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論 文 要 旨 （博士）

論文題目	ヒト脳内における顔色処理メカニズムの解明

（要旨　1,200 字程度）

　顔色は健康状態や感情状態を反映して変化する．故に，顔色はその人物の状態を示す重要なシグナルであるといえる．ヒトを含む霊長類の色覚は，同種の「肌の色」の変化を識別するために最適に選択されている可能性があると言われており，顔色は人類の進化にまで影響を与える程，重要な社会的シグナルといえる．したがって，顔色は他者の顔から情報を読み取る際に，重要な手がかりとなっており，顔の年齢や性別，健康状態，魅力などの知覚に影響を及ぼす．脳活動計測技術の発達に伴い，顔研究にも広く神経科学的手法が取り入れられ，ヒト脳内で行われる顔認知処理メカニズムは着々と解き明かされている．しかし，顔色の知覚に対する脳活動計測によるアプローチはほとんど行われていない．したがって，顔色が様々な顔情報の知覚に影響を与えるという現象は確認されているが，その脳内処理メカニズムについては未知である．本論文は，こうした背景のもと，心理物理的手法，脳波計測手法，脳画像法による多角的アプローチにより，ヒト脳内における顔色処理メカニズムの解明を目指したものである．

　本論文ではまず，物体の記憶色の強さ（物体色の定着の強さ）を顔と他の物体とで比較することにより，顔における色情報の重要性を検討した．記憶色と異なる色で着色した顔（青い顔）に対して，不自然さを反映する脳波成分 P3 が増大し，ヒトは特に顔上の色の違いに敏感に反応することを脳活動レベルで示した．次に，顔処理を反映する脳波成分 N170 に着目した脳波実験により，顔色の処理は顔呈示後約 170ms に生じることを示し，さらに顔処理に関係する領域に着目した fMRI 実験により，その処理が左半球の紡錘状回顔領域（FFA）で行われることを示唆した．このように本論文は，顔色の処理が生じる時間過程と脳領域の特定に成功した．

　さらに本論文では，ヒト対ヒトの対面コミュニケーションで非常に重要な情報源である表情の知覚に与える顔色の影響についても検討した．恐怖表情は，周囲の危険を表すシグナルであり，その危険を迅速に回避するために，恐怖表情に対して無意識的な処理が発生する．本研究は，この恐怖表情に対する無意識的な処理の駆動に顔色が関係することを示した．また，顔色には表情知覚を促進させる効果がある（例えば，赤い顔は怒っているように見える）という明確な証拠を示すことに成功し，表情を読み取る際に顔色が影響することを証明した．

　以上，本論文はヒト脳内で行われる顔色処理メカニズムの解明に向けたいくつもの研究成果を示した．将来的には，本研究で明らかにしたヒトの顔処理メカニズムを応用することによって，ヒト対ヒトさらには，ヒト対コンピュータのコミュニケーションを円滑にすることが可能となると考えられる．

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Abstract

Title	Human brain mechanisms for processing of facial color

(800 words)

Facial color is varied with the person's mental or physical condition. Thus, facial color provides useful clues for estimation of mental or physical condition of another person. Changizi et al. (2006) have claimed that color vision in primates was selected for discriminating skin color modulations, presumably for the purpose of discriminating emotional states, socio-sexual signals, and threat displays. Therefore, color information on the face is important in the standpoint of development. Moreover, facial skin color is related to the perception of age, sex, health condition, and attractiveness of the face. Thus, facial color is important facial information to facilitate social communication. With the development of neuroimaging techniques, many cognitive neuroscience studies about the face processing in the human brain have been conducted. In event-related potential (ERP) studies, the N170 component—a negative ERP component recorded between 140 and 200 ms from stimulus onset, with a peak around 170 ms at the occipito-temporal sites—clearly distinguishes faces from other objects. Functional MRI (fMRI) studies have demonstrated that some brain area such as the fusiform face area (FFA) and the occipital face area (OFA) are related to face processing. In this way, the mechanisms of face processing have been steadily unveiling. However, there are few studies focusing on the facial color. The thesis aims to investigate the mechanisms of facial color processing in the human brain through a multiple approach such as psychophysical and neuroimaging studies.

First, the thesis discusses the effect of facial color by comparing the strength of memory color between face with other objects. The unnaturalness-related ERP component (P3) was enhanced for the atypical-colored face (blue face) different from its memory color (flesh color), suggesting that the human is sensitive to the color difference on the faces. In the next step, the study investigated facial color effect for face-selective ERP component such as N170 and VPP (vertex positive potential). In the result, face-selective N170 observed at the left occipito-temporal site was modulated by facial color. Moreover, the study attempted to identify brain area involving processing of facial color using fMRI. In the result, the left FFA showed selectivity for facial color. These results suggest that the facial color is processed at around 170 ms after seeing the face, and in the left FFA. In this way, this thesis succeeded to identify when and where facial color is processed in the brain.

Moreover, the thesis discusses facial color effect on the perception of facial expression. Because facial color is especially sufficiently suggestive of emotional states as in the phrases: "flushed with anger" and "pale with fear". Previous ERP studies have shown that fearful faces are processed even in the absence of conscious awareness to shirk looming threat or danger rapidly. Against the backdrop, this study investigated the effects of facial color on the supraliminal and subliminal processing of fearful faces in the ERP experiment. In the result, facial color influenced subliminal processing of facial expression: automatic processing of fearful expressions was suppressed by the bluish color. The result suggests that the facial color is related to the drive of unconscious processing of the fearful expression. In addition, the psychological study investigated between facial color and expression on face perception. As a result, the experiment demonstrated that perception of facial expression is clearly influenced by facial color. For example, reddish faces were perceived as more anger. In contrast, perception of facial color is slightly affected by facial expression: sad faces were perceived as more bluish color. These results suggest interactive relationship between facial color and expression. The study provided unequivocal psychophysical evidence for facial color effect on the perception of facial expression.

This study marks an essential first step toward to reveal the mechanisms of facial color processing in the human brain. We identified timing and areas associated with facial color processing in the brain. In addition, we provided neural and psychophysical evidence for facial color effect on the perception of facial expression. In the future, the findings of the study might be of use to smoother person-to-person communication or even person-to-computer communication.