation incorporating SSVEP component. This proposed method solved the ambiguity problem about the latency of perceptual switching. The stimuli were presented ambiguous figure flickering at 8Hz and 12Hz to tag the two different perceptions with different oscillatory activities. Our aim is to investigate the neural activities relevant to perceptual switching from the SSVEP. The experiment showed that tagged-activity before perceptual switching showed significant difference between ambiguous figure and stable figure. These results suggest that SSVEP reflects different neural processing between ambiguous perceptual rivalry and physical reversal.

Taken together, these studies suggested the technique of decoding the visual neural processing related to perception and cognition and extracting them efficiently. These studies might be a key technology to lead many researches about brain activity to the application for industry.