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学位論文題目 The development of face processing during infancy  
— A near-infrared spectroscopic study —

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## 論文内容の要旨

The human face is an important visual stimulus for our social communication. Thus, it has been acknowledged that the processing of faces is different from that of other non-face objects. Neuroimaging studies with functional magnetic resonance imaging (fMRI) in adults indicated that particular areas of ventral and lateral occipital cortex are activated while looking at faces, but not while looking at objects. Fusiform gyrus (FFA) and superior temporal sulcus (STS) are regarded as the face specific area in adult brains. Additionally, such cortical regions are most often found in the right hemisphere. In other words, the right hemisphere of the human brain appears to be superior to the left for face perception.

There were many previous studies in adults using fMRI, however, it remains unclear which areas of the brain contribute to the processing of faces in infants due to technical problems and the difficulty that awake infants have in keeping their head still. Recently, near-infrared spectroscopy (NIRS) has been rapidly developing as a method to reveal the brain activity that underlies cognitive processing in human infants such as language and face recognition. To specify the development of infants brains associated with face processing, this dissertation including two studies investigated the hemodynamic responses for face processing in infants by NIRS, which is suited for the measurement of neural activity in awake infants.

The first study investigated whether a developmental difference occurs in brain activity when infants look at frontal and profile views using NIRS. For this objective, the author and her co-researchers compared the hemodynamic responses in two age groups; 5- and 8-month-old infants. The results showed that the concentration of oxy-hemoglobin (Hb) and total-Hb in the 5-month-old group increased only for frontal views in the right temporal regions. In contrast, the concentration of oxy-Hb and total-Hb in the 8-month-old group increased for both frontal and profile views in the

right temporal regions. Therefore, the present study indicated that the right temporal region was dominant for the perception of profile views as well as frontal views. In addition, the most important and interesting finding was that the infants' brain activity while observing faces became view-invariant at the age of 8 months but not at 5 months.

The second study investigated 7- and 8-month-olds' brain activity related to the perception of mother's and stranger's female faces by NIRS. The results found that oxy-Hb and total-Hb concentrations in the right temporal cortex increased against the baseline during presentation of the mother's face. For strangers' faces, the total-Hb concentration in the right temporal cortex was greater than the baseline. Additionally, the results showed that the greater hemodynamic response to mother's and strangers' faces occurred in the inferior area of the right temporal region. By contrast, oxy- and total-Hb concentrations in the left temporal cortex increased only when the mother's face was presented. The increased activity in the right temporal region for the presentation of faces irrespective of familiarity was consistent with a predominance of the right temporal region found in the first study. In contrast to the activity in the right temporal region, the greater hemodynamic response in the left temporal region was observed only in the perception of the mother's face. These findings suggest that the processing of the mother's face enhances activity in bilateral temporal region, and there is a different neural mechanism for processing mother's and strangers' faces in infants.

The present research is the first objective study to detect the development of brain responses to face processing in infants using NIRS. The results indicated that the neural activity in 5-month-olds responded only to the frontal views, whereas the neural activity in 8-month-olds responded to the profile views as well as the frontal views (the first study).

Additionally, the neural activity in 7- and 8-month-olds differentially responded to

between familiar and unfamiliar faces (the second study). Interestingly, the inferior area in the right temporal region showed greater activation in both the first and the second studies. Considering the measurement area in the present research, they could speculate that this activation in the right temporal region was related to the responses in STS. Thus, STS is the cortical region which responds to the processing of faces during infancy.

仲渡氏は、近年脳活動計測に広く活用されている近赤外分光法（Near-Infrared Spectroscopy ; NIRS）を用い、乳児の顔認知に関する脳血流量を計測し、顔認知の発達過程について検討した。乳児を対象とした脳血流計測は高度な技術を要するが、仲渡氏はプローブ装着に独創的な工夫を施して本実験を可能とした。

第一実験では、正面顔や横顔といった向きの異なる顔を知覚する際の脳活動に発達的な変化が見られるのかについて、生後5ヶ月児と8ヶ月児を対象として実験を行った。その結果、正面顔を提示したときには、5ヶ月児および8ヶ月児ともに、右側頭部位で脳血流増加が示された。一方で、横顔においては、8ヶ月児でのみ脳血流が右側頭部位で増加した。正面顔と横顔の処理の活動に月齢差が示されたことから、異なる向きでの顔の処理過程に発達的な変化がみられることが脳活動計測から確認され、上側頭溝（Superior Temporal Sulcus; STS）が関与している可能性が示唆された。

第二実験では、生後7-8ヶ月児を対象とし、乳児にとって日常見慣れた既知の顔であると母親顔と、見知らぬ女性の顔を見ている際の活動を比較した。計測の結果、母親顔を提示している間では、左右側頭部とも脳血流の増加が認められたが、未知の女性の顔に対しては、右側頭部でのみ脳血流が増加した。この結果は、成人での既知顔に対する左右両側頭部位の活動の増加を示した知見と一致している。そのため、乳児でも既知である母親顔の処理には、左右両側頭部位の活動に関わり、既知顔（母親顔）に対する特殊な処理過程が考えられた。

本研究の2つのNIRS実験により、乳児の脳内での顔認知機能の発達がより明らかに示された。つまり、生後5ヶ月頃までに正面顔に反応する領域が乳児の右側頭部で発達し、その後生後7ヶ月には母親顔に対する左右側頭部での活動増加を示し、8ヶ月頃には横顔も、右側頭部において顔として処理することが示された。乳児の顔認知に関連する反応領域として、右側頭部の下部領域での活動が確認され、上側頭溝での活動を反映していると推測された。したがって、本研究は、これまで明らかにされてこなかった乳児の顔認知に関与する反応領域を明確に示す最初の一連の研究となった。